NAnet Project

WORK PACKAGE 3

Analogues for the near-surface and surface environment

Project funded by the European Community under the 'Competitive and Sustainable Growth' Programme (1998-2002)

CONTENTS

1 INTRODUCTION

It is frequently asserted (e.g. US DoE, 2000) that natural analogues can be used to test conceptual and numerical models over large distances and long time scales that are impossible with laboratory or field experiments and that they are uniquely suited to building confidence in process-level models by means of 'validation'. Despite this, the use of analogue information in safety assessments and more generally in safety cases is generally sparse. The aim of the NAnet project is to critically review the past and present use of natural analogues with the intention of promoting more considered applications of them in future safety assessments and for public communication.

The objective of Work Package 3 within NAnet was to consider analogue processes occurring in the near-surface and surface environment which impact on repository performance. The scope of the work specifically excluded biologically influenced pathways, i.e. those related to radionuclide uptake, transfer and exposure to flora and fauna. The analogues considered therefore relate to studies dealing with, or impacting on, processes occurring at the geosphere-biosphere interface and to the effects of near-surface to surface contaminant transport (e.g. floodplain and riparian settings). Modelling, laboratory studies and field scale experiments were also excluded from consideration, although accidental consequences arising from anthropogenic contaminant sources impacting on natural systems were considered to be a valid component of the study.

In keeping with the containment function inherent in the design of repositories, any long-lived and poorly retarded radionuclides that might escape from deep geological radioactive waste repositories are not expected to reach the near-surface and biosphere for millennia and any releases that do occur may be protracted over periods of tens of thousands of years or more. As such, the period of safety assessment is necessarily long and, depending on regulatory requirements, will generally extend up to or beyond 10^6 years. Large scale environmental change, both to climatic conditions and to the landscape, is expected on such time scales and they will in turn likely affect hydrological responses at the geosphere-biosphere interface zone (GBIZ), of particular interest in the context of this study. It follows that in choosing suitable analogues for releases of radionuclides to the near-surface environment, consideration needs to be given to the full range of climatic, geomorphologic and agroecological situations that could arise over the next 10^6 years or more.

This document considers the potential application of near-surface analogues in supporting safety assessments of radiological impact and to their use more generally in supporting a safety case for land-based geological repositories for radioactive waste. In undertaking this report, the previous use of near-surface or biosphere analogues in safety assessments was investigated. It was found that very little use has been made to date, and the main reasons why biosphere analogue information in particular has not previously been applied systematically to published safety assessments is presented. The understanding derived from this analysis has been used as the basis for recommending a possible methodology for deciding on the use of near-surface analogues in future safety assessments.

2 STUDY FOCUS

In the context of the NAnet project, potential near-surface and surface analogues can conceptually be split into two parts, namely biologically-influenced and non-biologically influenced analogues. However, it is appreciated that this distinction is often difficult, and may sometimes be undesirable, to apply in practice. The focus that has been adopted for this study is on non-biologically influenced (or at least very poorly influenced) analogues of interactions between contaminated groundwaters and near-surface features, such as soil horizons and rivers, lakes and streams. Thus the studies of radionuclide migration and system evolution considered here involve physical system transfers only, as far as possible. The inter-relationship between the different pathways in the near-surface that are typically included in assessments can be understood by consideration of Figure 1. Apart from Human Intrusion scenarios, the pathways of interest for this study are the groundwater to sub-soil and to soil, and the groundwater to surface water bodies. However, it is important to appreciate that the climate and landscape architecture provide a larger environmental context that is important for a more detailed process understanding for both biologically and non-biologically influenced analogue studies.

Although geological disposal involves the migration of contaminants from repository depths, through the geosphere and to the near-surface, most of the literature concerning transport processes concerns studies in which surface deposition of contaminants has occurred and migration is through the unsaturated soil zone downwards to the water table. Whilst this is the reverse of what is to be expected from any repository releases that may occur, some of the detailed transport processes occurring in the sub-systems are fundamentally the same. In addition, in scenarios where agricultural wells are accidentally sunk into contaminated plumes, the surface deposition of contaminants onto soil and vegetation will essentially be analogous to atmospheric deposition. Consequently, any well developed studies based on atmospheric deposition of contaminants to the ground surface, with subsequent migration through the unsaturated and saturated zones, are considered to be within the remit of this report.

It is the case that much of the specific research on radionuclide migration in the near-surface, especially but by no means only in radioecology, has focussed on relatively few radioisotopes, e.g. Sr-90 and Cs-137. This has only been of marginal relevance to deep geological disposal as many other radionuclides tend to dominate the long-term impacts that may arise from releases from solid radioactive waste repositories. A compilation of the radionuclides considered to be of high relevance for a deep disposal repository from a radiological point of view was proposed in the European Project SPA (2000), based on the comparison of six European PA exercises (Table 1).

Table 1: Relevant radionuclides for biosphere assessment

Fission Products	Actinides
C-14, Se-79, Nb-94, Pd-107, Sn-126	Ra-226, Th-232, Np-237
Cl-36, Ni-59, Zr-93, Tc-99, Cs-135	Cm-245, Pu241, Am-241, Th-229, Cm-246, Th-230, Am-243, U-235, Pa-231
Ni-63, Sr-90, I-129	Pu-240, U-236, U-233, Pu-242, U-238, U-234, Pu-239

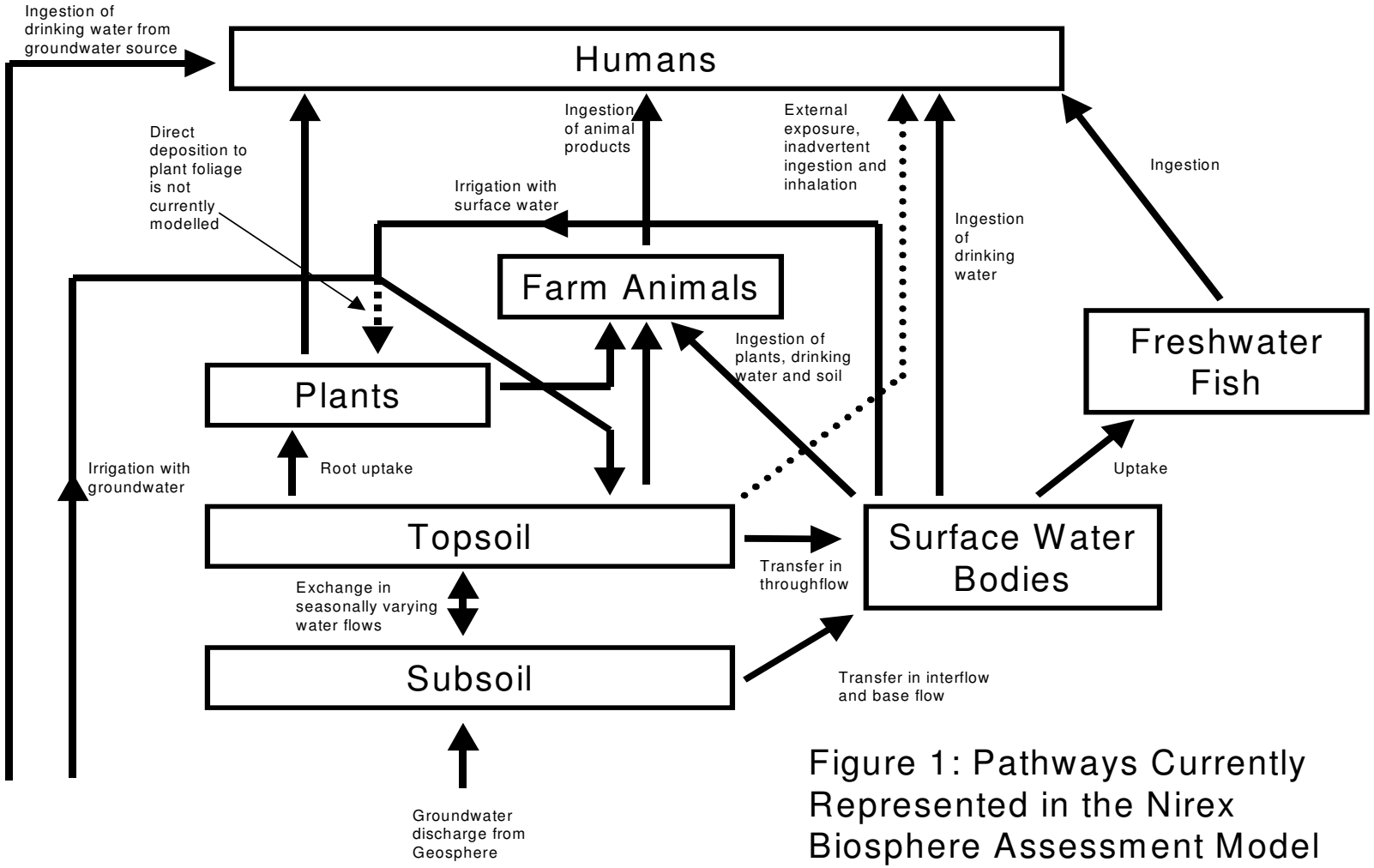

Figure 1: Pathways Currently Represented in the Nirex Biosphere Assessment Model

In this NAnet study, an initial attempt was made to concentrate on situations in which the key elements were involved in contamination or groundwater movement across the geosphere-biosphere interface zone (GBIZ). Not unexpectedly, such studies are few in number. The search was therefore broadened out to include studies of elements that might be considered analogous in their behaviour to the key elements of interest. This approach extended the number of potentially useful research studies that have been carried out. Further, it was acknowledged that even for some elements that did not represent analogues for the key radionuclides of interest, studies existed concerning transport or accumulation and retardation processes and so these were also included in the remit of viable analogues.

3 PAST USE OF NEAR-SURFACE OR BIOSPHERE ANALOGUES IN SAFETY ASSESSMENT

The literature on the past use of natural analogues for safety assessments deals almost exclusively with sites and situations that can be considered analogous to aspects of the near-field and geosphere components of radioactive waste disposal systems. It is rare to find any reference to analogues for near-surface or biosphere systems, components or processes. For example, in the 2003 listing of Nagra publications in the field of natural analogues there are some 150 references. However, none deal with biosphere analogues. Although there are a number of significant obstacles to the general use of natural analogues in safety assessments (Smellie et al., 1997) it is pertinent to ask "Why have near-surface and biosphere analogues rarely been used in support of safety assessments?"

