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MIGRATION AND BIOLOGICAL TRANSFER OF RADIONUCLIDES FROM SHALLOW LAND BURIAL

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FOREWORD

This document is the final report of the Coordinated Research Programme (CRP) on the Migration and Biological Transfer of Radionuclides from Shallow Land Burial. It contains a description of the objectives of the CRP, its meetings, its achievements and the work of its individual members.

The general subject of the CRP is currently of interest to many Member States and the Agency will continue to support work in this area. Following this Programme a new CRP will be organised focussing on the safety assessment of near surface radioactive waste repositories.

The CRP ran from 1985 to 1989 and was organised on behalf of the Agency by Ilkka Savolainen (1985-87) and Gordon Linsley (1987-89) both of the Division of Nuclear Fuel Cycle and Waste Management.

EDITORIAL NOTE

In preparing this material for the press, staff of the International Atomic Energy Agency have mounted and paginated the original manuscripts as submitted by the authors and given some attention to the presentation.

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1. INTRODUCTION

1.1. Background

In many countries shallow land burial is the preferred disposal route for the comparatively large volumes of low-and intermediate-level radioactive wastes which arise during nuclear power plant operations, nuclear fuel reprocessing and radionuclide applications at hospitals and research laboratories. Wastes of this type typically include solidified effluent treatment sludges and ion exchange materials from reactor clean-up systems but also contaminated paper trash, steelwork, soil, rubble etc. The wastes may be packaged in concrete and encased in steel or for the less active wastes simply wrapped in polythene, or not packaged at all. The radionuclide content will vary depending upon the source of the waste; it may contain fairly high concentrations of the moderate to long-lived beta and gamma emitters such as ^{60}Co, ^{90}Sr and ^{137}Cs but will contain only low concentrations of the long lived alpha - emitters such as the isotopes of radium and plutonium.

Some early experiences in the operation of shallow land repositories have indicated that in the short-term, at least, radioactive wastes can be disposed of safely by this route. However, while these experiences are encouraging, the safety of shallow-land burial for radioactive wastes remains to be demonstrated in the longer term. This is especially necessary now that many more large scale repositories of this kind are being planned. If sufficient attention is given to packaging and repository design, safety can be virtually assured for a few hundred years on the basis of engineering considerations alone, but in the longer term, or for repositories which rely more on the properties of the environment in which the wastes are buried to achieve isolation, reliance has to be placed on the predictions of mathematical models of the waste disposal system and its surrounding environment.

Models may be used to represent the behaviour of the radionuclides, assuming that they are eventually released from the buried waste packages, during their environmental transfer, until they reach man via his consumption of drinking water or foodstuffs. The environmental transport mechanisms involved in this process are not yet sufficiently well quantified and there is, therefore, a need to obtain improved data relating to the transfer process both on a generic and on a site specific level. By this means the reliability

of safety assessments of shallow land burial facilities can be improved to the level necessary to provide long term assurance of the safety of the disposal route.

The Agency sponsored a Coordinated Research Programme (CRP) on a similar topic from 1979 to 1982 with the title "Migration and dispersion of radionuclides from storage of radioactive waste in the terrestrial environment". This programme was organised at a time when the geological disposal of high level wastes was receiving most attention in many member states and this was reflected in the research topics considered by the eleven laboratories which took part in the CRP. While the data base in this whole subject area is still in need of improvement, the particular emphasis of the present CRP is on models and data relevant to shallow land burial.

1.2. Scope of the Programme

To improve the quality of safety assessments for shallow land burial facilities, further efforts are required to reduce modelling and data uncertainties in several areas. Some of the most important are concerned with the uncertainties in identifying the radionuclide inventory of wastes, in the prediction of rates of release of radionuclides from wastes into water, in the effects of engineered burial facilities on hydrogeological characteristics, in the migration behaviour of radionuclides through surrounding media, and in the transfer of radionuclides from groundwater to man. In order to keep the scope of the programme within reasonable bounds, it was limited to the environmental transport aspects of the problem. The following guidance was given to potential participants at the beginning of the programme:-

Release rates from wastes to groundwater

This topic is difficult to analyse in a general way because of the differing natures of the waste types and of their packaging. In addition, the extent to which the repository is engineered and enclosed within concrete or other linings will influence both the rate of infiltration and the flow patterns of groundwater around the site.

Migration of radionuclides through the upper layers of the geosphere

The movement of groundwater and of the radionuclides contained in it depends to a large extent on the nature of the substrata in which

repositories are located. There will be marked differences in migration behaviour depending on, for example, whether the repository is located in saturated formations, in unsaturated or partially saturated media. For a given site, the uncertainties are mainly concerned with predicting sorption behaviour which varies depending upon nuclide and the substratum through which migration takes place and in predicting water flow patterns and rates.

Transport of radionuclides from groundwater to man

The possibility exists that man could, at some future time, be exposed to irradiation as a result of the migration of radionuclides from a shallow land repository due to his consumption of contaminated drinking water and foodstuffs. (The possibility also exists of exposure due to inadvertent intrusion into a shallow burial site if no institutional controls are maintained). Data on the transfer of nuclides from rising groundwater into the rooting zone of plants, and on their subsequent uptake by plants are sparse, the majority of data relevant to plant uptake of radionuclides having been obtained from studies in which plant and soil are contaminated from above.

Radionuclides of interest

The potential exposure pathways which result from the transfer of radionuclides from waste into groundwater are only liable to be of concern after some hundreds of years following the closure of a repository, provided it has been suitably sited. The nuclides of principal interest with regard to these exposure pathways will therefore be those with long radioactive half-lives. Nuclides such as carbon-14, iodine-129 and technetium-99 which, in addition to having long radioactive half-lives and being present in wastes from the nuclear fuel cycle, tend to be relatively mobile, will appear in man's environment in advance of other long-lived but less mobile elements, such as caesium, uranium and the transuranics.

Nature of the research

There is a need for improved models for representing the transfer of radionuclides from waste into groundwater, their subsequent migration in groundwater and their transfer into biological materials, but

development of these models to a more advanced stage is at present hindered by a lack of relevant data. Thus, it is envisaged that the research topics covered in the CRP should include both measurement studies aimed at improving the data base and model development and model validation studies.

It is recognised that many research programmes are aimed at producing data which are site specific and the data may not be generally applicable. Nevertheless the basic problems and uncertainties will be similar and it is expected that the exchange of views and information which will result from the meetings of the CRP will produce a useful contribution to progress on this topic.

1.3. Participation and Meetings

The programme was well supported by Member States and many more applications were received for research agreements and research contracts than could be supported by the budget allocated. A total of 11 research agreements and 5 research contracts were allocated (the participating laboratories and Chief Investigators are listed in Annex. 1) but in addition a number of independent observers attended each of the three Research Coordination Meetings (RCMs). The RCMs were held in Vienna 4-8 November 1985, Oak Ridge, Tennessee, USA, 7-11 September 1987, and Paris, France 17-21 April 1989.

2. THE RESEARCH CO-ORDINATION MEETINGS

First RCM (Vienna)

A common feature of all of the RCM meetings was the presentation by participants of the recent work of their laboratories relevant to the subject of the CRP. At the first meeting, particular attention was given to the needs for research in relation to improving predictions of the possible radiological impact of radionuclide leakage from shallow burial facilities. Working groups were established to review the needs for research as indicated by 1) the requirements for compliance with established safety criteria, 2) different waste management strategies and 3) in order to reduce the uncertainties in

predicting radionuclide migration and biological transfer. The reports of these working groups are contained in Annex. 2. The RCM also considered what joint studies could be initiated amongst the CRP participants. Three topics were initially proposed but mainly as a result of inevitable changes in CRP participation from national laboratories only one of the joint studies was completed. This was a review of knowledge on biological transport from shallow land burial jointly prepared by scientists from two of the participating laboratories. This report is included as Annex. 3.

The conclusions of the first RCM were as follows :-

Consideration of performance assessments and performance objectives can be used to determine which processes are important for the safety of planned or existing radioactive waste burial practices. To be appropriate for a further study, the process under consideration must be
a) relevant to the assessment of a measure of radiological impact and,
b) not well understood. Concerning research needs on engineered barriers, it was felt that one important aspect is the documentation and publication of efforts that are being carried out on this topic. Questions raised concerning institutional control of burial sites and intrusion probability by humans are to a large extent of a social nature and have therefore only minor direct implications for the CRP on migration and biological transfer. A table presenting certain research of interest on different radionuclides is contained in Annex. 2. The major research areas of interest are indicated for fully engineered and simple trenches with respect to near field, far field, biosphere and intrusion into waste.

Problems related to the selection and use, for example of appropriate distribution coefficients (K_ds), soil to plant transfer factors (CRs), water to fish transfer factors and similar empirically derived coefficients occupied much of the discussion during the meeting. It was generally agreed that increased emphasis on process-oriented modelling techniques is a desirable long-term goal for safety assessment. The continued development and application of process-oriented models is therefore encouraged while recognizing the need to use empirically based models in the near-term.

Activities that support the development of process-oriented models include research on chemical speciation of radionuclides during and after disposal in shallow land burial and factors influencing the physical and biological transport. These involve the general areas of unsaturated flow, saturated flow and dispersal by biotic vectors.

Experimental validation of models used in safety studies is highly desirable. A consideration of analogues may help validate these models. Sensitivity analyses and identification of areas of uncertainty in models and data are also required.

Second RCM (Oak Ridge, USA)

One of the main reasons for having the second RCM at Oak Ridge was the possibility for the participants of the CRP to interact with scientists at the Oak Ridge National Laboratory (ORNL) working on problems related to radioactive waste disposal and also to visit the extensive burial grounds at ORNL. In addition to the presentation by CRP participants on their work relevant to the CRP since the last RCM, they were asked to review the status of shallow land burial operations or plans in their own countries.

ORNL staff made presentations on on-going research related to local hydrology, radioecology, assessment of the environmental impact of radioactive waste disposal and remedial actions. An account of the history of waste disposal at the Oak Ridge sites was also presented before a visit to the actual burial grounds.

Disposals have occurred at various locations with ORNL since the early 1940's. The precautions taken to ensure isolation from groundwater were often rudimentary in the early days of the site and there are several waste burial areas requiring remedial action to reduce radionuclide migration into the local watercourses. The radionuclide of principal concern is strontium - 90 which is both radiologically important and fairly mobile in soils and groundwater. The area is now being used as a test-bed for improving understanding of radionuclide transport processes and for evaluating various remedial strategies. The disused Hydro-Fracture Facilities were also visited. This disposal process was unique to Oak Ridge and involved injecting liquid radioactive waste to depths of about 300 metres in the form of a slurry of waste and cement. The practice was discontinued in 1984 after contaminated deep groundwater was detected in the vicinity of the plates of solidified waste.

The meeting reviewed the reports on research needs produced at the first meeting and also the joint paper on biological transfer (Annex 3).

Third RCM (Paris)

The third and final RCM was organised along similar lines to the second RCM. In addition to presentations on their work by participants, scientists from the laboratories of the hosting organisation the Commissariat à l'Energie Atomique and from the organisation with responsibilities for radioactive waste management in France, ANDRA, gave presentations on various studies related to shallow burial of radioactive waste.

The participants visited the national disposal facility at the Centre de la Manche, near Cherbourg and had further presentations by ANDRA staff. The Centre de la Manche site has been used as the national centre for the disposal of predominantly short-lived radioactive waste since 1969. The site will be filled to its maximum capacity of 485,000m^3 by 1991. The progress towards the development of the replacement site in Dèpartement de L'Aube near the village of Soulaines was described by several speakers. The French technique for the disposal of short-lived wastes (half-life < 30 years) is based on near surface storage of conditioned wastes in concrete structures. Any effluent from the wastes is caught and discharged to sea. However, the releases are very low. When the site is filled, the concrete structures will be covered with a clay and earth cap. Institutional control will be retained for 300 years at which time it has been determined that the radiological hazard will be sufficiently low to allow control of the site to be relinquished.

In the final part of the meeting discussions were held on a) engineered barriers, their role and performance and b) exemption criteria applied to low level radioactive waste disposal.

3. PROGRAMME ACHIEVEMENTS AND FUTURE RESEARCH

The CRP brought together an interesting mix of scientists working on the subject of near surface waste disposal and its environmental aspects. Some of the industrialised and more developed countries represented have well established disposal programmes for low level wastes (UK, France, USA, Japan, Sweden, Czechoslovakia, Argentina, India) while some of the developing countries represented are still at the preliminary planning stage (Thailand, Iraq). Accordingly, the interests of the participants are concerned with

different aspects. Those from countries with existing facilities tend to be more interested in the development and improvement of safety assessment techniques and of a coherent long term disposal philosophy. Participants from countries without disposal facilities tend to be mainly concerned with basic experimental studies aimed at obtaining an understanding of radionuclide behaviour in soils. However, this division was by no means complete and on-going experimental studies were also reported by participants from USA, Canada and France.

The CRP provided a useful forum for exchange of information, both for scientists from industrialised countries and those from developing countries. In particular, the visits to actual disposal sites in the USA and France and the associated meetings with scientists from the national laboratories provided exceptionally good opportunities for information exchange.

The CRP has proved to be popular and thus is a reflection of the current interests in the world in studies related to low level radioactive waste disposal. The subject is of potential interest to all Member States with significant quantities of radioactive wastes, both from the nuclear fuel cycle and from isotope uses in medicine, research and industry.