The first reason relates to the difficulties in using analogue information, especially where attempts are made to derive and apply quantitative data. Many of these difficulties arise because analogues reflect uncontrolled and natural systems and as such cannot be unambiguously interpreted. Whilst this is also true for the geosphere, it is especially the case for the near-surface and surface environments, which are in many respects much more complex. This complexity arises for several reasons. Firstly, the near-surface and surface environment is highly dynamic compared with other elements of the disposal system. In particular, biosphere components are in a state of constant change on a variety of temporal scales. Because of the long time scales that have to be considered in safety assessments the precise character of the near-surface at any particular site and time in the future becomes more uncertain the further into the future one considers. Secondly, the biosphere is highly variable, i.e. physical characteristics change depending on location. Consequently key features and processes impacting on radionuclide transport ideally need to be described on several spatial scales. Thirdly, the biosphere processes that could affect radionuclide transport and uptake need to be understood in the context of components that are intimately related via feedback mechanisms.

Another reason is historical. Most papers dealing with natural analogues employ definitions that explicitly or implicitly exclude the biosphere (e.g. Chapman, 1994; Miller, 1996; McKinley and Alexander, 1996). The original reason for this may be because in most assessments previously undertaken, the biosphere was considered primarily for the purpose of providing a discharge-to-dose conversion factor for each radionuclide and relatively little attention was paid to the role of the terrestrial biosphere within the disposal system in limiting potential exposures to radionuclides. Consequently the original application of natural analogues to radioactive waste disposal reflected the aim of illustrating or demonstrating the concept of radionuclide containment over geological timescales through the isolation and retardation of wastes provided for by the properties of the near-field and far-field. The function of the migration of radionuclides across the GBIZ to the biosphere in disposal process systems was simply given less emphasis and it may still be the case that several radioactive waste management organisations take the view that the biosphere has no role to play in the 'justification' or 'demonstration' of the concept of geological disposal.

A further reason is that most workers in the field of natural analogues have not considered the biosphere as falling within their sphere of influence. The biosphere community itself is equally culpable as it has simply not grasped the opportunity that analogue studies offer to enhance confidence in assessments, either because the

scientists involved were not aware of the potential role for analogue studies or because they chose not to them for other reasons.

In terms of potential use, it was found that for biologically-influenced biosphere analogues there is much information in the scientific literature that is relevant to safety assessments of geological disposal concepts. These mainly derive from studies of natural radioactivity, bomb fallout and atmospheric deposition following nuclear accidents. The associated field and laboratory experimental studies of the soil-plant-animal-man pathway carried out in the context of atmospheric deposition are also available for use in safety assessments. However, the fallout radionuclides for which most information is available tend not to be those of most interest in the context of deep disposal. It is also apparent that much of the information in the literature is not necessary applicable to the landscape and agroecological settings typical of geosphere-biosphere interfaces in potential groundwater discharge zones. In short, difficulties arise in finding relevant near-surface analogues because, in most cases and at first sight, one or more of the essential features of the analogue are inapplicable to the disposal concept being assessed. This is likely to be the factor that will always be used as an argument to limit the use of analogue information in assessments.

4 THE POTENTIAL USE OF NEAR-SURFACE AND SURFACE ANALOGUES

It is generally assumed in safety assessments that groundwater pathway-mediated radionuclides contaminate areas of soil that 'drive' the plant to animal to man pathways, most commonly in agricultural frameworks. This assumption needs to be tested in situations analogous to the environments anticipated to be relevant to long-term releases from repositories at specific sites. Regardless of this, it would seem that on the basis of hydrogeological reasoning (supported by the current review), in many, if not the majority of cases, discharges of contaminated groundwaters will be limited to stream waters and associated in-channel sediments, and to stream banks and a narrow strip of riparian land adjacent to the stream channel. These environments are typically non-agricultural and the food chain pathways associated with them tend to be intermittent and incidental.

It is recognised that contamination originating within streams and riparian areas may be dispersed across adjacent low-lying areas within the floodplain by flooding and overbank sedimentation and by biotic mechanisms and human actions. However, significant dilution and attenuation of contaminants is to be expected to accompany such processes. In all the above respects near-surface and surface environment analogues may be helpful in configuring and parameterising near-surface models for safety assessments in a realistic (rather than conservative), yet defensible and readily communicable way. Furthermore, it may be possible to demonstrate that assessments that employ analogues for model conceptualisation indicate reduced radiological impacts compared with assessments based on a priori conservative reasoning.

The challenge is to choose the most appropriate analogues for hypothetical future conditions that might pertain at a repository site. In order to overcome the previous reluctance to use analogues of the near-surface environment, the complexity of the analogue system must be appreciated in the same level of detail as the complexity at the present day at the repository site is understood. If this can be accomplished, it is suggested that analogues do have a valid and useful role to play in future assessment studies.

5 LITERATURE SURVEY

At the outset of the NAnet project it was anticipated that natural transport processes could readily be identified and a number of near-surface hydrologic situations could be used as analogues for future conditions at radioactive waste disposal sites. Consequently, a thorough literature search was conducted for both primary and secondary sources of information potentially relevant to near-surface environment analogues. The objective of the search was to find examples of studies that might merit consideration as analogues or information that might contribute to a database of near-surface analogues (non-biologically influenced analogues). The search resulted in a literature review of over three hundred publications (Appendix A).

Whilst there is probably no such thing as a perfect analogue in the context of radioactive waste disposal, whether this is in respect of the near-field, geosphere or biosphere, none of the papers reviewed for this report described a situation that was considered to be a direct analogue for a near-surface environment that might arise at some future date in the vicinity of a GBIZ (receiving a discharge of radionuclides from a deep repository). In practice such a close analogue would imply a source of a key radionuclide derived from deep groundwaters mixing with shallow waters prior to discharge to a stream or bank sediments, with information available on the system boundary conditions and on contaminant distribution in waters, soils, sediments and biota downstream.

Furthermore, much of the literature dealing with both natural and anthropogenic sources of pollution or contamination that is of potential value in the context of GBIZ analogues seems to be more relevant to near-surface disposal than to deep disposal. This is because the substances typically important in shallow burial concepts (e.g. heavy metals and uranium and thorium series radionuclides) are unlikely to reach the biosphere in significant concentrations from a deep repository but may do so, by various means, from a near-surface disposal facility. It is also apparent that the modes of contamination (e.g. solid residues from processing plants) and the concentration levels, cocktail of chemicals, and minerals/species involved are usually inconsistent with the perceived specification of potential analogues for near-surface situations in the context of deep disposal.

Despite the above misgivings, a number of the papers reviewed suggested the potential for using field studies of biosphere systems and processes that could be used in support of safety assessments. The most promising areas for biosphere analogues would seem to be consideration of specific examples of different classes of interaction between surface waters and groundwaters under different climate, landscape, geological, soil and ecosystem conditions. However, the range of situations that could arise simply due to the various combinations of these factors is enormous. Consequently, it is the responsibility of the experts involved to decide on what analogues are appropriate in the context of the research and safety assessment needs.

6 CATEGORIES OF BIOSPHERE ANALOGUE

For much of the future, the biosphere and near-surface environmental conditions relevant to long-term release of radionuclides are unlikely to be those directly observable within the catchment of a repository site at the time of its development and closure. For this reason, analogues are likely to be selected according to the principle of space-time substitution after careful consideration of likely patterns of climate, landscape and biosphere evolution. However, it is stressed that when considering natural evolution, the current conditions at an identified site may provide an excellent analogue for the future conditions at the same site and under similar environmental controls.

It is in the nature of groundwater flow that terrestrial natural discharges of contaminated groundwaters originating at depth (the geosphere) will occur preferentially within topographic lows in the landscape. These may be to lakes, valley bottom streambeds and banks, floodplain and riparian settings, or estuarine or coastal environments. In non-arid environments, the bulk of the discharges will tend to occur preferentially to surface waters in the form of streams, lakes or estuarine or coastal waters. Contaminated groundwaters originating at depth will, in most instances, interact with shallow groundwaters prior to discharge. The spatial and temporal nature of this interaction is of particular interest in the context of safety assessments and is likely to be site specific by reason of, for example, climatic context, topographic setting, local lithology and soil conditions, vegetation and human factors. Under arid conditions, discharges may occur within depressions that have no outlets. Each of these factors will provide part of the context for the utility or otherwise of an analogue study for a specific repository location.

As argued by Miller (1996), one of the most promising ways in which biosphere analogues may be employed is in identifying and describing present day landscape settings and, within them, geosphere-biosphere interfaces that can be used to help communicate biosphere concepts relating to potential future situations of interest in safety assessment. From this suggestion, and from a brief review of the literature, it is proposed that three categories of near-surface analogue information can be specified for use in model conceptualisation, model building, model verification and for confidence building:

- ***System Context Studies:*** these are those factors concerned with regional or super-regional spatial scales, such as analogue climate and landscape states.

- ***Whole System Studies:*** studies of discrete hydrogeological settings that depend on particular combinations of lithologies, soils and vegetation. They will generally correspond to groundwater or surface water catchments in which contaminant migration through the near-surface lithologies to soil or to rivers, lakes etc. have been studied and in which the effects of numerous transport-related processes have often been aggregated.

- ***Sub-System Studies:*** involves analogues of detailed contaminant transport-related processes, such as those involving physical and geochemical features and mechanisms.

In addition to the above three categories of near-surface analogue, analogues for future probabilistic events are recognised for the near-surface environment, e.g. the effects of seismicity, frequency of drilling boreholes, asteroid impacts etc. Analogues of these probabilistic events are not considered further in this report, nor are any

analogues for impacts arising from future human activities, including the habits of potentially exposed groups.

6.1 System context studies

6.1.1 Climate

At any particular location chosen as a repository site, and for which an analogue is sought, it will be important to identify the climate regime relevant for the time frame under consideration. This will be necessary in order to derive appropriate future meteorological boundary conditions and to set the socio-economic context for the potentially exposed group of humans or other biota that might populate the landscape. An example of the use of climate analogue information is provided in Appendix B. This is derived from detailed work undertaken by Nirex in the 5th Framework European Commission project BIOCLIM (www.andra.fr/bioclim). The meteorological information available from a self-consistent dataset of key variables can be applied to other locations with due regard to latitude, altitude and proximity to coastlines. The key parameters from this analogue information are mean monthly temperature and mean monthly precipitation and they can be used to estimate the amount of hydrogeologically effective rainfall at a particular site based on a calculation of evaporation losses. The approach used by Nirex is based on a technique originated by Thornthwaite (1948) and detailed by Shaw (1983) and was used in BIOMASS (2003). It is an approximate approach, but is robust across a wide range of climatic conditions. Potential evapotranspiration (PE, units mm) is calculated using:

$$PE_m = 16N_m(10T_m/I)^a$$

Where the subscript m denotes month
T_m (ºC) is mean monthly temperature
$I = \sum i_m$
$i_m = (T_m/5)^{1.5}$
$a = 6.7\ 10^{-7}I^3 - 7.7\ 10^{-5}I^2 + 1.8\ 10^{-2}I + 0.49$
N_m = monthly adjustment factor, related to hours of daylight.

An adjustment is made only for calculating i_m for months in which $T_m > 0$ and setting PE_m to zero for months in which $T_m \leq 0$.

For each month the calculated potential evapotranspiration is subtracted from the precipitation to give a measure of moisture excess. Negative values of moisture excess correspond to a moisture deficit. However, whereas the moisture excess values are considered realistic (implying saturated conditions and excess available water), the calculated moisture deficit values will generally be over estimates, as actual evapotranspiration is generally less than potential evapotranspiration when surface soils are unsaturated. It is the moisture excess that provides a measure of the hydrogeologically effective rainfall that will provide the bulk of any dilution flux in a near-surface aquifer.

6.1.2 Landscape

Following the BIOMASS (BIOsphere Modelling and ASSessment) methodology for biosphere system description (BIOMASS 2003), a landscape description provides information on topography and the spatial arrangement of landscape features, plus information on soils, sediments, waters, vegetation/landuse including agriculture and taking account of human influence as subsumed in present day and historical agroclimatic analogues (information concerning these factors and that would help in

the identification of suitable analogues is reproduced from BIOCLIM and BIOMASS literature in Appendix C). Landscape analogues of far future conditions could usefully be chosen on the basis of these factors if required. For the UK the topography of Central England (an area of generic interest and not a proposed repository location) is currently described as undulating lowland intersected by fluvially incised river valleys. This topography will change only to a limited degree over the next 200 ka, before the next anticipated glacial event in the UK (see BIOCLIM). The main consideration is that falling sea levels in periods of cold climate will result in exposure of sea-bed sediments with the subsequent evolution of a fluvially incised drainage system in those sediments. Also, throughout the period, river channel dimensions will adjust to alterations in the hydrological regime. The landscape description will facilitate the identification of similar landscape area that exist at the present time in alternative climate states.

The landscape context will generally relate to spatial scales that are smaller than those for which regional climate is described, but larger than the domain corresponding to the groundwater catchment of a disposal system. The landscape description will be strongly dependant on the geographical setting (inland or coastal) and altitude (lowland, upland or high mountain). The regional topographic relief that is exhibited is an especially important characteristic that influences the development of soils and vegetation. It is also the primary driving force for near-surface groundwater flows.

In general, the landscape at a site will be relatively slow to evolve and will tend to follow changes in climate states. The exception will be especially marked during times of glacial activity, when it might be expected that the topographic expression of the local bedrock would be accentuated and any poorly consolidated superficial deposits would be transported away by ice and fluvial action. Upon the retreat of glaciers, proglacial lakes and extensive alluvial systems are known to re-deposit glacially reworked sediment. Regardless of the rates of landscape change, in providing the long-term context for detailed analogue studies used in assessments, it will be necessary for the expected surface evolution of a site to be taken into consideration.

As can be readily appreciated, in detail landscape descriptions will vary significantly from location to location, although at a relatively course level of review some landscapes may superficially be representative of many others. Therefore, where only broad comparisons are required, loosely similar landscape settings to those envisaged to be representative of future conditions at a repository site could be used as illustrative analogues, but in detail it would not be possible to transpose the features of a poor analogue situation to a real site.

To date there are few examples of landscape analogue descriptions corresponding to potential geosphere-biosphere interfaces, although at the present time (2004) SKB do have studies planned in relation to their Forsmark and Oskarshamn study areas. In the context of shallow disposal, BNFL have developed landscape analogues for the region of the Drigg low level radioactive waste disposal site in Cumbria, NW England, covering the next 105 years (BNFL, 2002). The Drigg site is located by the coast and, as such, the landscape analogues take account of changes in climate and landscape responses to changes in climate and sea-level involving streams, estuaries and the coastline.

6.2 Whole system studies

One of the most promising uses of biosphere analogues in safety assessment is in providing examples of demonstrably self-consistent biosphere process systems as a basis for model conceptualisation and confidence building. This use of whole system analogues requires an approach that does not distinguish between biotic and abiotic FEPs, except as a matter of convenience in describing the system. For the most part this form of application will not directly illustrate aspects of radionuclide behaviour because the key radionuclides will not be present to be described or the impact of discrete processes on migration will be difficult to deconvolve. Exceptions can possibly be made for studies using detailed and comprehensive data, such as from Chernobyl (e.g. Appendix D). It is likely that in most cases, i.e. where radionuclide specific information is not available, the approach should be to identify the main factors that would determine radionuclide behaviour should a release occur to the system under study. These are likely to relate to exchange mechanisms controlling the advection and/or diffusion of groundwaters across the GBIZ and will include factors that influence dispersion. It would also likely include the recognition of discrete groundwater to surface transfer locations, i.e. discharge and infiltration areas. Subsequent field studies of the transport of introduced substances supported by modelling studies might be employed in further developing a detailed understanding of specific transport processes relevant to radionuclide behaviour.

The number of potential geosphere-biosphere interface situations and associated surface environmental conditions is extremely large and it will be necessary to select distinct examples that will best illustrate to stakeholders the range of potential futures that might arise at a specific repository site. Whole system near-surface analogues may have considerable value in communicating radionuclide transport concepts to stakeholders because they may visit and observe the situations envisaged and thereby appreciate the context for the assessment model in a way that it may be difficult to convey by words and numbers alone. This approach is currently planned to be undertaken by Nirex, who will identify a ‘library’ of real-life groundwater catchments that have been studied in detail and they will then be used as analogues for hypothetical future groundwater catchments for a generic repository location in the UK. The whole system descriptions will subsequently be used in near-surface contaminant groundwater numerical modelling for safety assessments if required.

As well as defining analogues based on well understood groundwater catchments that are representative of present day climate states, present day analogues based on alternative climate states and landscape contexts may be identified in alternative climatic zones. This is especially useful if the physical characteristics of the analogue are known as well as the key meteorological variables derived from local weather stations. The relevance of catchments in other areas needs to be assessed based on reconstructions of past sequences of landscape change and plausible future changes. This approach is particularly pertinent to those parts of Europe that have been influenced by glaciation and deglaciation as formerly glaciated landscapes may take thousands of years to ‘relax’ to non-glacial conditions.

6.3 Sub-system studies

Another promising application of near-surface analogues is in demonstrating that, in practice, a model (and its database) can adequately represent a given real world process in detail. In this type of application analogues are sought that describe the detailed distribution of contaminant in the near-surface system resulting from a protracted release via shallow groundwaters and relate these to specific transport or retardation processes. Ideally, the real world analogue will involve one or more

radionuclides that are of interest in the context of deep geological disposal. However, the study of other contaminants (e.g. stable selenium) may also serve a useful purpose in refining models.

On behalf of CIEMAT and ENRESA, Hooker, Miller and Robinson (2002) compiled a list of Features, Events and Processes (FEPs) that could occur in the geosphere-biosphere interface zone. These are listed alphabetically in Table 2 below. The FEP list provides a means with which to review potential analogues in order to check for comprehensiveness (and in turn each potential analogue study should be considered as a review of the comprehensiveness of the FEP list). Each geosphere-biosphere interface FEP derived by Hooker et al (op.cit.) has been correlated with a FEP from the NEA international FEP list (NEA, 2000) and the significance of each geosphere-biosphere interface FEP is indicated in the table as high, medium or low. This level of significance was determined by CIEMAT in terms of how much a geosphere-biosphere interface FEP, if it were relevant, could control radionuclide transport. However, such an assignment should be made independently by other organisations, with due regard for the relevance of a FEP at an individual site or with regard to specific regulations. Many of the individual FEPs can be grouped together into a smaller number of categories (shown in Table 2). In terms of deciding on the utility of a potential analogue study, it is this list that could first be consulted, before narrowing down to discrete processes.

Table 2 A FEP List for Geosphere-Biosphere Interface Zones.

GBIZ FEP Number	GBIZ FEP Name	Corresponding NEA FEP Number	Significance	Corresponding GBIZ Aggregated FEP Number (see Table 3)
1	Biocatalysis	3.2.06	High	1
2	Biochemistry	3.2.06	High	1
3	Biocolloids	3.2.06	Medium	1
4	Biocommunities	2.3.09	High	1
5	Biofilms	3.2.06	High	1
6	Biogases	3.2.06	Medium	1, 8
7	Biological weathering (including fungi and lichen)	3.2.06	Medium	1
8	Bioturbation	3.2.11	High	1
9	Capillary action	3.2.07	Medium	3
10	Chemical ageing and recrystallisation	3.2.01	Medium	5
11	Cliff recession	2.3.12	High	2
12	Contact metamorphism	1.2.05	Low	6
13	Diffusion	3.2.07	Medium	3
14	Down cutting and gorge formation	2.3.12	High	2
15	Dry lake bed remobilisation	2.3.12	Medium	2
16	Dual porosity	3.2.09	High	3
17	Ecosystem	3.2.13	High	1