It seems clear that further research in this area is needed. However, it is desirable for future work to be focussed on the resolution of a particular issue or towards the improvement of knowledge in a particular area of importance. Such a project would have the advantage of maximising international cooperation.

One project proposed and discussed at the final RCM in Paris concerned safety assessment studies, involving assessment model comparison and validation. It was recognised that such a project would result in good exchange between Member States and joint activities.

Subsequently it has been decided that as a follow up to the CRP described in this report a new CRP entitled "The Safety Assessment of Near-Surface Radioactive Waste Disposal Facilities" will be sponsored by the IAEA starting in 1990.

Annex 1

PARTICIPANTS IN THE CO-ORDINATED RESEARCH PROGRAMME

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Annex 2

WORKING GROUP REPORTS FROM THE FIRST CO-ORDINATION MEETING

WORKING GROUP 1

Relevance of Safety or Performance Objectives for Directing Research

We are concerned with predicting the radiological impact of shallow land burial with a view to demonstrating the adequate safety, taking note of the recommendations and suggestions from such bodies as NEA, IAEA, ICRP, etc., of such a practice. There is a need to make this demonstration of adequate safety:-

- to the relevant national authorities;
- to the general public;
- to other groups with a special interest, such as the local population;
- to the international community.

All these groups have, or may have, different views as to what constitutes adequate safety, both in terms of relevant measures of safety, e.g. risk* or dose and of the absolute value of such measures. They may also have different views which can be considered under the general heading of performance objectives as to what constitutes an adequate demonstration, verification and validation. In this forum we should be concerned with all these views and consequently the assessments of shallow land burial must be

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* There are several reasonable possibilities for the definition of risk as applied to the safety of waste disposal facilities. The question has been considered by various bodies and there is a consensus at an international level. In this report risk is defined as the probability of a health effect for an individual or his descendants. It is equal to the product of the probability of exposure at a particular annual dose rate, and the probability of a health effect arising from that annual dose.

able to provide answers to a wide range of safety related questions. Relevant measures of radiological impact could include:

- Maximum annual individual doses;
- Maximum annual individual risks;
- Collective doses;
- Collective risks;

Other relevant factors are the timing of such doses and risks (near or far future), and the distribution of collection dose among populations. (What is the individual dose rate that most of the collective dose is delivered at, and is the exposed population receiving the benefit of the practice leading to the disposal?)

How do these different aspects affect the research needs in migration and biological transfer? If there is interest only in a subset of these measures, then clearly the predictive capability required is less onerous and the research priorities may be fewer. Thus, in planning research it is important to consider in what respect the research may improve the assessment capability. To be of value, the process under consideration for further study must be a) relevant to the assessment of a measure of radiological impact and, b) not well understood. Arguments concerning a) and b) should not be confused, and in order to discuss a) sensibly we must have some consensus as to what are the relevant measures.

Some observations about criteria

Individual dose limit (for "reasonable" scenarios)

- Problem of defining reasonable scenarios
  In general it is always possible to envisage scenarios for release of radionuclides from shallow land burial facilities which result in very large doses. Again, in general, the larger doses are only predicted for the relatively improbable scenarios. It is difficult to decide upon what level of improbability makes a scenario "unreasonable", so that it does not need to be considered when demonstrating compliance with a dose limit.

- Major emphasis on dose

  Once it is decided that a scenario must be considered, the individual dose must be assessed taking into account all available information. If some uncertainty arises, further research may be necessary to demonstrate that the upper estimates of doses are within limits.

- Ignores uncertainty in the dose response relationship

  Once a dose limit is set it remains in force until it is altered. If evidence comes to light to show that the risk associated with unit dose is currently over- or under-estimated, then the basis to the dose limit is undermined, and an alteration is necessary. However, changing such limits is not always straightforward.

Individual risk limit

- Similar problem with scenario identification but also need to quantify the probability of the less probable events which have associated high consequences (doses). Determining the probability of uncommon events, especially in the longer term, is very difficult.

- Less emphasis on dose assessment since consideration of the probability can sometimes be used to demonstrate compliance with the risk limit. As noted above, there is generally some uncertainty associated with the dose assessment. However, the need to reduce this uncertainty (by research for example) may be obviated by consideration of the probability.

Collective dose (optimisation)

- Requires following transport of radionuclides beyond the path to the critical group, and hence may include more diverse processes than those considered for individual related criteria.

WORKING GROUP 2

Effects of Waste Management Strategies on Research Priorities

Engineered Barrier Research Needs

Engineered barriers are a component of virtually all newly proposed shallow land burial activities and, as well, are featured as remedial actions for many previously used sites. These barriers include waste package containers, repository structures, and controls for local flows of water and radionuclide transport. A wide array of such barriers is available for many specific applications. Research is needed to provide information that site managers may use to select among alternative strategies, and that modelling and assessment groups may use in estimating the value of such barriers in improving site performance. By and large, there is a paucity of such information.

Two approaches are clear for the proposed research: (1) Construction of demonstration sites where engineered barriers can be emplaced and experimentally evaluated, and (2) careful evaluation of the effectiveness of engineered barriers where they are constructed for remedial action purposes. Each of these approaches has distinct advantages and, to some degree, each would be of value. The former approach has the advantage of allowing greater control on the design, emplacement, and measurement that will be tested. Some barriers can probably not be tested except under the controlled conditions of a specifically designed facility. On the other hand, the expense of operating a large-scale engineering testing facility will be considerable and the most significant advantage of the latter approach is that the costs for proper evaluation of effectiveness will be considerably lower. Presumably, the conditions and local processes that are critical to site performance will have been obtained already in the determination that a remedial action is needed and for the selection/design of a particular action. What is then essential is the planning and implementation of the post-installation monitoring and data analysis which would reveal whether or not and to what degree the action has had the desired effect.

This engineering research is not only essential for design and assessment of shallow land burial sites but it is also possible within the timescale and scope of present world-wide activities. One aspect of research will be the documentation and publication of efforts that are being carried

out on this topic [see also IAEA Safety Series Report No. 63 "Design, Construction, Operation, Shutdown and Surveillance of Repositories for Solid Radioactive Wastes in Shallow Ground" (1984).]

Institutional Control

Institutional control of a waste repository, whether by limiting physical access or by some restriction on nearby land use and activities, is not credible on a timescale of thousands of years, but in the shorter term, perhaps for hundreds of years, it could provide a safeguard against intrusion. This may reduce the need for some physical barriers placed around the repository but some repository operators will prefer to have both while others may not take up such a continuing commitment. The ALARA Principle could guide the choice. It may be that institutional control carries with it a responsibility for remedial action should it become necessary and some preparation for this would be desirable.

Questions raised concerning institutional control - on the reliability of records, the clarity of warning markers and so on - are mainly of a political or social nature. They do not have much direct implication for the CRP on Migration and Biological Transfer.

Intrusion

Direct intrusion into a repository by plants, animals, or especially, humans is potentially an important route for exposure from a shallow land repository. Efficient containment barriers may increase the risk of this in the short term by keeping soluble radionuclides in the repository but the problem is likely to exist anyway in the longer term as some long-lived radionuclides are relatively immobile. It should be recognised that if risk criteria are being used, the probability factors for various types of intrusion are of great importance. These factors, though, involve consideration of social and industrial practices and are largely outside the scope of the CRP. There does seem to be a need, however, for further research work on the likely condition of the repository wastes at times of potential intrusion and the mechanisms and magnitudes for actual transfer of radionuclides to the intruder or as a consequence of the intrusion. This may partly involve study of plant and animal intruders in existing disposal sites.

Priority Radionuclides and Research Areas

Table 1 indicates five groups of radionuclides with broadly similar characteristics within each group. The major research areas of interest for each group are indicated for fully engineered and simple trenches with respect to the near field (the waste itself and the zone affected by the emplacement of the waste), the far field (the sub-surface zone beyond the near field in which geologic processes are the major interest), the biosphere (the surface environment receiving discharges from the geosphere) and the consequences of direct intrusion into waste.

TABLE 1

RADIONUCLIDE/GROUP	FULLY ENGINEERED TRENCH				SIMPLE TRENCH			
	NF	FF	BIO	INT	NF	FF	BIO	INT
Short-lived (< 30 y half-life) Includes important gamma emitters. Typical radionuclides of interest Co-60, Cs-137, Sr-90, Fe-55, Ru-106, Pm-147, Eu-152, Eu-154, Ir-192	-	-	-	A	-	-	-	A
Long-lived (> 30 y half-life) Immobile. Typically including actinides and their daughters, Ra-226, Ni-63, Ni-59, Ag-108m	B	C	-	D	-	C	-	D
Long-lived (> 30 y half-life) Mobile. Notably Tc-99, I-129	B	C	E	-	B	C	E	-
H-3	F	-	-	-	-	-	-	-
C-14	G	G	-	-	G	G	-	-

NF = Near Field
FF = Far Field
BIO = Biosphere
INT = Intrusion
- = either known or not necessary

The particular research interests indicated in the table are discussed below.

A. Effect of waste form and engineered features on the assessment of consequences of intrusion.

B. Effect of the detailed chemical environment in the repository as governed by the waste form and engineering materials, e.g. concrete and steel, on release of radionuclides to the far field. In particular, the effect of speciation on solubility and sorption.

C. As for B, but in the natural geochemical environment in the far field.

D. As for A, but including the long-term (> 1000y) behaviour of the waste form in so far as it affects assessment of doses following intrusion.

E. Long-term behaviour of Tc-99 in soils, and its availability for uptake into plants.

F. Cost-effective methods of retaining tritium until significant decay has occurred.

G. As for B and C, but including consideration of isotopic dilution, gas generation and microbiological effects.

Applications of Site-Specific Information in Design and Operation of Shallow Land Burial Facilities

Although it is not specifically a research topic, the working group would emphasise the importance of using certain key site-specific information in the design and operation of shallow land burial facilities. This key information includes hydrogeological parameters - water flow, water balance, etc. as well as ecological information - local species composition, successional status, etc. In general this information is gathered during the site-selection and site-characterisation stages and will be available for use in planning and operation.

Particular attention to site hydrology is required for the placement of performance monitoring stations and for the sampling programme for monitoring. To a first approximation the water balance for the site will reveal the relative probabilities for hydraulic transport of contamination once it has been mobilised. Likewise, the same information may affect the way in which site facilities are located, oriented and operated. Open trenches constructed along contour lines in sloping sites are less susceptible to "bathtubbing" than trenches constructed up- and down-slope.

Similarly, it will be important in site operation to account for certain ecological factors. For example, populations of burrowing animals and of plants with intrusive root systems may be significant vectors for radionuclide mobilisation and transport. The importance of ecological succession may become significant only after site maintenance has been

reduced. Institutional controls may vary in the level of activities carried out, but in general will open the site for natural repopulation from the surroundings. When this occurs, the possible effects of intrusive species on site integrity will increase and the probability of detection will decrease. Unless these factors are taken into consideration, there is a markedly greater likelihood of site failure to meet performance objectives.

WORKING GROUP 3

Research Needs in Migration and Biological Transfer

Radionuclide Migration in Soil

After release from the shallow land repository, the migration in the unsaturated and saturated zone is mainly dependent on the site characteristics, for example, soil type and water balance. In this context, of special interest is the evaluation and understanding of retention mechanisms of radionuclides. Attention should be given to phenomena influencing these retention processes.

Usually these are described in terms of distribution coefficients (K_d). This concept must include reaction kinetics and complexing agents in the waste and soils that influence transport mechanisms. Incorporation into the matrix, redox processes and the concentration of stable isotopes must also be considered. The Group considers that in future it is not enough to measure K_d-values and much more attention should be given to the understanding of mechanisms influencing the retention processes. In this context, a key problem would be the field of chemical speciation.

The Group recognises that there are problems in modelling the channelling of water flow in the lithosphere. The movement of water in the non-porous, fractured media is almost entirely along cracks and channels. There are large difficulties in the interpretation of hydrogeological data to obtain groundwater velocity. One of the difficulties in modelling of water flow is also due to a large variability in available data about hydrogeological data. The second problem is to evaluate the influence of hydrodynamic dispersion on contaminant transport. Means for characterisation of flow pathways in fractured media are inadequate and are needed.

Exposure Pathways

Exposure to man is primarily related to the radionuclide content in the groundwater. This contaminated groundwater can be used for irrigation or drinking water and may reach surface water bodies. Another possible pathway is through the contamination of the root zone, leading to plant uptake.

In the literature, there are assessment models available to calculate the doses to man from these pathways. However, there is some knowledge lacking. Additional data concerning migration processes in soil surface layer and validation of soil transport models is seen as a research need.

Further consideration should be given to the suitability of concentration factors (CR) for plant uptake near a shallow burial site. In the future, it may not be enough to use CR-factors but rather the mechanisms of uptake should be incorporated into modelling. Where possible CR-values should be correlated with other parameters such as K_d-values.

The key to a better understanding of the uptake of radionuclides by plants would be knowledge of the bio-availability of nuclides. Investigations into the speciation of the nuclides will not only help to better understand retention processes, but will also indicate the mobility and bio-availability of nuclides in general.

Consideration should be given to the possibility of radionuclide transport in soil by plants and animals. Burrowing animals may enter the burial site and transport nuclides by their activities to the upper layers of the soil. Deep root systems may penetrate the waste and mobilise radionuclides which are then available for plant uptake.

The releases of gaseous effluents from the repository into the environment may also cause a problem. Radionuclides of interest in this context are tritium, carbon -14, iodine -129 and radon. Further research on this topic is needed.

Recommendations and Comparisons of Models

For the transport of nuclides in the saturated and unsaturated zone, many models are described in the literature. Consideration of the applicability of these models and prior model comparisons should be made for

shallow ground burial. Experimental validation of these models is highly desirable. A consideration of analogues, both natural and man-made, may help in the validation of these models. Examples would be studies of natural ore bodies, mine tailings and waste disposal areas resulting from the chemical industry. Sensitivity analyses and the identification of areas of uncertaint in the model structure and data are also required.

There are uncertainties associated with all models. They often depend on the approximations and simplifications which are made as well as on the input data. All this influences the reliability of the results.

There are often problems when models are interfaced to describe transport through consecutive compartments. When several models are used special care should be taken to make them consistent. Concerted efforts should be put forward to link the release rate from the repository source to the transport models describing flow through the media.

Annex 3

Review Paper

BIOLOGICAL TRANSPORT FROM SHALLOW LAND BURIAL

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Abstract

In this paper a general overview is given of the limiting conditions for the survival of plants and soil animals. On the basis of this information the question of whether intrusion by plants and animals may be an essential exposure pathway in shallow land disposals is considered.

Introduction

As long as existing shallow land burial sites are maintained, or additional shallow land disposal sites are planned, assessments will be required to assure that contaminants remain isolated from the human environment. Biological pathways by which radionuclides can move from shallow land disposal sites and ultimately contribute to human exposure fit into one of two broad categories.

The first category involves agricultural pathways. One such scenario requires that after loss of institutional control (LOIC), crop plants are grown directly over a shallow land burial site. Crop plant roots contact contaminants and radioactive materials are translocated to aboveground plant parts. Consumption of plant and animal products from the associated food chain can lead to a radiation dose to humans.

Another agricultural scenario involves use of contaminated irrigation water. Leaching of radioactive materials from shallow land burial sites to surface water or to ground water permits the pathway to become established. In at least one reported case (Rickard and Kirby, 1987), tritium moving away from a waste burial site in subsurface flow was measured in the leaf water from nearby trees. The use of contaminated groundwater for irrigation provides a potential pathway back to man.

A second category for radiation exposure involves non-agricultural biotic transport pathways which will be of mayor concern in this paper. These pathways are usually indirect, lengthy and generally less well understood because relatively little has been done in terms of assessing their importance or magnitude. Plants and animals that recolonize shallow land burial sites can intrude into buried waste and may provide an important pathway for radionuclide transport.

In this context intrusion is defined as the penetration of roots and soil animals into burial sites thus inducing a mobilization of radionuclides and a subsequent transport into the biocycle. Plants may either take up radionuclides directly from the burial site or burrowing animals may transport radionuclides towards the vicinty of roots. Animals may also increase the bioavailability of radionuclides by mechanical disintigration of contaminated substances or by incorporation and subsequent excretion thus changing the chemical form of the radionuclides. Plant roots and animals have, however, only a limited capacity for penetrating into deep soil layers. Their activities are, on the one hand, limited genetically and, on the other hand, dependent on the soil properties.

Under active site maintenance programs, the quantities of contaminants permitted to accumulate on the surface of the burial grounds is likely to be small. However, when considered over longer periods of time and without institutional controls, biotic processes have a potential for contributing substantially to human exposure. Recently, efforts have been made to define and model radionuclide transport from shallow land burial by plant and animal processes (McKenzie et al. 1982a, McKenzie et al. 1982b, McKenzie et al. 1982c, McKenzie et al. 1984, McKenzie et al. 1985, McKenzie et al. 1986 and Shuman et al. 1985). For these models adequate parameters have to be bound.

In this paper a general overview will be given of the limiting conditions for the survival of plants and soil animals. Based on these propositions the question will be discussed whether intrusion may be an essential exposure pathway in shallow land disposals. The activities of microorganisms may futher be of importance especially under unaerobic conditions, they will, however, not be discussed in this paper.

Plant uptake considerations for shallow land burial

Recent reports have provided numerous examples of radionuclide transport from shallow land burial sites by plants (Arthur 1982, Cornam 1979, Dabrowski 1973, Fitzner et al. 1979, Klepper et al. 1979, Paine et al. 1979 and Webster 1979). Oblath (1986) made observations on radionuclide release from lysimeters constructed to simulate low-level waste burial. He found that the release of both Cs 137 and Sr 90, as a fraction of the total inventory, was at least an order of magnitude greater for pine trees than from effluent water leached from the same lysimeter.

Prior to plant uptake, roots must contact contaminated soils. At shallow land burial sites this may occur as a result of direct intrusion into the burial zone by deep rooted plants, or subsequent to processes that bring contaminants into contact with plant roots. The presence of a few deep rooted plants can effectively result in the "mining" of contaminants. Radioactive materials in the plant tissues become redistributed to the soil surface and throughout the soil profile as generations of plants grow, die and decompose. Contaminants at or near the surface then become available for further redistribution by the biota. Foxx et al. (1984) matched plant species occurring on low-level waste sites with rooting depth data to help identify the potential for intrusion and radionuclide transport from shallow land burial. They found that numerous plant species in the southwestern U. S. have known root depths that extend beyond the cover depths common to burial sites in arid regions of the United States.

The question raises what root depths can be expected at other burial sites. The rooting capacity of different plants is limited genetically but it is also very site specific. It is fluenced mainly by the climate and the soil properties at the disposal sites. Not only the properties of the top soil layer are of importance but also the soil profile, the

stratification of the different soil layers, the parent material, which in turn also influence the soil permeability, its hydraulic conductivity, the water movement, and the depth of the ground water table. In Figure 1 an example is given of root penetration of forbs and grasses growing on prairie soils. Figure 2 shows an example of root systems typical for trees in sandy soils in a northern temperate climate.

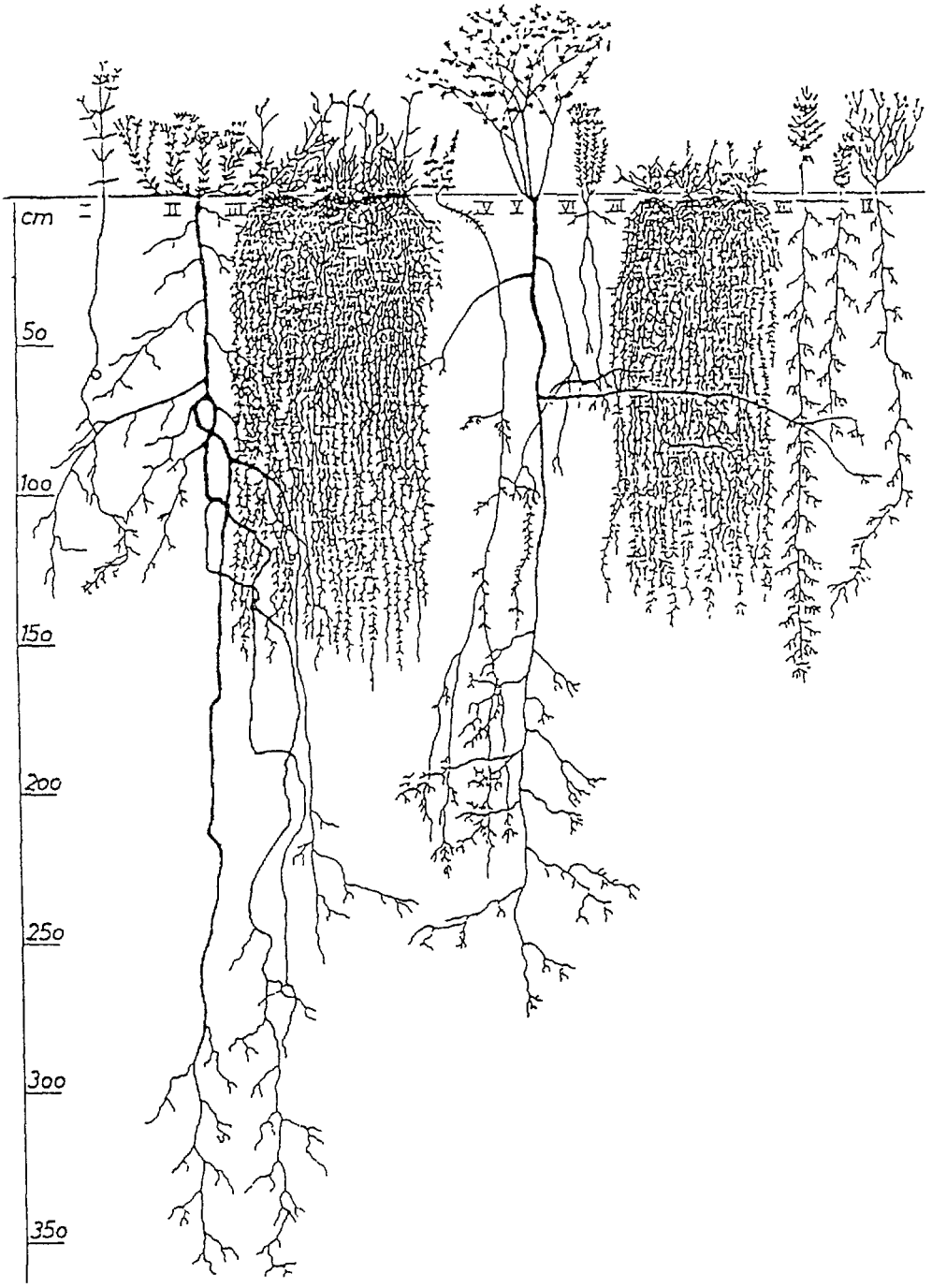

Figure 1: Development of roots of prairie plants in the prairie near Hays, Kansas. I Allionia linearis, II Kuhnia glutinosa, III Bouleloua gracilis, IV Malvastrum coccineum, V Psoralea tenuiflora, VI Sideranthus spinulisus, VII Buchloe dactyloides, VIII Ambrosia psilostachya, IX Lygodesmia juncea (Weaver and Albertson, 1943).

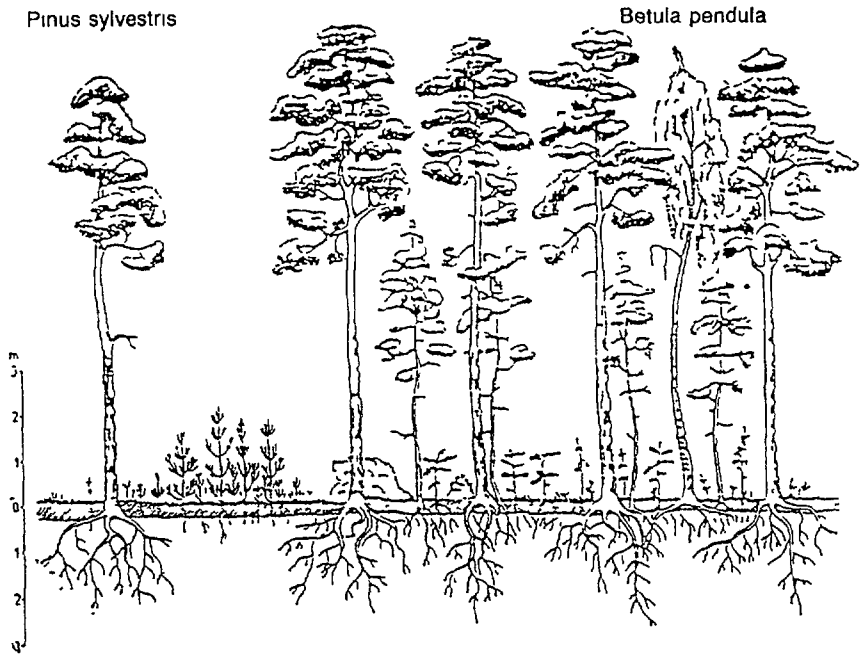

Figure 2: Scheme of the vegetation profile of a natural pine forest in Poland, according to Pawlowski, 1959.
Trees: Pine (pinus sylvestris) and weeping birch (betula pendula).

In prairie soils roots of grass and herbs was found till a depth of 3.5 m.

Extremely deep reaching roots may be found in arid climate. There, some plant species may draw their water from the very deep ground water table. Thus the roots of some species reach as deep as 20 m. In uranium mines of the Colorado plateau living juniper roots were found in a depth of 100 m. These plants accumulated uranium to a much higher degree than normally found in these plants (Cannon and Starret, 1956).
In Figure 3 the rooting pattern from the surface to the ground water table in an arid soil is shown.

Certain plants, as for instance the European larch, may penetrate natural barriers, such as dense clay layers, in search of water and nutrients. Most plant species modify their rooting patterns according to the soil properties. Spruces, for instance, may be shallow or deep rooting depending on the depth of the soil horizon available. Other trees like firs have a genetically fixed rooting pattern and will try to develop deep roots on any site.