GBIZ FEP Number	GBIZ FEP Name	Corresponding NEA FEP Number	Significance	Corresponding GBIZ Aggregated FEP Number (see Table 3)
18	Estuarine systems	2.3.04	High	4
19	Evapotranspiration	2.3.09	Low/medium	1
20	Fault movement	1.2.03	High	7
21	Fracture flow (advection)	3.2.07	High	3
22	Gas exsolution	3.2.09	Low	8
23	Gas transport (including bubble-mediated radionuclide transport)	3.2.09	Medium	8
24	Gas-water interactions	3.2.09	Medium	8
25	Ground and porewater chemistry and evolution	3.2.05	High	9
26	Groundwater discharge	3.2.07	High	3
27	Groundwater mixing and dilution	3.2.07	High	3
28	Groundwater recharge	3.2.07	Medium	3
29	Hydrothermal systems	1.2.06	High	6
30	Inorganic colloid formation	3.2.04	Medium	9
31	Inorganic colloid mediated transport	3.2.04	Medium	3, 4
32	Landslides	2.3.12	Medium	2
33	Life processes (anabolic and catabolic)	3.2.11	High	1
34	Liquefaction	2.3.12	Low	2
35	Marine transgressions and regressions	1.3.03	High	4
36	Matrix diffusion	3.2.07	High	3
37	Mineral dissolution and co-dissolution	3.2.01	High	5
38	Mineral precipitation and co-precipitation	3.2.01	High	5
39	Organic complexants and their decay rates	3.2.05	Medium	9
40	Osmosis	3.2.07	Medium	3
41	Outgassing	3.2.09	High	8
42	Percolation	3.2.07	High	3
43	Physical retardation (filtration and anion exclusions)	3.2.07	Medium	3
44	Physical weathering	2.3.12	Medium	2
45	Porous flow	3.2.07	High	3

GBIZ FEP Number	GBIZ FEP Name	Corresponding NEA FEP Number	Significance	Corresponding GBIZ Aggregated FEP Number (see Table 3)
	(advection)			
46	Radioactive decay	3.1.01	High	9
47	Radionuclide solubility	3.2.02	High	9
48	Radionuclide sorption	3.2.03	High	9
49	Radionuclide speciation	3.2.02	High	9
50	River maturation (including meandering)	2.3.04	Low	2
51	Riverbank storage	2.3.04	Low	4
52	Rock-mass transport	2.3.12	High	2
53	Saline water interface	2.3.06	High	3
54	Sediment compaction and cementation	2.3.12	High	2
55	Sedimentation and deposition	2.3.12	High	2
56	Seismic pumping	3.2.07	Medium	3, 7
57	Seismicity	1.2.03	Medium	7
58	Soil formation and development	2.3.02	High	2
59	Tsunami	2.3.06	High	4, 7
60	Underground rivers	3.2.07	High	3
61	Unsaturated (two phase) flow	3.2.09	High	8, 3
62	Volcanism	1.2.04	High	6
63	Water table fluctuations (including flooding and lake drying)	3.2.07	Medium	3

Table 3 The aggregated FEP List for the GBIZ

Aggregated FEP Number	Aggregated FEP Name
1	Biological activity
2	Erosion, sediment movement and redistribution
3	Ground and porewater movement, and contaminant transport
4	Surface water bodies and flow, and contaminant transport
5	Sorption and mineral precipitation processes
6	Igneous and metamorphic processes and related hydrothermal activity
7	Seismic and tectonic activity
8	Gas flow and contaminant transport
9	Ground and porewater chemistry, radionuclide solubility and speciation

The sub-system analogue approach employs examples of contaminant (or tracer) behaviour to illustrate aspects of process behaviour at or above the geosphere-biosphere interface. Naturally, the analogues chosen should be pertinent to the processes that are expected for a given conceptualisation of a near-surface environment. Most of the potential analogue studies that fall into the category of sub-surface migration (e.g. nitrate studies) illustrate the nature of the interaction between groundwaters and surface waters in a particular location. Some studies, such as those involving heavy metals, may illustrate the distribution of sediment-associated contaminants downstream and away from stream channels and hence reveal information on the role of high flow events in surface water bodies.

The analogues chosen for near-surface radionuclide transfer and retardation processes (including reconcentration, release and dilution mechanisms and their rates) need to consider spatial and temporal variability in order that they can be placed in the context of whole system studies.

Promising analogues include studies of plumes of substances originating in the near-surface environment e.g. arsenic, selenium, uranium, studies of nitrate and other agriculturally-derived substances that especially illustrate transport behaviour in wetlands and floodplain / riparian settings (see Appendix E for an example) and the use of other anthropogenic analogues, e.g. leakage from nuclear reprocessing facilities or from mine wastes (see Appendix F for an example).

The geosphere-biosphere interface is likely to be an area where biogeochemical transformation takes place and where the vegetation is specifically adapted to riparian conditions. Riparian zones are typically associated with fluctuating water levels and redox conditions that change in response to varying degrees of soil saturation and to temperature and microbial activity in relation to the available organic matter and oxygen, nitrate, iron, manganese and sulphur content of the soil. In terms of representing biogeochemistry, analogue studies that demonstrate redox controls on radionuclide behaviour in riparian situations are especially useful, as are studies of the partitioning and availability of contaminants for uptake based on speciation. Biogeochemical analogues could be sought for the purpose of testing the applicability of dynamics of radionuclide concentrations in soil under different conditions. For example, the partitioning of a radionuclide between solid and solution phases and its bioavailability may be different under riparian, valley slope and interfluve settings.

6.4 Additional features and processes

The following processes of interest were noted during the review as having the potential to influence the distribution of radionuclides in the vicinity of a GBIZ or in the surface environment.

- Flooding and overbank deposition of particle-associated contaminants
- Resuspension onto vegetation of particle-associated contaminants
- Detailed variation in soil conditions influencing the exchangeable and plant-available fraction of contaminants
- The influence of floodplain lithology: Buried channels, gravel layers (lenses), peats and silts as factors influencing the pathways and hence interaction of groundwaters and surface waters

- Volatilisation of selenium and other (radionuclide) elements from soils and plants. This is an area that has recently been studied under laboratory conditions (Bostock 2004)

- Build-up of irrigation-evaporation residues on plant leaves

Despite their potential use, no specific studies were identified as analogues for inclusion as part of NAnet.

7 PROPOSED OUTLINE METHODOLOGY FOR THE USE OF ANALOGUES IN SAFETY ASSESSMENTS

Until fairly recently, most safety assessments did not deal with the evolution of the biosphere. Instead time invariant boundary conditions were specified for the disposal system and the near-surface environment was treated very simply in a highly stylised and (it is assumed) conservative manner. However, it will probably not be acceptable in future for assessments to neglect system evolution because, a) large scale landscape change is inevitable over the time scales of interest, and b) environmental change 'drives' the near-surface system and is likely to give rise to radiological risks that would not be identified in a time-invariant analysis.

Theme 1 of the BIOMASS programme had the objective of developing 'Reference Biospheres' for solid radioactive waste disposal (BIOMASS, 2003). For the purpose of this programme an assessment biosphere was defined as:

> *The set of assumptions and hypotheses that is necessary to provide a consistent basis for calculation for the radiological impact arising from long term releases of repository-derived radionuclides into the biosphere.*

The view was expressed, quite reasonably, that a set of biosphere assumptions 'should not be regarded as somehow simulating the actual biosphere that will necessarily be present when a future release to the biosphere occurs. Rather, it is appropriate to consider them as adequately representative of possible outcomes for assessment purposes' (BIOMASS, 2003). It is rather odd, therefore, that, in a 560 page document, there is no mention of the potential role of biosphere analogues as 'representative' biospheres and as sources of corroborative information or for confidence-building. Part of the explanation seems to be the desire to obtain agreement for the application of simple, stylised, 'measuring instrument' biospheres and to avoid having to deal with the complexities of real world biospheres, especially in the context of evolving systems. It is a matter of judgement as to whether the BIOMASS approach will win favour with stakeholders in its current form.

An acknowledged weakness in the BIOMASS reference biosphere methodology is the limited consideration given to potentially important dynamic effects in the near-surface, especially those brought about by climate change. In order to address this perceived limitation, the EC 5th Framework programme BIOCLIM developed a methodology for deriving climate and environmental change scenarios that are necessary precursors for considering the effects of climate and environmental change on the near-surface and surface environments. However, the potential use of analogues was not explicitly considered in that project either, except that it was implicit in the derivation of recommendations that the past evolution of a site is potentially an excellent analogue for future evolution.

The BIOMASS and BIOCLIM methodologies provide a useful starting point for considering how near-surface analogues could be applied in future safety assessments. As reference biospheres are not intended to be 'predictions' of future site conditions, but simply plausible illustrations of near-surface and surface environments within which to test calculations of radiological impacts, whole system analogue studies could be used in the conceptualisation of the reference biospheres. Furthermore, sub-system analogues can potentially support the simplifications necessary in assessments by demonstrating that adequate process understanding has been used in parameterising and validating system and sub-system numerical models.

Each national safety assessment exercise will parameterise the biosphere according to local conditions pertaining at the present time or otherwise expected in the future and whilst generic analogues might readily be chosen for the near-field and geosphere, the complexity of the near-surface environment means that potentially suitable analogues have to be chosen with care.

When identifying suitable analogues, it would first be necessary to consider how they may be used in support of safety assessments. This might be for developing conceptual models (at various levels of detail) or for providing quantitative information to parameterise, calibrate or validate numerical models of radionuclide migration in the near-surface.

A thorough description of the near-surface at the present day is required as a starting point for considering future changes. This would need to consider all the near-surface components considered in BIOMASS. It would also be necessary to have a good understanding of the Quaternary evolution of the near-surface system from palaeo-studies as a basis for extrapolating system change into the future, driven by climate and environmental change. These drivers provide the regional context and it will be necessary to define the salient parameters representing the (downscaled) climate states applicable to the area in question and then identifying and describing the range of landscape settings appropriate to each climate state, taking account of a given sequence of climate and landscape change from the present. The analogue data for precipitation and temperature should be chosen from climate stations that provide a broadly similar geographic setting to the repository site of interest, e.g. maritime or inland and similar altitude. Landscape analogues need only be broadly similar in order to narrow the range of whole system analogue sites that would be suitable for study.

After defining the analogue attributes that set the regional context, consistent whole system analogues would need to be identified by considering the range of geosphere-biosphere interface situations relevant for the landscape settings that are known to have occurred in the past or that might occur in the future, given the full range of future climate scenarios postulated. The GBIZ descriptions need to be provided in terms of lithological, soil and structural controls. These primarily affect hydraulic conductivity (saturated and unsaturated) and porosity (storage). The vegetation and ecosystems likely to be present need to be part of the scenario descriptions as they affect potential evapotranspiration and capillary rise. Groundwater-surface water interactions are also dependant on human interactions, e.g. through dewatering by groundwater abstractions or diversion of water courses. Once each of these factors has been described for each climate and landscape state, suitable analogues of the whole system can be sought.