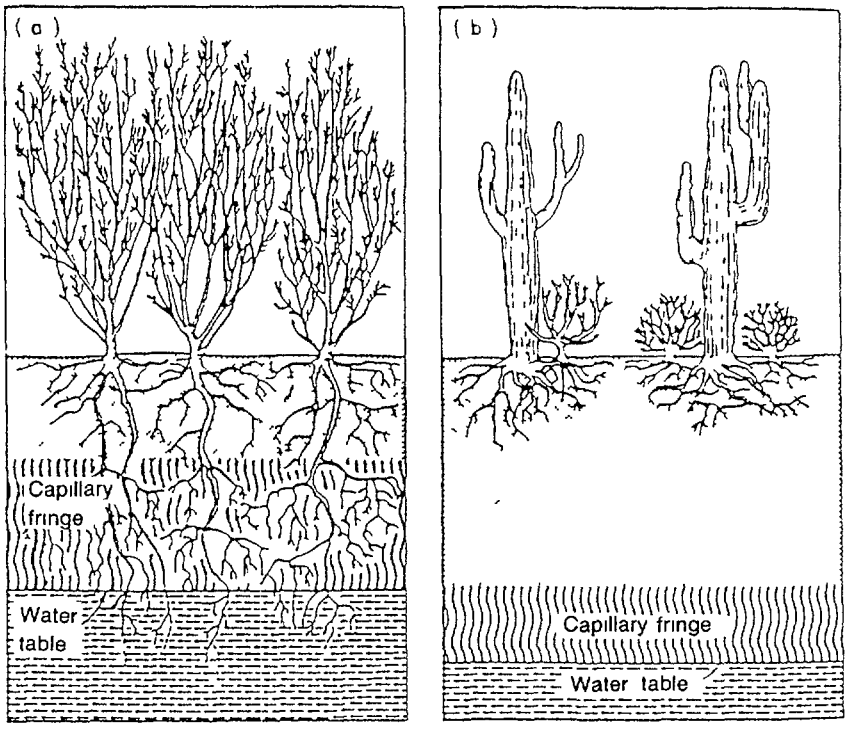

Figure 3: Distinction between (a) phreatophytes and (b) xerophytes shown by their occurrence in relation to the water table (After Robinson, 1958).

Essential parameters for plant growth are light, temperature, air, water, and the available nutrients. The rooting activity of plants depends on their specific needs and the site specific parameters which are limiting to plant growth.

Light:

Sun light provides the energy necessary for photosynthesis and consequently for plant growth. If the light intensity is low (seasonal effects, shade) the root growth may be reduced due to the dificient energy supply.

Temperature:

Generally speaking one can say the warmer the climate the deeper the roots. Decreasing soil temperatures have a reducing effect on root growth.

Air:

Oxygen is essential for root growth. Oxygen consuming processes in roots provide energy for active ion absorption and for the maintenance of a sufficient turgor in the roots to enable the flux of water and diluted minerals from the roots to the green parts of the plants. Under anaerobic conditions most roots will cease to grow or even start to decompose. Some plant species, however, have the ability to penetrate through such perched layers in search of better aerated deeper soil layers (e.g. sandy soil beneath a clay layer). The oxygen content of soil air is usually decreasing with increasing depth below surface. Root growth is generally concentrated in well aerated soil zones.

Nutrients:

Roots take up ions. These nutrients may either be absorbed directly from the soil solution or actively desorbed from clay minerals or organic matter.
Symbiotic processes with associated microorganisms further facilitate root uptake of minerals. Root growth is generally limited to soil regions which have a sufficient nutrient supply to satisfy the needs of the respective plant.

pH-Value:

The pH-value of soils is only of minor influence to plant growth. There are plant species which have adapted to extemely acidic or calcerous soils. Pinus ponderosa, for instance, may endure pH-values from 2.7 to 11. The growth of some forbs and grasses will only be impaired by pH-values of less than 4. There are many species which may survive even under extreme conditions, e.g. salt tolerant plants.

Modeling radionuclide transport from shallow land burial by plants

McKenzie et al. (1982) first reviewed transport and radiation exposure pathway models to determine whether plant and animal related processes were evaluated during assessment of shallow land burial operations in the United States. They found that models existing at that time considerd only atmospheric and surface/ground water transport mechanisms.

Models used to calculate the quantative transfer of radioactive material from soil to plants commonly employ concentration factors (the ratio of the concentration of an element in fresh vegetation to that in dry soil).

Concentration factors are based on empirical relationships obtained from greenhouse and field studies. In the absence of radionuclide data, values for concentration factors are sometimes estimated from concentrations of stable elements in plants and soil (Ng et al., 1982).

One tacit assumption in estimating plant uptake of radioactive materials from soils is that the radionuclides are in contact with the bulk of the plant roots. Although there is considerable variability in root depth and distribution, the root mass for most plants is primarily in the upper few decimeters. Most laboratory or greenhouse studies that provide data on radionuclide transfer from soil to plant have been conducted with plants grown in pots or other containers that have had the radionuclide uniformly mixed in the soil. Field studies that provide estimates of concentration factors commonly have the radionuclide mixed in the upper soil layer; typically the top 15-20 cm. This soil thickness corresponds to the "plow layer", or the layer of surface soil that is mixed during agricultural tillage operations. Therefore, the assumption of substantial root contact with contaminants seems to apply best to accidental release scenarios in which radionuclides are dispersed from the atmosphere and mixed into cropland soils by tillage.

Initially, plants growing on shallow land burial sites gain access to radioactive materials only after their roots penetrate uncontaminated overburden. Under this scenario, most of the plant roots are in non-contaminated soil with only a few of the deeper roots making contact with the buried contaminants. The configuration of plant roots relative to contaminants in the soil is reversed from the one previously discussed for agriculture. Moreover, the assumption concerning the quantity of roots in contact with contaminants does not apply, and concentration factors may not be appropriate for calculating radionuclide uptake by plants. Kennedy et al. (1985) describe a computer code (BIOPORT) that was developed to calculate expected radionuclide transport by the plants and animals from shallow land burial sites. The plant model in that code used concentration factors without regard to the configuration of the wastes relative to root distributions. Later,

McKenzie et al. (1986) provided improvements and modifications to the code that included two alternative submodels for plant uptake. (The revised BIOPORT/MAXI1 computer code for calculating radionuclide transport and resulting dose to man under a human occupancy scenario is provided in McKenzie et al. (1985)). Their Plant Model 1 calculated plant uptake independently of the fraction of roots in the waste zone. It assumed that a few deep roots in contact with the waste would permit the plant to accumulate the same quantity of radioactivity as if all roots were in contact with the waste. Plant Model 2 effectively reduced the calculated concentration of radioactivity in the plant material in proportion to the fraction of the plant roots in the waste zone.

Animal intrusion considerations for shallow-land burial

Radionuclide transport subsequent to animal intrusion by burrowing is a commonly reported phenomena at obsolete shallow waste burial sites in the United States. Radioactive materials may be transported to the soil surface with excavated soils, ingested by the animals and passed through food chains or redistributed through physical contact with the animal's external surface. In addition, burrows left by animals may increase infiltration and the potential for contaminant leaching.

The soil fauna is usually devided into microfauna, mesofauna, macrofauna, and megafauna. The microfauna includes all animals smaller than 0.2 mm. They are of minor impact on decomposition processes, normally accounting for about 3 % of the total weight of soil organisms. These single cell protozoa consist mainly of rhizopoda, ciliatae, and flagellatae. They feed on diluted organic substances, detritus and also on bacteria which they thus stimulate to a higher reproduction rate. Typical representatives of the mesofauna (0.2-2 mm) are nematodes, mites and collembolae. Worms (oligochaetae), spiders, ants, and larvae of different insects belong usually to the macrofauna (2-20 mm); some bigger forms are, however, part of the megafauna if they surpass a size of 20 mm.

Soil animals disintegrate dead plant material and carcasses mechanically and are thus increasing the target surface for further disingtegration by microorganisms. In calcerons soil organic litter is mainly decomposed by different species of snails and earth worms. In anaerobic and acidic

soils different larvae of craneflies and other insects contribute to these disintegration processes. The organic material is transfered into the soil by different animal activities. Collembolae, mites, snails, termites and some earthworm species may secrete enzymes to break up cellulose and lignin (Schachtschabel et al., 1982). The soil fauna can also change the physical properties, improving the aeration and drainage by bore holes. Minerals and organic matter may be translocated vertically and horizontally by animal activity.

An important representative of the meso- and megafauna are the earthworms. Different species may be found in nearly all kinds of soil all over the world except for the arctic and desert zones and they are also absent in peat bogs and dune sand. Their population is higher in calcerous soil with a high organic content. These earth eaters have a daily intake rate which equals their own weight. Their excrements have an enriched content of essential plant nutrients, e.g. N, P, K, Ca, Mg, thus facilitating plant growth. Their tubes and boreholes are coated with organic substances and are often used by plant roots. They also improve the soil aeration and drainage. In Europe earthworms usually penetrate the soil till a depth of 50 cm, in profound soils bigger species may be found till a depth of 3 m. Under favourable conditions earthworms have been reported in depths of 6 m (Hungary) and 8 m (Soviet Union). Earthworms are responsible for the vertical translocation of soil materials and metals (from deep soil layers up to the surface) and, on the other side, may transport plant material from the surface downwards. In meadows and under favourable conditions worms have been reported to translocate 7 to 14 kg soil/m^2 annually (Graff and Makeschin, 1979). Worms are sensitive for systemic fungizides (e.g. benzimidazoles) but are very tolerant against other pestizides and toxicants like arsenic, lead, cadmium, copper and mercury. These elements can be accumulated in earthworms to such a high degree that their consumption may be lethal to birds or fishes.

Besides earthworms other rooting and burrowing animals may also cause soil displacement and are influencing the permeability and homogenity of soils.

In arid zones desert woodlice (hemilepistus species) translocate about 1.5 t/ha during 3 months (Schmalfuß, 1975). Unlike earthworms they feed mainly on mineral particles only 20 % of their feces consists of organic

matter. They are however limited to the upper surface soil layer not digging deeper than about 30 cm (Graff and Makeschin, 1979).

The activities of ants are also mostly limited to the upper 30 cm soil layer. In forests their earth movement is calculated to amount to about 5 kg of sand per square meter and year. Tropical ant species may dig as deep as 10 m in order to get close to the ground water level (Dunger, 1964). Fitzner et al. (1979) reported that several hundred ant colonies (Pogonomyrmex owyheei) were present on burial grounds on the Hanford Site in southeastern Washington. The mean depth of five excavated colonies was 2.3 m and the volume displaced was about 1800 cm^3. Also, the ants are known to seek out disturbed sites for colony formation, thus they may selectively occupy burial sites in preference to the surrounding environment.

In savanna regions termites play an importent role. They move about 6 kg of earth per square meter annually. Termitaries may extend to about 4.5 m below ground and 3 m above ground. In Zambia termitaries of 300 t were found at a density of 0.4 termitaries per ha. The thus collected earth represents a soil layer of 7 to 15 cm above ground (Rose et al., 1981).

Surface layers resulting from the activity of invertebrates are generally enriched in their nutrient and mineral content and the permeability of these overburdens is increased compared to the original soil thus facilitating plant growth but also lateral dispersion due to the loose agregate produced by animal activity. Soil animals may also be responsible for rock disintegration by bringing up rock particles to the suface to be exposed to further weathering (Matthews, 1974).

There are also several mammals living partly or almost entirely in soil. Their activity in soil is generally limited to building dens which, once established, may be used for several generations, thus rendering a comparatively smaller contribution to the bioturbation of soil.
The sett of badgers may be as deep as 5 m below surface, foxes may reach a similar depth while the burrows of rabbits and mice will hardly surpass a depth of 1 m and more generally only half a meter below surface (Niethammer and Krapp, 1982).
Most effective in translocating soil are moles which, according to Soviet studies (Abaturov, 1968, Voronov, 1968), may displace 10 to 120 t

of soil/ha annually. Their burrows are up to 100 m long but hardly any deeper than 0.5 m. Since they feed mainly on earthworms and their daily intake rate may reach up to 150 % of their own weight they may reduce the earthworm population severely.
In steppe and half-desert zones with chernozem and solonetz soils ground squirrels (citellus sp.) are also of importance. Their annual soil displacement of up to 1.6 t/ha is smaller than that of moles but their burrows reach as deep as 2 m (Abaturov, 1972).

O'Farrell and Gilbert (1975) reported on the dispersal of radiative materials by jackrabbits. Burrowing animals, probably badgers or coyotes, burrowed into a soil covered trench containing cesium and strontium salts. The jackrabbits ingested the exposed salts and spread contaminants over a wide land area through their urine and feces. Other reported instances of mammal burrowing on shallow land disposal sites include pocket mice (Perognathus parvus) at the Hanford Site (Landeen and Mitchell 1982), pocket gophers (Thomomys bottae) at Los Alamos (Hakonson et al. 1982), and Ord's kangaroo rats (Dipodomys ordii (Woodhouse)) and deer mice (Peromyscus maniculatus (Wagner)) at the Idaho National Engineering Laboratory (Arthur et al. 1986).

Gano and States (1982) reviewed literature on factors affecting habitat selection and maximum recorded burrowing depths for several small mammals that were considered likely to inhabit waste burial sites in the western United States. They concluded that vegetation type, soil texture and soil depth were major variables influencing site selection by the animals. Their summary showed that a number of mammals burrowed to depths approaching two meters, and that the deepest burrowing mammals (prairie dogs) had reported maximum burrow depths of about 4.3 m.

Landeen and Mitchell (1982) found that small mammals burrowing on a decommissioned radioactive waste pond tended to burrow deeper in areas that were least compacted. The inference from their work is that disturbed soils tend to promote deeper burrowing.