Finally, the detailed processes that are considered to be potentially pertinent to the hydrogeological system operating under each landscape setting need to be decided, based on the level of detail required for the assessment context and based on the understanding of the operation of the transport process for the associated soils, sediments and biota (and possible agroecological systems) chosen. Once the transport processes and the physical conditions are decided at a local scale, appropriate sub-system analogues can be sought.

It is noted that whilst the above approach provides a basis for nested analogues to support a safety case, the categories of analogues can be used in isolation if required (i.e. they do not have to form a nested study). However, the assumptions surrounding such use would have to be made explicit and the relevance for hypothetical future near-surface systems might be more difficult to justify.

8 CONCLUSIONS AND RECOMMENDATIONS

The review of the past use of near-surface analogues in safety assessments and more generally to support confidence in safety cases, indicates that little credit has been taken from them to date. Analysis of the possible reasons for this suggests that the historical emphasis has been on using analogues for near-field and geosphere studies and biosphere researchers have not been aware, or have been wary, of their possible use. This is probably for at least two reasons. Firstly the biosphere is inherently more complex in many respects than the near field or geosphere. Secondly, in most assessments the near-surface and biosphere have simply been considered as a medium for dose conversion rather than as a barrier or a domain in which dilution, accumulation and/or retardation, need to be explicitly modelled in a physical sense. This is at odds with the evolving concept of the biosphere acting as a dynamic domain in its own right, where conceptualisations of radionuclide concentrations transported along near-surface pathways can be modelled effectively to reduce uncertainties in biosphere calculations and to reduce in a defensible manner some of the conservatism that has existed to date through the use of transfer coefficients between discrete biosphere compartments at equilibrium.

A key conclusion from this study is that the present day description of the near-surface and surface environments at a particular site provide an excellent analogue for the conditions that will prevail in the future, given a similar climate state and other boundary conditions. Furthermore, knowledge of the environmental evolution at a specific site, in response to past climate and environmental change, can also be considered analogous to what might occur in the future, given similar conditions of change.

The BIOMASS methodology of reference biospheres is a rational and economical scheme that provides a robust and defensible basis for radiological calculations - providing that the conceptualisation and parameterisation of the biospheres is consistent with reality. The only way to judge adequacy in this respect is to have a detailed knowledge of present day conditions at a site and a good understanding of a site's Quaternary evolution. This understanding forms the basis for a description of plausible future conditions, e.g. using the BIOCLIM methodology. Well-chosen analogue studies can be used to support the construction and parameterisation of conceptual models for hypothetical future near-surface conditions.

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A conceptual approach for evaluating the storage and release of contaminants derived from process based land degradation studies: an example from the Guadalentin basin, Southeast Spain Imeson, A. C. Cammeraat, L. H. Prinsen, H. AGRICULTURE ECOSYSTEMS AND ENVIRONMENT Long-Term Perspectives for Effects of Rural Land Use Changes on Soil Contaminants 1998 VOL 67; NUMBER 2/3 , page(s) 223-237 ELSEVIER SCIENCE DIVISION 0167-8809. The implications for land use change for the storage and release of contaminants in the Guadalentin catchment in SE Spain are considered. As part of a large project examining the impact of !and use and climate change on arid land degradation, information has been collected on how soil properties, hydrology and vegetation are evolving on abandoned land. This information was used to characterise land degradation response units in two areas, one on slates the other on marls and limestone. The way in which changes and degradation processes on the different land units influence the ability of the land units to retain contaminants, as well as the risk of these being transported by erosion, was evaluated. It was concluded that in the slate area, the only areas of risk are in the valley bottom flo... ©ELSEVIER SCIENCE DIVISION 1998 All rights reserved.

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An investigation into technetium binding in sediments Keith-Roach, M. J. Morris, K. Dahlgaard, H. MARINE CHEMISTRY 2003 VOL 81; NUMBER 3-4 , page(s) 149-162 Elsevier Science B.V., Amsterdam. 0304-4203. Coastal environments with reducing waters and/or sediments represent potential sinks for 99Tc discharged to sea. Here, we have examined estuarine sediments from four geochemically distinct locations that have been exposed to 99Tc discharged from Sellafield. Both the relative uptake and the operationally defined sediment "component" that holds the Tc were investigated in order to establish whether particular biogeochemical processes are predominately responsible for reducing and binding Tc in sediments. Despite the artefacts that can pose problems for sequential extractions, this scheme [Int. J. Environ. Anal. Chem. 51 (1993) 187] appears to be robust with regard to Tc. The results show that relative uptake of Tc varied greatly between the sites, with the highest occurring at an almost perm...

An investigation of radionuclide uptake into food crops grown in soils treated with bauxite mining residues Cooper, M. B. Clarke, P. C. Robertson, W. McPharlin, I. R. JOURNAL OF RADIOANALYTICAL AND NUCLEAR CHEMISTRY Proceedings of the Third International Conference on Methods and Applications of Radioanalytical Chemistry 1995 VOL 194; NUMBER 2 , page(s) 379 ELSEVIER SEQUOIA SA 0236-5731.

An overview of results from the Coupled Model Intercomparison Project Covey, C. AchutaRao, K. M. Cubasch, U. Jones, P. Lambert, S. J.; Mann, M. E. Phillips, T. J. Taylor, K. E. GLOBAL AND PLANETARY CHANGE 2003 VOL 37; NUMBER 1-2 , page(s) 103-133 Elsevier Science B.V., Amsterdam. 0921-8181. The Coupled Model Intercomparison Project (CMIP) collects output from global coupled ocean-atmosphere general circulation models (coupled GCMs). Among other uses, such models are employed both to detect anthropogenic effects in the climate record of the past century and to project future climatic changes due to human production of greenhouse gases and aerosols. CMIP has archived output from both constant forcing ("control run") and perturbed (1% per year increasing atmospheric carbon dioxide) simulations. This report summarizes results form 18 CMIP models. A third of the models refrain from employing ad hoc flux adjustments at the ocean-atmosphere interface. The new generation of non-flux-adjusted control runs are nearly as stable as-and agree with observations nearly as well as-the flux-a...

Analogue Scenarios of Future Climates of the UK Palutikof, J. P. Goodess, C. M. SAFETY STUDIES- NIREX RADIOACTIVE WASTE DISPOSAL NSS R Future climate change and radioactive waste disposal 1991 ISSUE 257 , page(s) 225-244 Nirex; 1991.

Analysing and modelling solute and sediment transport in the catchment of the Wahnbach River Bogena, H. Diekkruger, B. Klingel, K. Jantos, K. Thein, J. PHYSICS AND CHEMISTRY OF THE EARTH PARTS A B C 2003 VOL 28; NUMBER 6-7 , page(s) 227-237 Elsevier Science B.V., Amsterdam. 1474-7065. A concept for the continuous modelling of erosion, solute and sediment transport at the catchment scale is presented. The simulation is based on the application of the OPUS model designed for single slopes. In order to apply the model at the catchment scale, the study area (54 km2) is discretized into numerous slopes. The simulation results are compared with measurements at different spatial and temporal scales of a mesoscale catchment used for drinking water supply. Three small sub-catchments, ranging between 21 and 29 ha, are used to validate the model at the local scale. Process observations at this scale are used to modify the OPUS model. While for the validation of the long-term water and solute transport daily measurements at the catchment outlet were available and used, the long-ter...

Analysis of Models Assessing the Radionuclide Migration from Catchments to Water Bodies Monte, L. HEALTH PHYSICS 1996 VOL 70; NUMBER 2 , page(s) 227-237 WILLIAMS AND WILKINS 0017-9078. In this paper the analysis of models for assessing the migration of radioactive substances from catchments to water bodies was carried out. Comparisons are made between the mathematical form of the experimental dissolved radionuclide transfer functions (Transfer Function = the amount of radionuclide flowing per unit time from upstream drainage basin to a water body following a single-pulse deposition of radioactive substance) evaluated for rivers in Europe contaminated after the Chernobyl accident, with the "Green Functions" (Green Function = the radionuclide flow per unit time from catchment to water body calculated by the model as a result of a single-pulse input deposition) characterizing some of the most common models. Generally transfer functions are the sum of some time-dependent exp...

Analysis of the Interaction between Surface Water and Groundwater Using Radon-222 HAMADA, H. JAPAN AGRICULTURAL RESEARCH QUARTERLY 1999 VOL 33; PART 4 , page(s) 261-266 TROPICAL AGRICULTURAL RESEARCH CENTRE, MINISTRY OF 0021-3551.

Anthropogenic changes in spring water quality in the area of the town of Bialystok (northeastern Poland) Gorniak, A. Jekatierynczuk-Rudczyk, E. ACTA HYDROBIOLOGICA- POLISH ACADEMY OF SCIENCES 1997 VOL 39; NUMBER 1/2 , page(s) 19-28 INSTITUTE OF FRESHWATER BIOLOGY 0065-132X

Anthropogenic effects on shallow groundwaters in the Munsterland Region FRG Loehnert, E. P. NATIONAL CONFERENCE PUBLICATION- INSTITUTION OF ENGINEERS AUSTRALIA NCP Vol 2B; Groundwater Papers 1994 NUMBER 14//2B , page(s) 707-709 The Institute; 1994 0313-6922 858256207.

Anthropogenic emissions of ^2^1^0Po, ^2^1^0Pb and ^2^2^6Ra in an estuarine environment Martinez-Aguirre, A. Garcia-Leon, M. Gasco, C. Travesi, A. JOURNAL OF RADIOANALYTICAL AND NUCLEAR CHEMISTRY 1996 VOL 207; NUMBER 2 , page(s) 357-367 ELSEVIER SEQUOIA SA 0236-5731. An extensive study on the distribution of natural radionuclides in an estuarine ecosystem located in Southwestern Spain is presented. This environment is highly affected by the wastes released by a phosphoric acid industry which uses phosphate rocks as raw material for fertilizer production. This rock has generally high concentrations of U and its daughters. The estuary is formed by two rivers, Odiel and Tinto, which have a common mouth into the Atlantic Ocean and a salt marsh (Odiel marsh) affected by the income of Odiel riverwaters. This river receives directly the liquid and part of the solid (gypsum) wastes released from the industries. Besides that, most of the phosphogypsum wastes are stored in uncovered piles at the right margin of the Tinto river. The study has concluded that the w...