EVALUATION OF THE RELEVANCE OF BIOTIC PATHWAYS FOR RADIOECOLOGICAL ASSESSMENTS

As has been shown above the potential intrusion of plant roots and burrowing animals into the buried waste can only be assessed realistically if mayor parameters are known, such as

- the ecosystem (climate; precipitation rate, type of soil, plant community, etc.)
- type of shallow land burial (depth of trench cover, waste management practices; aerobic or anaerobic soil layers, etc.)
- type of waste (fraction of organic waste; packing material, radionuclide inventory, etc.)

Intrusion of plant roots into buried waste is most likely to occur if the low-level waste is covered with a relatively thin layer of sandy soil and if the waste ground renders aerobic conditiens and is out of reach of the influence of stagnant water. On the other hand, the possibility of biotic intrusion can almost be excluded, if the waste is buried some meters deep below heavy, fertile soil. The waste layer itself is also a barrier to root growth since it is mostly anaerobic and methane emitting thus inhibiting root growth of most plants, similarly impenetrable like perched soil layers. Soil animals are also not likely to penetrate such a waste layer.

As a first conclusion it can be said that the intrusion pathway can be neglected if other pathways for mobilizing radionuclides are conceiveable like, for instance, the activity of anaerobic organisms or the influence of stagnant water. The possibility of a future intrusion can also be influenced by management practices of the burial and by the type of packing material used. Covering the disposal site with concrete, for instance, will prevent the intrusion of plant roots and soil animals for decades. Thin packings (plastic, cardboard) may easily be penetrated by roots and soil animals while ferro-concrete, concrete or betumen casing are almost impermeable.

These scenarios outlined above show the problem of making long-term assessments. Covers and packing material are aging, anaerobic conditions in the waste disposal ground are subject to changes, the soil cover may

be removed by water- or winderosion. On the long term the probabilitity for a mobilization of radionuclides by intrusion processes is increasing, the certainty of prognoses, however, is decreasing. A realistic assessment of the impact of intrusion on mobilizing radionuclides is failing even for presently existing waste disposal sites, for lack of knowledge of essential parameters.

Due to the heavy casing of modern disposal grounds, intrusion will be very improbable during the first decades after shut down which implies that for such disposal sites intrusion may only be of relevance for radionuclides with a half-time of more than 5-50 years.

For older waste disposal grounds where the waste is often much less shielded, corresponding activity measurements can be carried out. If the plants growing on these sites are contaminated its source has to be traced back distinguishing very carefully whether the contamination is due to intrusion or other mobilization processes with subsequent root uptake.

REFERENCES

Abaturov, B. O. 1968. In: Graff, O. and F. Makeschin (eds.). 1979.

Abaturov, B. O. 1972. In: Graff, O. and F. Makeschin (eds.). 1979.

Arthur, W. J. 1982. Radionuclide Concentration in Vegetation at a Solid Radioactive Waste-Disposal Area in Southeastern Idaho. J. Environ. Qual. 11:394-399.

Arthur, W. J., O. D. Markham, C. R. Groves, B. L. Keller, and D. K. Halbord. 1986. Radiation Dose to Small Mammals Inhabiting a Solid Radioactive Waste Disposal Area. Journal of Applied Ecology, 23: 13-26.

Brauns, A. 1968. Praktische Bodenbiologie. G. Fischer, Stuttgart.

Cannon, H. L. and W. H. Starret. 1956. In: Rose, A. W., H. E. Hawkes, and J. S. Webb (eds.). 1981).

Cornam, W. R. 1979. Improvement in Operating Incident Experience at the Savannah River Burial Ground. Pp. 787-794. In: Carter, M. W., A. A. Moghissi and B. Kahn (eds.), Management of Low-Level Radioactive Waste. Volume 2. Pergamon Press, Elmsford, Now York.

Dabrowski, T. E. 1973. Radioactive Tumbleweed in the 100 Areas. UNI-65, United Nuclear Industires, Inc., Richland, Washington.

Dunger, W. 1964. In: Graff, O. and F. Makeschin (eds.). 1979.

Fitzner, R. E., K. A. Gano, W. H. Rickard, and L. E. Rogers. 1979. Characterization of the Hanford 300 Area Burial Grounds. Task IV -Biological Transport. PNL-2774, Pacific Northwest Laboratory, Richland, Washington.

Foxx, T. S., G. D. Tierney, and J. M. Williams. 1984. Rooting Depths of Plants on Low-Level Waste Disposal Sites. LA-10253-MS. Los Alamos National Laboratory, Los Alamos, New Mexico.

Gano, K. A. and J. B. States. 1982. Habitat Requirements and Burrowing Depths of Rodents in Relation to Shallow Waste Burial Sites. PNL-4140. Pacific Northwest Laboratory, Richland, Washington.

Graff, O. and F. Makeschin. 1979. Der Einfluß der Fauna auf die Stoffverlagerung sowie die Homogenität und die Durchlässigkeit von Böden. Zeitschrift für Pflanzenernährung und Bodenkunde, 142: 476-491.

Hakonson, T. E., J. L. Martinez and G. C. White. 1982. Disturbance of a Low-Level Waste Burial Site Cover by Pocket Gophers. Health Physics, 42: 868-871.

Kennedy, W. E., Jr., L. L. Cadwell and D. H. McKenzie. 1985. Biotic Transport of Radionuclides from a Low-Level Radioactive Waste Site. Health Physics 49: 11-24.

Klepper, E. L., L. E. Roger, J. D. Hedlund and R. G. Schreckhise. 1979. Radioactivity Associated with Biota and Soils of the 216-A-24 Crib. PNL-1948. Pacific Northwest Laboratory, Richland, Washington.

Kutschera, L. 1960. Wurzelatlas mitteleuropäischer Ackerunkräuter und Kulturpflanzen. DLG Verlags-GmbH, Frankfurt.

Lexikon der Biologie. 1986. Herder, Freiburg.

Maslov, V. I., K. I. Maslova, and R. M. Alexakhin. 1980. Redistribution of Natural Radioactive Elements Resulting from Animal and Plant Life, Activity in Regions with High Radioactivity. In: Gesell, T. F. and W. M. Lowder (eds.), Natural Radiation Environment III, Vol. 1, CONF 780422, Proceeding of a conference held April, 1978, Houston, Texas. DOE Symposium Series 51, U. S. Department of Energy., Washington D. C.

McKenzie, D. H., L. L. Cadwell, C. E. Cushing, Jr., R. Harty, W. E. Kennedy, Jr., M. A. Simmons, J. K. Soldat, and G. Swartzman. 1982a. Relevance of Biotic Pathways to the Long-Term Regulation of Nuclear Waste Disposal, A Report on Tasks 1 and 2 of Phase I. NUREG/CR-2675, Vol. 1, U. S. Nuclear Regulatory Commission, Washington, D. C. 20555.

McKenzie, D. H., L. L. Cadwell, L. E. Eberhardt, W.E. Kennedy, Jr., R.A. Peloquin, and M. A. Simmons. 1982b. Relevance of Biotic Pathways to the Long-Term Regulation of Nuclear Waste Diosposal, Topical Report on Reference Western Arid Low-Level Sites. NUREG/CR-2657, Vol. 2, U. S. Nuclear Regulatory Commission, Washington, D. C.

McKenzie, D. H., L. L. Cadwell, L. E. Eberhardt, W. E. Kennedy, Jr., R. A. Peloquin, and M. A. Simmons. 1982c. Relevance of Biotic Pathways to the Long-Term Regulation of Nuclear Waste Diosposal, Topical Report on Reference Eastern Humid Low-Level Sites. NUREG/CR-2657, Vol. 3, U. S. Nuclear Regulatory Commission, Washington, D. C.

McKenzie, D. H., L. L. Cadwell, L. E. Eberhardt, W. E. Kennedy, Jr., R. A. Peloquin, and M. A. Simmons. 1984. Relevance of Biotic Pathways to the Long-Term Regulation of Nuclear Waste Diosposal, Phase 1 - Final Report. NUREG/CR-2657, Vol. 4, U. S. Nuclear Regulatory Commission, Washington, D. C.

McKenzie, D. H., L. L. Cadwell, K. A. Gano, W. E. Kennedy, Jr., B. A. Napier, R. A. Peloquin, L. A. Prohammer, and M. A. Simmons. 1985. Relevance of Biotic Pathways to the Long-Term Regulation of Nuclear Waste Diosposal, Estimation of Radiation Dose to Man Resulting from Biotic Transport: The BIOPORT/MAXI1 Software Package. NUREG/CR-2657, Vol. 5, U. S. Nuclear Regulatory Commission, Washington, D. C.

McKenzie, D. H., L. L. Cadwell, W. E. Kennedy, Jr. L. A. Prohammer, and M. A. Simmons. 1986. Relevance of Biotic Pathways to the Long-Term Regulation of Nuclear Waste Disposal: Phase II, Final Report. NUREG/CR-2675, Vol. 6, U. S. Nuclear Regulatory Commission, Washington, D. C.

Matthews, W. H. 1974. Geology Made Simple. W. H. Allen, London.

Schmalfuß, M. 1975. In: Graff, O. and F. Makeschin (eds.). 1979. Der Einfluß der Fauna auf die Stoffverlagerung sowie die Homogenität und die Durchlässigkeit von Böden. Zeitschrift für Pflanzenernährung und Bodenkunde, 142: 476-491.

Ng, Y. C., C. S. Colsher, S. E. Thompson. 1982. Soil to Plant Concentration Factors for Radiological Assessments. NUREG/CR-2975, U. S. Nuclear Regulatory Commission, Washington, D. C.

Niethammer, J. and F. Krapp. 1982. Handbuch der Säugetiere Europas. Akademische Verlagsgesellschaft, Wiesbaden.

Oblath, S. B. 1986. Radionuclide Release from Low-Level Waste in Field Lysimeters. Proceedings Preprint, American Nuclear Society Meeting - Spectrum '86, Low-, Intermediate-, and High-Level Waste Management and Decontamination and Decommissioning, Niagara Falls, NY, September 14-18, 1986.

O'Farrell, T. P. and R. O. Gilbert. 1975. Transport of Radioactive Material by Jackrabbits on the Hanford Reservation. Health Physics, 29: 9-15.

Paine, D., K. R. Price, and R. M. Mitchell. 1979. Evaluation of a Decommissioned Radioactive waste Pond. RHO-Sa-99, Rockwell Hanford Operations, Richland, Washington.

Pawlowski. 1959. In: Schubert, R. (eds.). 1986. Lehrbuch der Ökologie. G. Fischer, Jena.

Rickard, W. H. and L. J. Kirby. 1987. Trees as Indicators of Subterranean Water Flow from a Retired Radioactive Waste Disposal Site. Health Physics, 52: 202-206.

Robinson, T. W. 1958. In: Rose, A. W. H. E. Hawkes, and J. S. Webb (eds.). 1979. Geochemistry in Mineral Exploration. Academic Press, London.

Rose A. W., H. E. Hawkes, and J. S. Webb. 1979. Geochemistry in Mineral Exploration. Academic Press, London.

Scheffer, F., P. Schachtschabel, H.-P. Blume, K.-H. Hartge, and U. Schwertmann. 1982. Lehrbuch der Bodenkunde. F. Enke, Stuttgart.

Shuman, R. D., M. J. Case, and S.K. Rope. 1985. Documentation of a Simple Environmental Pathways Model of the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory. EGG-WM-6916. EG and G., Idaho Falls, Idaho.

Voronov, H. P. 1968. In: Graff, O. and F. Makeschin (eds.). 1979. Der Einfluß der Fauna auf die Stoffverlagerung sowie die Homogenität und die Durchlässigkeit von Böden. Zeitschrift für Pflanzenernährung und Bodenkunde, 142: 476-491.

Weaver and Albertson, 1943. In: Kutschera, L. (eds.). 1960. Wurzelatlas mitteleuropäischer Ackerunkräuter und Kulturpflanzen. DLG Verlags-GmbH, Frankfurt.

Webster, D. A. 1979. Land Burial of Solid Radioactive Waste at Oak Ridge National Laboratory, Tennessee: a case history. Pp. 731-746. In: Carter, M. W., A. A. Moghissi, and B. Kahn (eds.), Management of Low-Level Radioactive Waste, Vol. 2. Pergamon Press, Elmsford, New York.

Annex 4

SUMMARIES OF INDIVIDUAL RESEARCH ACTIVITIES PRESENTED AT THE FINAL CO-ORDINATION MEETING

SOIL CHEMICAL EXCHANGE AND MIGRATION OF RADIONUCLIDES (SCEMR) AND PLANT TRANSFER FACTORS IN NORTHERN ENVIRONMENTS

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Disposal of hazardous wastes by burial involves several barriers to the migration of the wastes, one of which is the unsaturated soil zone. The long-term consequences of capillary rise of water and its dissolved contaminants through the unsaturated soil is not easy to assess. Similarly, downward migration after a surface contamination event, such as irrigation with contaminated groundwater, is a complex process. The principle part of this study examined both the leaching and capillary rise of Tc, I, Np, U, Th, Cs, Cr and Mo through a sandy soil. The results are important for validation of the SCEMR solute transport code and are described in detail by Sheppard et al. (1987). Eighty undisturbed soil cores from a forest floor were contaminated, half were contaminated 10 cm from their base to simulate contact with contaminated groundwater (groundwater cores), and the other half were contaminated below the litter layer to simulate soil surface deposition (leaching cores). Cups at the base of the cores served as receptacles for groundwater or for leachate. The cores were placed in the ground with their surfaces exposed to natural rainfall. After one year, half of the cores were exhumed, and the remaining were exhumed in 1988 after four years. The following summary reflects data from the cores exhumed after one year.

Soil moisture and temperature conditions in the cores reflected the trends of moisture and temperature at the coring site. Leachate analyses and exhumation data of the leaching cores indicated element mobility as Tc $\geq$ I >> Mo $\geq$ Cr >>> U $\geq$ Np, Cs, Th, with Tc the most mobile and Th the least mobile. Only Tc, I, Mo and Cr passed through the cores in the leachate in the first year. The groundwater cores showed that Tc, I, Mo, and Cr are most likely to reach surface soils from contaminated groundwater based on one year of data. Partition coefficient (K_d) values were measured by sampling the porewater in exhumed soil layers. Freundlich isotherms rather than K_d would more acurately represent sorption of I, Cs, Cr and U. The apparent K_d values decreased in the order Th > U $\geq$ Cr > Mo > Cs > I $\geq$ Np $\geq$ Tc. For Tc, I, and U, K_d values from batch sorption experiments were also compared with the K_d values obtained from the exhumation porewater and soil. The field K_d values were up to three orders of magnitude higher than the batch sorption values.

Validation of the SCEMR code has been postponed, pending results of the second half of the cores left until 1988. The results will be published in the open literature. Preliminary results show the model predicted expected water flows quite well.

The secondary part of this study examined plant concentration ratios (CRs) and translocation factors (TFs) of naturally occurring elements. Many of the statistical characteristics of these ratios have not been critically assessed, especially in field surveys. The statistical characteristics, particularly the measures of variation, are important for stochastic modelling of plant uptake. We surveyed the CR and TF values for 23 elements throughout the geographic range of one plant species, blueberries (Vaccinium angustifolia), in Canada. A paper describing the

results has been accepted for journal publication (Sheppard and Evenden 1989). Although the ratios imply linear relationships, the numerator concentrations were not closely correlated with the denominator concentrations. Clearly, the ratios depended on site-specific factors. The variation in the ratios was not clearly related to the means or to characteristics of the elements. The overall geometric standard deviation for CRs was 2.5 and for TFs was 1.6. The values of CR were intercorrelated for certain groups of elements and these groups reflected the periodic classification of elements. Thus, correlation between elements in stochastic models, which may reduce overall variability, is valid. Site variables such as soil pH, soil bulk density, soil fertility and plant growth condition were only slightly useful in statistically explaining some of the variation in CR values.

References

Sheppard, M.I., D.H. Thibault and J.H. Mitchell. 1987. Element leaching and capillary rise in sandy soil cores: Experimental results. J. Environ. Qual. 16: 273-284.

Sheppard, S.C. and W.G. Evenden. 1989. Characteristics of plant concentration ratios assessed in a 64-site field survey of 23 elements. J. Environmental Radioactivity (accepted, March 17).

SAFETY ASSESSMENT OF A DISPOSAL FACILITY FOR LOW AND MEDIUM LEVEL WASTE: RESULTS OF A SENSITIVITY ANALYSIS

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The second French Centre for disposal of low and medium-level waste will become operational in the early 1990s. Setting up a disposal facility requires the radiological capacity of the site to be defined in relation to the expected level of waste production and to the short and long-term safety objectives. When the site characteristics are considered to be satisfactory and there is a firm commitment to set up a disposal facility, it is obviously desirable to determine how best to make use of the site. An attempt is therefore made, using an iterative approach between the study of the environment and the evaluation of the radiological consequences, to specify the site and engineering characteristics and the activity limits to be adopted for this disposal facility. The latter will ultimately be reflected in waste-package specifications for the producers. They are an important factor in the cost of disposal and of management of certain types of wastes.

The following are conclusions from a generic analysis of the transfers via the water pathway, taking account of realistic geometry and flow characteristics.

It appears that, for a situation involving a realistic use of water immediately downstream of the site, the maximum individual radiation doses from the disposal of low and medium level waste corresponding to the waste production of 50 reactors for 30 years are below 10^{-5} Sv. per year.

The analysis of the reference scenario shows that the assumptions adopted lead to a result which is over-estimated. The safety margin appears large when studying the sensitivity of this global result to the different parameters.

It also emerges that the level of confinment required seems, from the radiological protection point of view, very high when compared to the real need.

In the case of Sr-90 and Ni-63, the total activity limits could depend on the well scenario during the post-survey period.

It seems, however, that, because of the average specific activities, the site volumetric capacity will lead to an activity inventory smaller than the radiological capacity.

Except for tritium, it appears that no limitation of the radioactive inventory should result from the study of the water pathway to man.

In order to define the radiological capacity for C 14, it is necessary to distinguish between organic labelled compounds (hospital waste) and graphite from the gas-cooled reactors. Ingestion dose factors for carbonate and bicarbonate are needed in the latter case.

To demonstrate that using water from a well on the site is possible after the survey period, migration characteristics for Sr-90, Ni-63, C-14 and Nb-94 need to be studied in both saturated and unsaturated zones. This point may be an important argument for public acceptance, but the interest is reduced from the point of view of safety.

MIGRATION AND INTERACTION OF RADIOACTIVE WASTE RADIONUCLIDES IN MAJOR SOILS OF IRAQ

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Shallow land disposal of radioactive waste is a common practice at many nuclear facilities. Movement of the disposed waste may occur in soluble forms and the transport vectors include diffusion and/or mass transport associated with moisture flux. The potential for radionuclide migration from a nuclear waste repository depends on physicochemical characteristics of radionuclide, chemical nature of the waste, physical and chemical characteristics of porous media, and environmental conditions. Therefore, understanding of the migration and interaction of waste radionuclides in waste-soil system is a task of major importance in assessing the potential for contamination and to provide a basic information for the responsible handling and safe disposing of radioactive materials.

1.Leaching Characteristics of Waste ^{137}Cs and ^{60}Co

In this study three individual experiments were conducted. The liquid waste (raw, diluted, and diluted then pH adjusted) was applied to large undisturbed soil columns (river sediment, loam, and silty clay loam) and leached for 180 days with deionized water (DW) and groundwater (GW) as well as to small packed soil columns. Distribution of Cs and Co was determined by either scanning of gamma radiation along the soil columns (in the large undisturbed soil columns) or sectioning and measuring their concentraion (in the small soil columns).

Results indicated that the bulk (98%) of both radionuclides were retained in the upper 10 cm of large soil columns under the various experimental conditions. The upper one cm of soil columns

was found to be the most important layer in retaining the majority (approx. 70% of total Cs and 55% of total Co) of radionuclides and also in exhibiting the changes during leaching. The cumulative leaching fraction (f) of Cs from the upper one cm of river sediment was 0.80 after 180 d of leaching with DW reduced to 0.64 in the other two soils. However, the f value of Co ranged from 0.30 to 0.48 in the three soils leached with GW.

The dilution of liquid waste and the adjusting of the pH reduced the mobility of both Cs and Co as indicated by the greater amounts retained by the top soil and explained by the salt-sieving phenomenon. The amounts of Cs retained at the upper one cm of packed river sediment received one pore volume of liquid waste was 53 to 61 fold greater with the diluted than with raw form. Similar behavior was obtained with the application of several increments of liquid waste. In both treatments (the dilution and pH adjusting), Co showed greater mobility than Cs. The results given will aid in understanding the radionuclides dynamics in the event of accidental or inadvertent release into the surrounding medium.

2. Mobilization and Fractionation of ^{137}Cs and ^{60}Co

The presence in the waste of complexing agents such as organic chelates used in decontamination operations and natural organic acids from the soil promotes the formation of strong complexes with certain radionuclides. In this experiment, the influence of several leachants (river water, NH_4OAc, KCl, $CaCl_2$, EDTA, and DTPA) on mobility of Cs and Co was investigated in columns of loam and clay soils. Concentration distribution of both radionuclides was measured in the soil columns and in the effluent during 90 to 160 d of leaching. The remained unleached Cs and Co in the soil columns were fractionated into 10 sequential fractions.

At the end of 90 d of leaching with H_2O and $CaCl_2$, the bulk of Cs applied remained in the upper 1 cm of soil columns. An appreciable reduction was observed under NH_4OAc, KCl, and EDTA. Greater mobility of Co was evident in most columns leached with H_2O and NH_4OAc. However, in none of these columns as well as in columns received Cs, a detection of both radionuclides was observed in the effluent. Conversely, EDTA and DTPA removed 90% of total Co out of soil columns in 13 to 21 d and 98% in 160 d.

The major soil constituents appeared to be responsible for retaining Cs were the clay, silt, and Fe oxides. The leaching consistently increased the magnitude of Cs bound to clay minerals and in most cases decreased the fractions of water soluble, exchangeable, carbonate, and organic. The amorphous Fe oxides were the major soil fractions in retaining Co followed by the carbonate and clay minerals. The leaching always reduced the magnitude of amorphous Fe oxides.

3. Distribution Coefficient of ^{137}Cs and ^{60}Co in calcareous soils

Distribution coefficients (K_d), retention factors (R_d), and rates of migration of Cs and Co were determined in 10 soils varied in characteristics by employing batch and column techniques. Effect of liquid to solid ratio, concentration of isotopes, type of solution (deionized water, groundwater, and $CaCl_2$), and state of isotope application (carrier-free or carrier) on the above coefficients were also considered.

The K_d for Cs followed the same pattern in the studied soils and decreased with both the increased equilibrium concentration and liquid to solid ratios. However, the magnitude of this effect was largely varied and reflected the role that the content and type of clay minerals play on sorption. Also, the K_d for Cs decreased with the increased ionic strength suggesting the involvement of ion exchange in sorption. Much less K_d values were obtained for Co than for Cs and the results showed order-of-magnitude differences. Unlike Cs, the K_d for Co was found to increase when equilibrated with the groundwater indicating the presence of precipitation and complexation mecanisms.

For both carrier-free or carrier experiments, Cs showed less retardation compared with Co when leached with groundwater. Also, the magnitude of K_d values is comparable with the batch technique only for the Cs case shaken at 1:1 or 10:1 liquid to solid ratios.

SHALLOW BURIAL PROJECTS — DELFT GEOTECHNICS: SOIL HETEROGENEITIES AND TRANSPORT OF RADIONUCLIDES

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Introduction

Delft Geotechnics is a leading independent institute in the field of geotechnical engineering. The institute specialises in consultancy and research in the fields of soil mechanics, foundation engineering, environmental geotechnology, and geohydrology. The institute has over fifty years national and international experience, and has a staff of over 300.

Within Delft Geotechnics the Chemistry and Environmental Geotechnology Department has a specific role in the following areas of endeavour:

- consulting sevices and contract research in the field of soil pollution in general and the one resulting from industrial waste disposal practices in particular
- the design and evaluation of containment techniques for industial wastes in landfill situations
- the design and evaluation of remedial actions in response to soil pollution incidents
- the evaluation of repositories for medium and low level radioactive waste

With respect to this last item our department is doing research into the influence of soil heterogeneities on the migration of radionuclides from shallow burial sites of low level radioactive wastes since 1982. The program consisted of the following stages and is still going on.

I Theoretical study
in this stage the basic concepts of effective retardation capacities with respect to safety criteria for shallow burial sites where developed and tested with numerical experiments. This part of the project was financed by the Dutch Ministry of Economic Affairs.

II Laboratory experiments
to verify the concepts and models developed under I laboratory experiments where carried out for saturated as well as for unsaturated systems. This part of the project was financed by the EC and the Dutch Ministry of Economic Affairs.

III Field verification
in this stage the models and concepts developed under the earlier stages are being verified against field experiments. For this purpose tracer test data from the Drigg experiment which is currently being carried out by the British Geological Survey are being used. This stage is being financed by the EC and the Integrated Soil Research Program of the Dutch Govenment.

IV Unsaturated experiments in a geocentrifuge
because of the practical difficulties which where encountered during stage II in doing unsaturated laboratory experiments a test program is being started to do experiments in a geocentrifuge. At this moment first pass experiments are being carried out in a small laboratory centrifuge. There is no external financing found for the project untill now.

Objectives and scope

The key design constraint for a shallow burial site is that the concentrations and fluxes of hazardous compounds migrating away from the trench should never cause harm or other problems. The technical problem is then to predict the expected concentration and flux patterns as a function of space and time. In particular, the problem hinges on the correct assessment of the effective retardation of the radionuclides by interaction with the soil itself. In order to be effective, this adsorption barrier has to delay the transport of the nuclide long enough for radioactive decay to reduce its amount to insignificant levels.

The actual adsorption capacity of a soil for the nuclides is largely associated with the clay and organic constituents. These can be distributed evenly throughout the soil or concentrated in specific lenses or horizons. This adsorption capacity can only be mobilised, if there is an opportunity for the nuclide to come into contact with the adsorption sites, and this depends in turn on the details of the soil structure. The relationship between the soil structure and the effectiveness of the adsorption barrier is the specific subject matter of this study.