Antinomy as a Tracer of the Anthropogenic Influence on Soils and Estuarine Sediments Cal-Prieto, M. J. Carlosena, A. Andrade, J. M. Martinez, M. L.; Muniategui, S. Lopez-Mahia, P. Prada, D. WATER AIR AND SOIL POLLUTION 2001 VOL 129; PART 1/4 , page(s) 333-348 KLUWER ACADEMIC PUBLISHERS GROUP 0049-6979.

Application of a Water Quality Model in the White Cart Water Catchment, Glasgow, UK Liu, S. Tucker, P. Mansell, M. Hursthouse, A. ENVIRONMENTAL GEOCHEMISTRY AND HEALTH 2003 VOL 25; NUMBER 1 , page(s) 57-62 Kluwer Academic Publishers 0269-4042. Water quality models of urban systems have previously focused on point source

(sewerage system) inputs. Little attention has been given to diffuse inputs and research into diffuse pollution has been largely confined to agriculture sources. This paper reports on new research that is aimed at integrating diffuse inputs into an urban water quality model. An integrated model is introduced that is made up of four modules: hydrology, contaminant point sources, nutrient cycling and leaching. The hydrology module, T & T consists of a TOPMODEL (a TOPography-based hydrological MODEL), which simulates runoff from pervious areas and a two-tank model, which simulates runoff from impervious urban areas. Linked into the two-tank model, the contaminant point source module simulates the overflow from the s...

Application of boron isotopes for tracing sources of anthropogenic contamination in groundwater Barth, S. WATER RESEARCH 1998 VOL 32; NUMBER 3 , page(s) 685-690 PERGAMON PRESS 0043-1354. Natural sodium borate minerals from non-marine evaporite sequences are used for world production of sodium perborate, an industrially manufactured bleaching agent added to a variety of detergent formulations and cleaning products. During end use, water-soluble boron compounds are discharged with domestic aqueous effluents into sewage treatment plants, where little or no boron is removed and, hence, the anthropogenic boron load is almost entirely released into the aquatic environment. Natural sodium borate minerals are characterized by a rather narrow range in boron isotopic composition within the large natural variations, such that an isotopic approach may be used to decipher an anthropogenic boron source (mainly from industrial perborate, the dominant use of mined boron) in a given natura...

Application of quantitative land surface analysis methods to soil water content spatial variability studies Mitusov, A. V. Shary, P. A. International Association of Hydrogeologists; New approaches characterizing groundwater flow , page(s) 757-762 Balkema; 2001 902651848X; 9026518498; 9026518501.

Applied remote sensing for parameterizing solute transport and sediment models in the ARSGISIP project Fluegel, W.-A. Mueschen, B. Quiel, F. Rodolfi, G. IAHS PUBLICATION Integrated Methods in Catchment Hydrology - Tracer, Remote Sensing and New Hydrometric Techniques 1999 ISSUE 258 , page(s) 67-74 IAHS PRESS - INTERN ASSOC HYDROLOGICAL SCIENC 0144-7815.

Assessing potential risks from exposure to natural uranium in well water Hakonson-Hayes, A. C. Fresquez, P. R. Whicker, F. W. JOURNAL OF ENVIRONMENTAL RADIOACTIVITY 2002 VOL 59; NUMBER 1 , page(s) 29-40 0265-931X.

Assessment of acid rock drainage pollutants release in the uranium mining site of Pocos de Caldas - Brazil Fernandes, H. M. Franklin, M. R. JOURNAL OF ENVIRONMENTAL RADIOACTIVITY Technologically enhanced natural radiation; Natural radioactivity, technological enhancement, detection and migration 2001 VOL 54; NO 1 , page(s) 5-26 Elsevier; 2001 0265-931X.

Assessment of Forest Management Effects on Nitrate Removal by Riparian Buffer Systems Hubbard, R. K. Lowrance, R. TRANSACTIONS- AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS 1997 VOL 40; NUMBER 2 , page(s) 383-394 ASAE AMERICAN SOCIETY OF AGRICULTURAL 0001-2351. A study was conducted to determine the impact of different forest management techniques on shallow groundwater quality in coastal plain riparian zones. Considerable past research had shown that riparian zones are effective in removing or assimilating nitrates entering from upslope agricultural fields via shallow lateral flow, but the impact of different forest management techniques on this process was unknown. The study was conducted at a site near Tifton, Georgia, on a second-order coastal plain stream. The riparian buffer system consisted of a grass buffer, a managed forest zone, and a forest zone adjacent to the stream. Three forest treatments were studied: mature forest (MF), clearcut (CC), and selective thinning (ST). Following a nine-month pretreatment period, trees were completely o...

Assessment of radionuclide retardation: uses and abuses of natural analogue studies: Response to McKinley and Alexander Brush, L. H. JOURNAL OF CONTAMINANT HYDROLOGY Chemistry and Migration of Actinides and Fission Products 1993 VOL 13; NUMBER 1/4 , page(s) 269 0169-7722.

Assessment of radionuclide retardation: uses and abuses of natural analogue studies: Response to McKinley and Alexander Landstroem, O. Tullborg, E.-L. JOURNAL OF CONTAMINANT HYDROLOGY Chemistry and Migration of Actinides and Fission Products 1993 VOL 13; NUMBER 1/4 , page(s) 267 0169-7722.

Assessment of radionuclide retardation: uses and abuses of natural analogue studies: Response to McKinley and Alexander Ivanovich, M. JOURNAL OF CONTAMINANT HYDROLOGY Chemistry and Migration of Actinides and Fission Products 1993 VOL 13; NUMBER 1/4 , page(s) 263 0169-7722.

Assessment of radionuclide retardation: uses and abuses of natural analogue studies: Response to McKinley and Alexander Jackson, R. E. JOURNAL OF CONTAMINANT HYDROLOGY Chemistry and Migration of Actinides and Fission Products 1993 VOL 13; NUMBER 1/4 , page(s) 261 0169-7722.

Assessment of radionuclide retardation: uses and abuses of natural analogue studies McKinley, I. G. Alexander, W. R. JOURNAL OF CONTAMINANT HYDROLOGY Chemistry and Migration of Actinides and Fission Products 1993 VOL 13; NUMBER 1/4 , page(s) 249 0169-7722.

Assessment of the anthropogenic influx of metallic pollutants in Yarmouk River, Jordan Abu-Rukah, Y. Ghrefat, H. A. International Association of Hydrogeologists; New approaches characterizing groundwater flow , page(s) 1107-1110 Balkema; 2001 902651848X; 9026518498; 9026518501.

Basin-scale geohydrologic drought flow features of riparian aquifers in the southern Great Plains Brutsaert, W. Lopez, J. P. WATER RESOURCES RESEARCH 1998 VOL 34; NUMBER 2 , page(s) 233-240 AGU AMERICAN GEOPHYSICAL

UNION 0043-1397. Low-streamflow hydrographs from 22 subbasins in the U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS) Washita River Experimental Watershed complex in central Oklahoma were subjected to recession slope analysis; this method, after that of Brutsaert and Nieber [1977], was derived from a Dupuit-Boussinesq formulation for the groundwater outflows from the adjoining phreatic aquifers. The long-time aquifer response characteristics were generally found to be close to linear, and the short-time response characteristics were consistent with Boltzmann similarity. Representative values of the resulting basin-scale effective groundwater parameters were (35 days,)^-^1 for the low-flow extinction coefficient (i.e., a storage half-life of 25 days); 0.021 m^2S^-^1 for the hydraulic ... ©AGU AMERICAN GEOPHYSICAL UNION 1998 All rights reserved.

Beach groundwater dynamics Horn, D. P. GEOMORPHOLOGY -AMSTERDAM- 2002 VOL 48; NUMBER 1-3 , page(s) 121-146 Elsevier Science B.V., Amsterdam. 0169-555X. An understanding of the interaction between surface and groundwater flows in the swash zone is necessary to understand beach profile evolution. Coastal researchers have recognized the importance of beach watertable and swash interaction to accretion and erosion above the still water level (SWL), but the exact nature of the relationship between swash flows, beach watertable flow and cross-shore sediment transport is not fully understood. This paper reviews research on beach groundwater dynamics and identifies research questions which will need to be answered before swash zone sediment transport can be successfully modelled. After defining the principal terms relating to beach groundwater, the behavior, measurement and modelling of beach groundwater dynamics is described. Research questions ... ©Elsevier Science B.V., Amsterdam. 2002 All rights reserved.

Behavior of a surface applied radionuclide and a dye tracer in structured and repacked soil monoliths Albrecht, A. Schultze, U. Bugallo, P. B. Wydler, H. Frossard, E.; Fluhler, H. JOURNAL OF ENVIRONMENTAL RADIOACTIVITY 2003 VOL 68; NUMBER 1 , page(s) 47-64 Elsevier Science B.V., Amsterdam. 0265-931X. There has been increasing evidence in recent years about the impact of soil structure on vadose zone hydrology and the distribution of surface applied chemical substances. We have carried out a combined dye and radionuclide tracer study on two monoliths from the same location, one structured and one repacked, as part of an ongoing study to investigate the link between preferential flow, leaching of surface applied substances and their distribution within the soil.A tracer solution containing 1300 Bq/L 58Co and 0.31 mmol/L Sulforhodamine B (SB) was added with roughly constant irrigation during a period of three weeks. The dye served as a tracer for water movement within the soil and thus allowed linkage of the radiotracer (58Co) with the flow pattern. Both were monitored in the outflow and ... ©Elsevier Science B.V., Amsterdam. 2003 All rights reserved.

Behavior of technetium in paddy soils Yanagisawa, K. Muramatsu, Y. Ban-Nai, T. JOURNAL OF RADIOANALYTICAL AND NUCLEAR CHEMISTRY 1997 VOL 226; NUMBER 1/2 , page(s) 221-223 ELSEVIER SEQUOIA SA 0236-5731. In order to understand the chemical form of soluble technetium in paddy soil and its availability to a rice plant, soil incubation and uptake experiments have been carried out using ^9^5^mTc as a tracer. The chemical form of the soluble Tc was observed by gel chromatography and found not to be pertechnetate, but rather to be associated with soluble organic matter. An uptake experiment with rice seedlings using nutrient solution showed that this Tc-organic matter complex was less available than pertechnetate. ©ELSEVIER SEQUOIA SA 1997 All rights reserved.