Conclusions

- the migration patterns are signigficantly dependent upon the macro-soil structure. There is generally an early break-through at the target for low concentration (toe), and the maximum concentration is reached only slowly (tailing)
- this effect is especially marked for adsorbing species, where controlled by the thinnest of lenses, the initial breakthrough is controlled by the by-passing through the sand. The theoretical retardation capacity of the path is not mobilised in time to prevent this early breakthrough, and the effective barrier function of the soil is much reduced
- for the combination of parameters corresponding to a clay-sand system the retardation barrier function is only significant for lenses thinner than about 30 cm
- for very thin lenses the breakthrough at the target can be calculated using the well-known solutions to the convection - dispersion equation and the retardation factor
- for very thick lenses the initial breakthrough is best estimated by assuming that the lens is solid and takes no part in the system
- for intermediate cases a rough estimate of the effective retardation factor can be made using the various fissure models developed for geological storage purposes, but they are not entirely satisfactory
- for an accurate assessment of the migation patterns in the aquifer, a fully determinate numerical calculation can be made. However, an extensive field data base is required, and this will undoubtedly limit the use of this option
- for the unsaturated zone it is unclear what models should be used at this point in time
- the thin-slit experiments in the saturated system require repeating on a longer time scale
- the unsaturated experiments require repeating using an experimental set-up that uncouples the saturation and hydrodynamic aspects of the problem such as centrifuge tests
- first pass calculations indicate that modelling a field experiment relies heavilly on accurate permeability measurements, and a detailed insight in the layering of the system. More simple homogeneous or stratified approaches could not be tested yet because there was no height avaraged breakthough measured untill now.

MIGRATION AND BIOLOGICAL TRANSFER OF RADIONUCLIDES FROM SHALLOW LAND BURIAL

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This paper summarizes the activities carried out by the Radiological Protection and Safety Management of the National Atomic Energy Commission, Argentina, in relation to the studies performed for the actualization of the radiological impact assessment of the low level liquid radioactive waste disposal in shallow land trenches in Argentina, within the Research Contract No. 4189/R0/RB and 4189/R1/RB.

At the first stage of this work a hydrogeologic characterization of the radioactive waste disposal area was performed. For this purpose, the area in question was surveyed and the fluctuations of the phreatic water table were studied, particularly in relation to rainfall. As a result of this, charts of morphology of phreatic surface were made.

At the same time studies were performed in order to obtain realistic values of the delay factors of the radionuclides in the surrounding media. For this purpose, a static technique was implemented to determine the distribution coefficient. Later on, laboratory tests were performed using geologic material belonging to the disposal area, and the influence of different factors in the variability of these coefficients was analysed.

At the same stage, studies were started about the different available models of radionuclide migration in geologic media in order to select the one that could best describe the actual situation, and that, at the same time, involved the use of the hydrologic parameters obtained for the area under observation.

At the second stage of this work a series of boreholes were drilled with the purpose of obtaining the necessary hydrogeologic parameters of the phreatic aquifer as well as of the next semiconfined one. Thus, geological samples were taken in order to make mineralogic and sedimentologic tests. It was then possible to determine that, in general and up to 25 meters deep, all the existing material is a combination of silt and clay. On the other hand, the studies were completed with the mineralogical and chemical composition and the granulometric distribution of the geologic material, as well as the determination of the present organic material and the analysis of underground water.

A model was selected that would permit the quantification of nuclide migration in the porous media, taking into account the specific parameters of the site in question. This model develops a methodology that makes it possible to define the source term, a mathematical model that use hydrogeologic parameters experimentally measured and give as a result the radionuclide concentration in the site accessible to the public. To obtain these results the assumptions for the model are: the transport of the radionuclides diluted in the underground water occurs in homogeneous and isotropic porous media, and that the fluid is incompressible and of constant viscosity. The physical and chemical phenomena considered in the transport process are: convection, longitudinal and transversal dispersion, radionuclide sorption in geologic material and radioactive decay.

The dosimetric model used assumes that the significant contribution to the individual doses are: consumption of water and fish , external irradiation from river sediments and ingestion of vegetables irrigated with contaminated water.

The distribution coefficient (K_d) was utilized to estimate the radionuclide delay in the geologic media, taking into account its limitations associated with their empirical character. The necessary studies was performed to obtain the K_d values fitted to particular experimental conditions, related to the contact time, the carrier concentration in solution, the range of pH values, the presence of competitive ions and the solid/liquid ratio.

Furthermore, special attention was paid to the fulfilment of a sensibility analysis of the model used. To perform this, the extreme values of the different parameters involved in the estimations of radionuclide migration have been used. With this purpose, the hydrogeologic parameters were varied taking into account the present possible uncertainties especially in relation to the dispersivity, the infiltration velocity, the permeability and the K_d .

At the third stage , studies related to the human intrusion phenomena were performed. The estimation of the associated radiological impact considers that the events happen after the site has been closed and no further disposal of wastes takes place. Two alternative scenarios was selected as the most pessimistic cases of a large number of possible scenarios that result in a direct alteration of the normal evolution of the site.

One of them is related with the construction of a house in the trench site, and the other with the inhabitants of a house placed in the same site, including the ingestion of vegetables grown in the kitchen garden placed on the trench material diluted with fertile soil distributed in the surrounding of the house.

The pathways considered are: for the construction scenario, inhalation of suspended particles during the excavation and the external irradiation resulting from direct exposure to the trench material; and for the residential scenario, inhalation of dust containing sorbed radionuclides, direct irradiation and ingestion of vegetables cultivated in the kitchen garden.

Simple compartimental models have been formulated based on the previously described scenarios that makes it possible to estimate compromissed effective dose equivalent due to the different pathways of exposure.

Furthermore, to improve the calculations concerning the migration of radionuclides in porous media, the solutions of the mass transport equation and the adequate boundary conditions in heterogeneous media have been studied. On the basis of this study a calculation program of radionuclides concentration in underground water after travelling through two layers of different geologic properties have been implemented.

MIGRATION OF SOME RADIONUCLIDES THROUGH THE SURROUNDINGS OF A SHALLOW LAND BURIAL FACILITY

(Abstract)

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Laboratory migration tests were carried out to study the migration behaviour of the most hazardous radionuclides ^{137}Cs, ^{60}Co, ^{90}Sr and ^{125}I in the substance of the engineered barrier and in the surrounding of a planned repository. Experimental results were applied for fitting a migration model to the data and for determining the actual dispersion coefficients for the given barriers and radioisotopes. The long term dispersion of the radioisotopes was predicted by means of these actual dispersion coefficients for about 300 years and safety aspects of the planned repository were estimated.

SUMMARY OF THE INVESTIGATIONS OF PHENOMENA AFFECTING RADIOLOGICAL MODEL PREDICTIONS FROM RADIONUCLIDES IN SURFACE LAYER OF THE EARTH

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Our investigations were concentrated on three main topics: Mobilization of radionuclides by intrusion of roots and animals, application of the specific activity model for dose calculations and derivation of exempt limits for low contaminated waste. The results of the investigations can be summarized as follows:

Mobilization of radionuclides by intrusion of roots and animals into the burial sites

The question was investigated together with L. Cadwell, Battelle, NW, USA. A report has been presented on the 2nd coordinated meeting in Oak Ridge, Tennessee.

Intrusion of plant roots into buried waste is most likely to occur if the low-level waste is covered with a relatively thin layer of sandy soil and if the waste ground renders aerobic conditions and is out of reach of stagnant water. On the other hand, the possibility of biotic intrusion can almost be excluded, if the waste is buried some meters deep below heavy, fertile soil. The waste layer itself is also a barrier to root growth since it is mostly anaerobic and methane emitting thus inhibiting root growth of most plants, it is just as impenetrable as perched soil layers. Soil animals are also not likely to penetrate such a waste layer.

As a first conclusion it can be said that the intrusion pathway can be neglected if other pathways for mobilizing radionuclides are conceivable like, for instance, the activity of anearobic organisms or the influence of stagnant water. The possibility of a future intrusion can also be influenced by management practices of the burial site and by the type of packing material used. Covering the disposal site with concrete, for instance, will prevent the intrusion of plant roots and soil animals for decades. Thin packings (plastic, cardboard) may easily be penetrated by roots and soil animals while ferro-concrete, concrete or bitumen casing are almost impermeable.

For these outlined scenarios it is, however, difficult to make long-term assessments. Covers and packing material are aging, anaerobic conditions in the waste disposal ground are subject to changes, the soil cover may be removed by water- or winderosion. On the long term, the probability for a mobilization of radionuclides by intrusion processes is increasing as well as the uncertainty of a prognosis. A realistic assessment of the impact of intrusion on mobilizing radionuclides is failing even for presently existing waste disposal sites, for lack of knowledge of essential parameters.

As has been shown above the potential intrusion of plant roots and burrowing animals into the buried waste can only be assessed realistically if major parameters are known, such as

- the ecosystem (climate; precipitation rate, type of soil, plant community, etc.)
- type of shallow land burial (depth of trench cover, waste management practices; aerobic or anearobic soil layers, etc.)
- type of waste (fraction of organic waste; packing material, radionuclide inventory, etc.)

Due to the heavy casing of modern disposal grounds, intrusion will be very improbable during the first decades after shut-down which implies that for such disposal sites intrusion may only be of relevance for radionuclides with a half-time of more than 5 - 50 years.

For older waste disposal grounds where the waste is often much less shielded, corresponding activity measurements can be carried out. If the plants growing on these sites are contaminated its source has to be traced back distinguishing very carefully whether the contamination is due to intrusion or other mobilization processes with subsequent root uptake.

Application of the observed ratio model for dose calculations

In this study an attempt is made to find a more reliable way in describing the soil-plant transfer then by using transfer factors which are defined as the concentration ratios of the radionuclides in the vegetation to soil.

For a more accurate assessment of the radionuclide uptake physiological considerations have to be taken into account. Using the plant uptake of Sr 90 and Cs 137 as an example it is demonstrated that the soil-plant transfer is mainly influenced by three parameters:

- the regulation of the concentration of essential elements in the vegetation,
- the antagonism between the radionuclides and their competitive essential elements,
- the plant availability of radionuclides and of their respective essential elements in the soil.

The consideration of these parameters leads to the observed ratio model.

Our investigations show that this model is fairly well applicable for Sr/Cs but less for K/Cs. This is due to the difficulties in estimating the plant available forms of these latter elements in soil.

Derivation of exempt limits for low contaminated waste

Exempt concentrations of radionuclides for low-level radioactive wastes were derived. The study is based on an idea developed by the IAEA, which was originally published as the "de minimis" concept.

A criterion for uncontrolled disposal of low-level radioactive waste is, that the radiation exposure of the public and of each individual caused by this disposal is so low, that radiation protection measures need not to be taken. As a limit for the individual radiation dose the IAEA suggests an annual effective dose equivalent of 10 µSv.

This dose limit was adapted for the derivation of exempt concentrations in this study. Potential exposure pathways to man following the disposal to municipal landfill and by the incineration were analyzed and relevant models developed. According to these models concentrations leading to an individual dose of 10 µSv/y were calculated for 81 radionuclides.

A comparison with the IAEA study indicates that the results are very similar although these studies were performed independently from each other and some basic assumptions differ, e. g. the amount of radioactive waste.

MIGRATION AND BIOLOGICAL TRANSFER OF RADIONUCLIDES FROM SHALLOW LAND BURIAL

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The most important pathway by which radionuclides from a repository can contaminate the biosphere is migration via the groundwater. Therefore, the main attention in repository design is paid to the prevention of entrance of water into disposal modules. This can be achieved by implementing an efficient drainage system and by providing the disposal modules with impermeable protective coats such as clay. In the frame of this study the properties of various clay materials has been examined and a development of groundwater migration models performed.

According to the modelling experiences it can be concluded that basic mechanism that apply to realistic site characteristics can be simulated with simplifying assumptions. Analytical models are preferable for sensitivity analyses and preliminary investigations of transportphenomena using conservative data, even when realistic field data are lacking. The simplifying assumptions accepted in the analytical models limit their ability to describe a real system.

Numerical models posses the ability to treat more complicated systems with heterogeneous aquifers, time depending release rates, ground water velocities and varying precipitation rates. However, for a real system lacking data can easily disturb the reliability of the model prediction and to limit use. Therefore, the use of analytical models has been prefered.

Siting studies for disposal of reactor wastes carried out in the past resulted in two disposal sites located close to the two existing nuclear power plants. A part of their safety assessments have been performed under this contract.

Data on the hydrogeological systems were collected. They consisted of chemical and physical properties of the groundwater, lithological informations, water bearing characteristics of hydrogeologic unit, groundwater regime and water use and climatological data. Special attention was given to the evaluation of retention properties of soils with respect to the influence of various concurent ions.

The activity of the most important radionuclides have been taken into account in the safety assessments. The values in shallow ground repository correspond to the waste production from eight 440 MW_e and four 1000 MW_e PWR . The maximum of total activity is expected around the year 2020.

In assessing of the radiological impacts from shallow ground disposal hypothetical exposure events that could occur on both short and long term bases have been analysed.

The shallow ground disposal techniques even in case of multibarrier concept will not retain the waste completely in place over time. Some migration is to be expected and it is important that it should be acceptable in amount and rate.

The release rate of radionuclides into water due to flooding of the repository depends on the contact time of water with wastes, the surface area of wastes, the run-off rate and the kinetics of leaching process. It is assumed that the released fraction is about 2.10^{-3}.

The available data base have enabled to carry out migration calculations. The output consists of the rates of discharge of radionuclides into water wells and into the nearby streams. The contamined groundwater can enter the terrestrial food chains by the irrigation.