Beryllium Geochemistry in the Lesni Potok Catchment (Czech Republic), 7 Years of Systematic Study Navratil, T. Skrivan, P. Minarik, L. ZIgova, A. AQUATIC GEOCHEMISTRY 2002 VOL 8; NUMBER 2 , page(s) 121-133 Kluwer Academic Publishers 1380-6165. The biogeochemical study was carried out at the Lesni potok (LP) catchment, Central Bohemia, Czech Republic. The ecosystem was impacted by heavy acid deposition during the industrial development in 1980-1990. The catchment is forested mostly by two tree species, Norway spruce and European beech. The Be concentration in the granite bedrock is 12.6 mg kg-1. The plagioclase contains the highest Be concentrations out of the rock-forming minerals. Elevated concentration of Be (5.4 mu;g L-1) in surface waters is a result of its mobilization from the soils (3.9 mg kg-1) and weathered rock by acid precipitation. As the pH of the precipitation and consecutively pH of the surface waters is increasing in the Czech Republic, the Be concentrations in the surface waters gradually decrease. Groundw... ©Kluwer Academic Publishers 2002 All rights reserved.

Bioavailability of Uranium and Nickel to Vegetation in a Contaminated Riparian Ecosystem Punshon, T. Gaines, K. F. Bertsch, P. M. Burger, J. ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY Problems of Scale in Containment Assessment 2003 VOL 22; PART 5 , page(s) 1146-1154 SETAC Press; 1999 0730-7268.

Boron Isotopic Compositions of Near-Surface Fluids: A Tracer for Identification of Natural and Anthropogenic Contaminant Sources Barth, S. R. WATER AIR AND SOIL POLLUTION 2000 VOL 124; PART 1/2 , page(s) 49-60 KLUWER ACADEMIC PUBLISHERS GROUP 0049-6979.

Catchment hydrogeological characterisation and evaluation: an hierarchical approach Salama, R. B. NATIONAL CONFERENCE PUBLICATION- INSTITUTION OF ENGINEERS AUSTRALIA NCP 1994 NUMBER 14//2A , page(s) 403-408 INSTITUTION OF ENGINEERS, AUSTRALIA 0313-6922. A methodology has been developed directly from an understanding of geomorphology, hydrogeology and the understanding of the effects of these systems on groundwater and solute movement in the landscape. The methodology takes into account the role of geology in controlling weathering patterns, and the influence of topography in forming geomorphic and hydrogeomorphic units. It also combines geology and geomorphology in controlling surface runoff, infiltration, recharge and discharge. The parameterisation and characterisation techniques are classified into three levels; broadscale, analytical and accurate. Comparing the three methods for hydrogeological characterisation and evaluation of a catchment showed that there are small differences when estimating areas of recharge and discharge and pre... ©INSTITUTION OF ENGINEERS, AUSTRALIA 1994 All rights reserved.

Change in groundwater chemistry as a consequence of suppression of floods: the case of the Rhine floodplain Sanchez-Perez, J. M. Tremolieres, M. JOURNAL OF HYDROLOGY -AMSTERDAM- 2003 VOL 270; NUMBER 1-2 , page(s) 89-

104 Elsevier Science B.V., Amsterdam. 0022-1694. Spatio-temporal variations of nitrogen, phosphorus and base cation concentrations in groundwater were related to the drastic change in hydrological conditions of the Rhine alluvial floodplain (Eastern France), which has been disconnected from the river by canalisation. The Groundwater chemistry was studied in two alluvial forests with contrasting hydrological conditions: one in a sector unflooded for 30 years, the second one in a sector still subject to flooding. Nutrient concentrations were measured at two levels, in the root zone (1.5m depth) and in the gravel below the root layer (4.5m depth).In the unflooded sector, the average nitrate concentration was significantly lower in the shallow groundwater (2.06mgl-1 NO3-) than in the deeper layer (5.84mgl-1NO3-). In contrast, in the flooded ...

Characterisation and Validation of Natural Radionuclide Migration Processes Under Real Conditions in a Fissured Granitic Environment Astudillo, J. Nuclear science and technology , page(s) 163-178 CEC; 1994 9282670910.

Chloride profile technique to estimate water movement through unsatured zone in a cropped area in subhumid climate (Po Valley-NW Italy) Lo Russo, S. Zavattaro, L. Acutis, M. Zuppi, G. M. JOURNAL OF HYDROLOGY -AMSTERDAM- 2003 VOL 270; NUMBER 1-2 , page(s) 65-74 Elsevier Science B.V., Amsterdam. 0022-1694. Two methods based on a chloride concentration profile were applied to evaluate the annual groundwater recharge in a subhumid area cropped with maize where chloride anthropogenic inputs were greater than the natural ones. The site is located in the alluvial Po plain (NW Italy). The two methods were a steady-state model and an approximate diffusive movement equation. They were applied to the Cl- content of retention water extracted from porous cups on 24 sampling dates through one year. The sampling depth ranged from 0.2 to 2.6m, and the concentration was steady in time below 1.6m. Considering all the approximations introduced (homogeneous and non-dispersive medium, constant diffusion coefficient with depth, all the liquid phase in movement, no macroporosity, steady state conditions), the re...

Chlorine-36 Investigations of Groundwater Infiltration in the Exploratory Studies Facility at Yucca Mountain, Nevada Levy, S. S. Fabryka-Martin, J. T. Dixon, P. R. Liu, B. Turin, H. J. Wolfsberg, A. V. MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS Scientific Basis for Nuclear Waste Management XX 1997 VOL 465 , page(s) 901-908 MATERIALS RESEARCH SOCIETY 0272-9172. Chlorine-36, including the natural cosmogenic component and the component produced during atmospheric nuclear testing in the 1950's and 1960's (bomb pulse), is being used as an isotopic tracer for groundwater infiltration studies at Yucca Mountain, a potential nuclear waste repository. Rock samples have been collected systematically in the Exploratory Studies Facility (ESF), and samples were also collected from fractures, faults, and breccia zones. Isotopic ratios indicative of bomb-pulse components in the water (^3^6Cl/Cl values > 1250 x 10^-^1^5), signifying less than 40-yr travel times from the surface, have been detected at a few locations within the Topopah Spring Tuff, the candidate host rock for the repository. The specific features associated with the high ^3^6Cl/Cl values are pred...

Coastal sensitivity to environmental change: a view from the beach Hansom, J. D. CATENA -GIESSEN THEN AMSTERDAM- Landscape sensitivity; Landscape sensitivity 2001 VOL 42; NO 2-4 , page(s) 291-306 Elsevier; 2001 0341-8162.

Collection and Monitoring of One-meter Cubic Soil Monoliths for Leaching Studies Kranz, W. L. Kanwar, R. S. Pederson, C. E. TRANSACTIONS- AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS 1998 VOL 41; NUMBER 2 , page(s) 333-344 ASAE AMERICAN SOCIETY OF AGRICULTURAL 0001-2351. This report presents methodology for excavating one-meter cubic undisturbed soil monoliths for detailed laboratory investigations of solute transport through the soil profile. Eight soil monoliths were collected in 1992 from three field areas that had been under consistent tillage systems since 1978. The soil was predominantly a Kenyon silt loam (Typic Hapludoll) with the water table maintained by subsurface drainage. Each monolith was instrumented with time-domain reflectometer (TDR) waveguides, and mini-tensiometers to monitor changes in soil water content and soil matric potential on three sides. A rainfall simulator was constructed to apply water at a rainfall intensity of 33 mm-h^-^1 to a 0.8 m x 0.8 m surface area of the monolith. A conservative tracer (KBr) was applied to the soil s...

COMIDA: A Radionuclide Food Chain Model for Acute Fallout Deposition Abbott, M. L. Rood, A. S. HEALTH PHYSICS 1994 VOL 66; NUMBER 1 , page(s) 17 WILLIAMS AND WILKINS 0017-9078.

Concentration and Distribution Patterns of Naturally Occurring Radionuclides in Sediments and Flood Plain Soils of the Catchment Area of the River Elbe Barth, A. Jurk, M. Weiss, D. WATER SCIENCE AND TECHNOLOGY Contaminated Sediments 1998 VOL 37; NUMBER 6/7 , page(s) 257-262 PERGAMON PRESS 0273-1223. The impact of uranium mining and milling as well as that of traditional mining activities on river sediments and flood plain soils in the catchment area of the river Elbe was investigated over the years 1994 to 1995. Contamination resulting from mining activities has been identified by comparing the median values for the measured radionuclides, and by establishing the ratio between Ra-226 and Ra-228. The transport and deposition of contaminated materials as a result of high water events, and river discharge of waste water from mining and milling facilities, can be considered to be the main paths of sediment and soil contamination. Sediments and flood plain soils located in the vicinity of former uranium mining and milling sites are primarily influenced by discharges of waste water. Long di...

Contamination of settling ponds and rivers as a result of discharge of radium-bearing waters from Polish coal mines Chalupnik, S. Michalik, B. Wysocka, M. Skubacz, K. Mielnikow, A. JOURNAL OF ENVIRONMENTAL RADIOACTIVITY Technologically enhanced natural radiation; Natural radioactivity, technological enhancement, detection and migration 2001 VOL 54; NO 1 , page(s) 85-98 Elsevier; 2001 0265-931X.

Contributions of water-rock interactions to the composition of groundwater in areas with a sizeable anthropogenic input: A case study of the waters of the Fundao area, central Portugal Pacheco, F. Van der Weijden, C. H. WATER RESOURCES RESEARCH 1996 VOL 32; NUMBER 12 , page(s) 3553-3570 AGU AMERICAN GEOPHYSICAL UNION 0043-1397. We used a combination of a grouping algorithm and a weathering algorithm to assess the contributions made by chemical weathering and anthropogenic inputs to the groundwater composition in a granitoid area. The first algorithm is based on the mathematical concept of equivalent relations between objects and is used to find groups of water samples. Using the grouping algorithm, we identified groups with similar chemistries in a set of data relating to the water composition in 160 springs and wells in the Fundao area (Portugal). The second algorithm is based on stoichiometries, mass, and charge balances in weathering reactions and is used to relate the water composition of each identified group to water-mineral interactions in the area. Background information on the petrology and mineralogy of...