The applied model of migration through food chains has been originally used in radiological evaluations of contamination

following atmospheric releases of radionuclides.The values of required parameters have been selected on the basis of comprehensive literature survey.

The maximum individual doses as a result of abnormal situation considered reached up to 3 mSv/a in the time of maximum content of radionuclides in repository. The dose in the early period is caused by tritium, whilst later other nuclides will be important.

Similar analysis have been performed also for waste storage tank and pipe line ruptures. The resulting doses have been of the order 10^{-4}Sv/a.

Uncertainty analyses carried out have been intended for the identification of parameters significance, for model predictions reliability and to identify the objects of future research. The role of leach rate, groundwater flow velocity, sorption properties, dispersion characteristics and porosity have been studied.

MIGRATION AND BIOLOGICAL TRANSFER OF RADIONUCLIDES FROM SHALLOW LAND BURIAL

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Participation of India in the research programme started in March 1986. The work carried out under this research project can be categorised into six parts.

1. Characterisation of shallow land burial site in India.

2. Characterisation of waste disposal systems.

3. Development of mathematical models for prediction of radionuclide migration in porous saturated media.

4. Development of a radiological (biological) model for prediction of dose rates resulting from discharge of contaminated water to various water bodies.

5. Applications of the codes developed in 3 & 4 to specific sites taking into account realistic input parameters generated/compiled in 1, 2 for different boundary conditions.

6. An experimental validation programme for comparative studies oftheoretically predicted values and actual results.

The detailed work carried out in each of the six parts is as follows:

1. All the available geological, geohydrological and physicochemical data for different waste disposal sites viz. Trombay, Tarapur, Narora and Rajasthan were compiled. Various experiments were planned and performed to generate unavailable data.

2. In order to determine source term for migration studies, relevant data on waste characteristics, leaching behaviour, packaging details, engineering barriers and backfill etc., were compiled for the Trombay site and Narora sites.

3. A preliminary 1-Dimensional mathematical model based on an analytical solution was conceived and a computer code "DISP-STEP" was developed for step input. The code was run on a Norsk-Data computer system taking input parameters for Narora site. Systematic parametric studies were performed varying distribution co-efficients, mixing lengths, groundwater velocities for Cs^{137} and Sr^{90} radioisotopes.

4. A radiological model has been developed to study activity uptake and resultant dose rate to living organisms as a result of discharge of contaminated water containing 20 different radioisotopes to sea. The model was further changed for different water bodies like wells, lakes, rivers, canals etc. for reference time frames of 1 year, 10 years, 100 years and 1000 years.

5. The codes developed in 3 & 4 were run on computers for Narora sites taking into account realistic input parameters generated/compiled in 1 & 2. The results obtained were very pessimistic for the following reasons.

   a. No credit was taken for engineered barriers.

   b. A non-decaying step input was assumed which is unlikely for any real waste repository having finite operational life. In view of this the computer code was modified to "DISP-BAND" changing boundary conditions to decaying band. The results of the same are being analysed.

6. In-situ radionuclide migration experimental studies are planned at RSMS, Trombay. Under this Sr^{85} and Cs^{134} isotopes will be injected into a pit at 1 metre depth and will be covered with soil and compacted. Holes will be drilled at 2, 5, 10 meters away from the point of injection in the direction of groundwater for collection of soil and weathered rock samples. Analysis of this will give sorption properties, recharge rate, radionuclide migration pattern. Similar studies are planned in the saturated zone at one of the riverside waste disposal sites for model validation.

SUMMARY OF THE WORK ON RADIONUCLIDE MIGRATION AT JAERI

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I. Migration Tests of Radionuclides in Sandy Soil Layer (1985 - 1986)

1. Objectives

As an alternative to a field migration test, radionuclide migration tests in a laboratory have been conducted by using apparatuses realizing natural soil layer conditions, to evaluate the ability of the soil layer to retard the migration of radionuclides. This study intends to contribute the safety assessment of shallow land disposal of low-level radioactive wastes.

2. Experimentals

Samples of aerated coastal sandy soil were obtained from on-site of JAERI by an open cut method in an undisturbed state. Aquifer samples were obtained by a shovel excavator in a disturbed state.

Migration tests in an aerated soil layer column, which simulate the flow in the aerated layer of contaminated water released from a disposal facility, were carried out by sprinkling a radioactive solution containing ^{60}Co, ^{85}Sr and ^{137}Cs over the top of the soil layer to realize continuous downward flow in the column.

Migration tests in an aquifer vessel, which simulate the flow of contaminated water in the aquifer, were conducted by a point dilution method, i.e., the radioactive solution was continuously injected into the vessel which realizes a steady state horizontal flow with the synthetic groundwater.

3. Main results

(1) The concentration of the radionuclides in an effluent passed through the aerated soil layer column was ca. 10^{-5} μCi/ml for both ^{60}Co and ^{137}Cs, and less than the detection limit for ^{85}Sr. The corresponding value for the aquifer vessel was ca. 10^{-7} - 10^{-6} μCi/ml for ^{60}Co, and less than the detection limit for both ^{85}Sr and ^{137}Cs.

(2) The distribution profiles of the radionuclides in the aerated soil layer column showed that most portions of the radionuclides were retained at the top layer of the soil, and the difference in the profiles of the radionuclides was observed at the lower concentration ranges less than 10^{-4} μCi/ml, and suggested that the migration velocity of ^{85}Sr was lower than that of ^{60}Co and ^{137}Cs. The profiles observed in the aquifer vessel indicated that ^{60}Co had the highest horizontal migration velocity among the radionuclides tested here.

(3) This study also confirmed the experimental evidences as were obtained with a disturbed soil column that ^{85}Sr migrated in soil layer with an ion exchange mechanism, and ^{60}Co which forms

hydrolysis products migrated faster than ionic species. On the contrary, in the case of the undisturbed soil layer used in the study, silt materials affected significantly the migration of ^{137}Cs.

4. Conclusions

Retardation factors calculated with experimental data obtained here indicate that coastal sandy soil holds significant ability to retard the migration of the radionuclides. Analysis of the experimental data with a conventional mass transport equation suggests the necessity of developing a specific analytical model to treat the data especially for the migration of particulate species e.g., hydrolysis products of ^{60}Co and silt materials adsorbing ^{137}Cs.

II. In-Situ Cold Tracer test on Nuclide Migration in Saturated and Unsaturated Zone (1987 - 1988)

1. Objectives

This program involves a field migration test with cold tracers in the site of JAERI to clarify the behavior of groundwater flow and solute transport, and a measurement of the distribution coefficient for coastal sandy soil to obtain basic data needed for the analysis of migration data. This study intends to demonstrate the validity of a conventional nuclide migration model, to prepare data base, and to establish an environmental monitoring plan.

2. Experimentals

Field tests for saturated and unsaturated zone were separately carried out to clarify the migration behavior in both zones. As a tracer, D_2O and uranine were used for water flow measurements, and non-radioactive Co, Ni, Sr, Cs and Eu were employed for solute transport measurements. The tracer was injected into unsaturated layer or saturated layer. The concentration of the tracer in each layer was periodically measured to obtain the dispersive and convective behavior of water flow and solute transport. The distribution coefficients of the elements used here as a cold tracer were measured by a batch method by using the corresponding radioactive tracers.

3. Main results

(1) The flow of infiltrating water in aerated zone could be modeled as a piston flow. The velocity of the solute transport in aerated zone was significantly lower than that of the water flow, indicating the barrier effect of the soil layer against the migration of the solutes.

(2) In saturated zone, the migration velocity of the solutes followed the order: Sr, Ni, Co, Eu and Cs. The retardation factor of Sr was estimated to be ca. 20.

(3) The distribution coefficients of Co, Sr and Cs measured in a carrier free concentration were 88, 57 and 140 ml/g for unsaturated soil, and 310, 87, and 260 ml/g for saturated soil, respectively. The distribution coefficient remained unchanged over the very low concentration ranges of a specific element and co-existing ions, beyond which it was decreased with an increasing concentrations of the element and co-existing ions.

4. Conclusions

This study provides the information on the behavior of water flow and solute transport in saturate and unsaturated zone, which might be important in the safety assessment of shallow land burial of low-level radioactive wastes.

III. Radionuclide Migration Test for Aerated Soil Layer of a Candidate Disposal Site (1988 - 1989)

1. Objectives

Radionuclide migration tests on aerated soil layers sampled from a candidate disposal site have been conducted to obtain the migration behavior of radionuclides. This study aims at the evaluation of retardation ability of soil layer, and the contribution to the safety assessment of the candidate disposal site.

2. Experimentals

Three kinds of undisturbed soil layers, loam, sand and tuff, used in the tests were obtained from the aerated zone of candidate disposal site by using a boring machine without using water.

Migration tests in an aerated soil layer column, which simulate the flow of contaminated water from a disposal facility to the aerated soil layer, were carried out by sprinkling a radioactive solution containing ^{60}Co, ^{85}Sr and ^{137}Cs over the top of the layer, and by depressurizing the column through the bottom to accelerate the permeation of the solution.

3. Main results

(1) An extremely low concentration of ^{60}Co was detected in an effluent passed through the soil layer column, while both ^{85}Sr and ^{137}Cs were less than the detection limit.

(2) The distribution profiles of the radionuclides in the soil layer column indicated that a large portion of the radionuclides retained at the top soil layer, while only a small portion of them migrated into a deeper soil layer, especially for particulate species such as hydrolysis products of ^{60}Co, and ^{137}Cs adsorbed on silt materials.

4. Conclusions

The soils used here gave larger retardation factors for the radionuclides tested, indicating the aerated soil layer of the candidate disposal site had a significant ability to retard the migration of radionuclides. It was found that a conventional mass transport equation using the distribution coefficient to represent the interaction of radionuclides and soil might not describe the migration behavior of particulate species. We are, therefore, now developing new models taking into account of a filtration process for ^{137}Cs adsorbed on silt materials and adsorption/desorption kinetics for hydrolysis products of ^{60}Co.

MIGRATION AND BIOLOGICAL TRANSFER FROM SHALLOW LAND BURIAL FACILITIES

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Recently the NRPB published a detailed assessment of the radiological impact of the United Kingdom's principal low-level solid radioactive waste disposal facility at Drigg [1]. Additionally there has been continued development of the BIOS family of computer codes used to assess the transport of radioactivity in the biosphere and the doses delivered to humankind as a result of the disposal of solid radioactive waste.

The assessment of the Drigg site was commissioned by British Nuclear Fuels plc (BNFL), the operators of the site, both as part of an overall environmental assessment programme at the Drigg site and also specifically as a major input to the recent review, initiated by the Authorising Departments in 1986, of the authorisation for the disposal of wastes at Drigg. Other components of the site investigation programme, for example hydrogeological fieldwork and modelling and soil adsorption studies, were used with other data as inputs to the radiological assessment work which in turn assists in directing priorities of the investigation studies.

A wide variety of possible mechanisms for the release of radionuclides from disposal trenches are considered. These include leaching in groundwater into the trench drainage system and into adjacent aquifers, release in gases generated in the waste, as well as inadvertent intrusion by mankind for site investigation and building purposes, and for the extraction of groundwater. Consideration is also given to the risks to individuals living near the site from fires during disposal operations and to others who may live on the site after building has occurred.

The measures of radiological impact calculated include maximum annual individual risks and collective effective dose equivalent commitments, truncated at various times. Results predicted for maximum annual individual risks from past disposals may be compared with appropriate targets or limits. Results for unit future disposals may be used in conjunction with inventory data to determine the impact of potential future disposals. Results for collective doses may be used similarly. The collective dose arising from the disposal of the same waste by other options is also discussed for comparative

purposes. The major assessment assumptions relevant to the more significant of the predicted impacts are highlighted and the implications for the impact of variations in input data are discussed.

A new model for the transport of radionuclides in the biosphere has been developed for use in multirun uncertainty/sensitivity studies. MiniBIOS is a simpler model than the BIOS model, from which it is derived. The application of uncertainty/sensitivity analysis techniques to aspects of the migration of radionuclides in the near surface environment, with variations in parameters affecting the dose delivered to individuals by parallel and multiple pathways is presently under consideration.

The other area in which the migration and biological transfer from shallow land burial facilities has been studied by NRPB is in relation to waste management options for decomissioning wastes. This forms part of a study for the Commission of the European Communities on a "Methodology for assessing suitable systems for management of reactor decommissioning wastes". The calculations were performed for a number of different waste inventories that reflected different options or different stages in the decommissioning process. As this was intended to be a demonstration of a methodology, a generic site was assumed and a range of results was obtained for each waste type by considering a range of geosphere parameters based on those reported in reference 2. Both migration in the groundwater and intrusion pathways were considered. BIOS was used to calculate the migration in the biosphere and the pathways to man. Both peak individual risks and integrated collective doses were calculated and the results were used to show how a comparison between the waste management options could be made. A report will be published later in the year.

REFERENCES

1. Assessment of the Radiological Impact of the Disposal of Solid Radioactive Waste at Drigg. Smith GM, Fearn HS, Smith KR, Davies JP and Klos RA. Chilton, NRPB-M148, (1988).

2. Calculations of the Radiological Impact of Disposal of Unit Activity of Selected Radionuclides. Smith GM, Fearn HS, Delow CE, Lawson G and Davis JP. Chilton, NRPB-R205, (1987).