Controlled release experiments to determine the effects of shade and plants on nutrient retention in a lowland stream Wilcock, R. J. Scarsbrook, M. R. Costley, K. J. Nagels, J. W. HYDROBIOLOGIA -THE HAGUE- 2002 VOL 485; NUMBER 1/3 , page(s) 153-162 Kluwer Academic Publishers 0018-8158. Understanding nutrient uptake and retention in streams remains an important challenge for lotic scientists. In this study a series of pulse and continuous releases of dissolved nutrients were made to shaded and unshaded (reference) reaches of a small lowland stream to determine whether suppression of macrophyte growth by riparian shade impaired nutrient retention. The nutrients were dissolved reactive phosphorus (DRP), total ammoniacal nitrogen (NH4-N) and nitrate nitrogen (NO3-N). Nutrient reductions ranged from 100% of DRP when stream water was anoxic, to 5-10% for NH4-N and NO3-N in the reference reach. Nutrient removals were affected by travel times in each reach. Percentage removals of NH4-N (46 +- 10) and NO3-N (52 +- 14) were higher in the shaded reach than in the swifter moving ref...

Coupling groundwater and riparian vegetation models to assess effects of reservoir releases Springer, A. E. Wright, J. M. Shafroth, P. B. Stromberg, J. C. Patten, D. T. WATER RESOURCES RESEARCH 1999 VOL 35; NUMBER 12 , page(s) 3621-3630 AGU AMERICAN GEOPHYSICAL UNION 0043-1397.

Denitrification Efficiency in Groundwater Adjacent to Ditches within Constructed Riparian Wetlands: Kankakee Watershed, Illinois-Indiana, U.S.A. Sidle, W. C. Goodrich, J. A. WATER AIR AND SOIL POLLUTION 2003 VOL 144; NUMBER 1 , page(s) 391-404 Kluwer Academic Publishers 0049-6979. Dual isotope evaluations of NO3- in groundwater adjacent to ditches within constructed riparian wetlands across the Kankakee watershed may assist the determination of denitrification efficiency. Groundwater sampling indicates that NO3--N exceeded 10 mg L-1 in constructed riparian wetlands but not in native wetlands within the riparian zones of the Kankakee basin. An apparent local empirical threshold for nitrification occurs in groundwater near ditches with less then 1:11 depth to width dimensions within similar hydrogeology. The 15N and 18O composition of groundwater nitrate varies widely in these constructed riparian wetlands. Groundwater nitrate associated with broader ditches (e.g. 1:35) most closely matches the denitrification isotope signature of native riparian wetlands in t...

Denitrification in a Grassed and a Wooded, Valley and Ridge, Riparian Ecotone Schnabel, R. R. Cornish, L. F. Stout, W. L. Shaffer, J. A. JOURNAL OF ENVIRONMENTAL QUALITY 1996 VOL 25; NUMBER 6 , page(s) 1230-1235 AMERICAN SOCIETY OF AGRONOMY 0047-2425. Dentrification is one of the major mechanisms responsible for changes in NO^-~3-N concentrations in shallow groundwater as subsurface flow passes from agricultural fields to the stream. In this study, denitrification is examined in a grassed and wooded riparian ecotone common to the Valley and Ridge physiographic province in Pennsylvania. Denitrification rates of 102 and 10 æg N kg^-^1 soil d^-^1 were measured using soil slurry and intact core incubation techniques, respectively. The grassed riparian site exhibited greater denitrification rates than the wooded site. Carbon amendments resulted in an increase in denitrification at the wooded site and suggest that denitrification may be C limited at this site. Denitrification generally decreased with distance away from the stream and also dec...

Denitrification potential of nontidal riparian wetland soils in the Virginia Coastal Plain Pavel, E. W. Reneau, R. B. Berry, D. F. Smith, E. P. Mostaghimi, S. WATER RESEARCH 1996 VOL 30; NUMBER 11 , page(s) 2798-2804 PERGAMON PRESS 0043-1354. In the Atlantic Coastal Plain, riparian wetlands are thought to play an important role in the removal of NO^-~3 from groundwater. The denitrification potential of the Bibb (coarse-loamy, siliceous, acid, thermic Typic Fluvaquents) series, located in the Nomini Creek Watershed, Virginia, was evaluated in the laboratory using soil columns under saturated flow conditions. Soil columns were infiltrated with synthetic groundwater containing 3.2 ñ 0.1 mmol NO^-~3-N (44 ñ 2.0 mg NO^-~3-N l^-^1). Soil samples were collected from two surface horizons and one subsurface horizon in May (soil temperature 16.4øC), September (19.9øC), and November (13.5øC) of 1993 at 12 sites along the stream. Denitrification rates (N~2O-N evolution in the presence of acetylene) were significantly higher for soils incub...

Derivation of a screening methodology for evaluating radiation dose to aquatic and terrestrial biota Higley, K. A. Domotor, S. L. Antonio, E. J. Kocher, D. C. JOURNAL OF ENVIRONMENTAL RADIOACTIVITY 2003 VOL 66; NUMBER 1-2 , page(s) 41-59 Elsevier Science B.V., Amsterdam. 0265-931X. The United States Department of Energy (DOE) currently has in place a radiation dose standard for the protection of aquatic animals, and is considering additional dose standards for terrestrial biota. These standards are: 10 mGy/d for aquatic animals, 10 mGy/d for terrestrial plants, and, 1 mGy/d for terrestrial animals. Guidance on suitable approaches to the implementation of these standards is needed. A screening methodology, developed through DOE`s Biota Dose Assessment Committee (BDAC), serves as the principal element of DOE`s graded approach for evaluating radiation doses to aquatic and terrestrial biota. Limiting concentrations of

radionuclides in water, soil, and sediment were derived for 23 radionuclides. Four organism types (aquatic animals; riparian animals; terrestrial animals; ... ©Elsevier Science B.V., Amsterdam. 2003 All rights reserved.

Determination of ground water evaporation using pan evaporometer data in different depth to water table and soil texture conditions Zare, M. Raeisi, E. Mirbagheri, S. M. International Association of Hydrogeologists; New approaches characterizing groundwater flow , page(s) 1319-1324 Balkema; 2001 902651848X; 9026518498; 9026518501.

Determination of hydraulic boundary conditions for the interaction between surface water and groundwater Macheleidt, W. Nestler, W. Grischek, T. SPECIAL PUBLICATION- GEOLOGICAL SOCIETY OF LONDON Sustainable groundwater development 2002 NO 193 , page(s) 235-244 London; Geological Society; 2002 0305-8719 1862390975.

Determining the sources of stormflow from the fluorescence properties of dissolved organic carbon in a forested headwater catchment Katsuyama, M. Ohte, N. JOURNAL OF HYDROLOGY -AMSTERDAM- 2002 VOL 268; NUMBER 1-4 , page(s) 192-202 Elsevier Science B.V., Amsterdam. 0022-1694. Concentrations of SiO2 and dissolved organic carbon, as well as the fluorescence properties of the latter were used as tracers of stormflow sources in a forested headwater catchment in Japan. Separate analyses were made of throughfall and of groundwater in the saturated and transient saturated zones, using three-dimensional fluorescence spectrometry. Groundwater in the saturated zone showed almost no fluorescence, whereas groundwater from the transient saturated zone showed fluorescence patterns characteristic of fulvic acid. Throughfall showed fluorescence of a non-fulvic character. Stormflow water showed fulvic-type fluorescence, showing that groundwater from the transient saturated zone contributed 62.7% of the total discharge. The source area for transient saturated zone groundwater ac... ©Elsevier Science B.V., Amsterdam. 2002 All rights reserved.

Deuterium as Natural Tracer in Groundwater from Neighbouring Area of Danube Delta Biosphere Reserve FEURDEAN, L. FEURDEAN, V. ISOTOPES IN ENVIRONMENTAL AND HEALTH STUDIES 1999 VOL 35; PART 3 , page(s) 183-212 GORDON AND BREACH 1025-6016.

Development of Groundwater and Ecological Models for Protecting a Southwestern Riparian Ecosystem Richter, B. D. Richter, H. E. TECHNICAL PUBLICATION SERIES- AMERICAN WATER RESOURCES ASSOCIATION TPS Ground water ecology 1992 92-2 , page(s) 231-246 AWRA; 1992.

Development, maintenance and role of riparian vegetation in the river landscape Tabacchi, E. Correll, D. L. Hauer, R. Pinay, G. Planty-Tabacchi, A.-M. Wissmar, R. C. FRESHWATER BIOLOGY Rivers in the landscape: riparian and groundwater ecology 1998 VOL 40; NUMBER 3, page(s) 497-516 BLACKWELL SCIENTIFIC PUBLICATIONS 0046-5070.

Distribution and Movement of Nitrate in Soils from Snowpack in a Stream Riparian Zone, Waterloo, Ontario von Waldow, H. Gainham, C. Landriault, L. Price, J. S. Stone, M. CANADIAN WATER RESOURCES JOURNAL 2002 VOL 27; PART 2 , page(s) 175-190 CANADIAN WATER RESOURCES ASSOCIATION 0701-1784.

Distribution and variability of ^7Be in soils under different surface cover conditions and its potential for describing soil redistribution processes Wallbrink, P. J. Murray, A. S. WATER RESOURCES RESEARCH 1996 VOL 32; NUMBER 2 , page(s) 467-476 AGU AMERICAN GEOPHYSICAL UNION 0043-1397. Measurements of ^7Be in soils can be used to indicate movement of topsoil, and this study aims to contribute to this technique by examining ^7Be in soils under a range of conditions. The penetration and areal concentration of ^7Be have been measured in bare soil, grassland, and eucalypt forest and compared with total measured fallout. Inventories in the bare soil decreased progressively from 64 to 46% of total fallout over the sampling period, probably owing to a decrease in infiltration capacity. This may have an effect on the interpretation of ^1^3^7Cs inventories under similar conditions. For grassed soil, average inventories were 96-142% of total fallout; for eucalypt litter plus soil, inventories were 73-95%. Natural variability of areal concentration of the nuclide was calculated to ... ©AGU AMERICAN GEOPHYSICAL UNION 1996 All rights reserved.

Distribution of bedrock and alluvial channels in forested mountain drainage basins Montgomery, D. R. Abbe, T. B. Buffington, J. M. Peterson, N. P. Schmidt, K. M. Stock, J. D. NATURE -LONDON- 1996 ISSUE 6583 , page(s) 587-588 MACMILLAN MAGAZINES LTD 0028-0836. Mountain river networks often consist of both bedrock and alluvial channels, the spatial distribution of which controls several fundamental geomorphological and ecological processes. The nature of river channels can influence the rates of river incision and landscape evolution, as well as the stream habitat characteristics affecting species abundance and aquatic ecosystem structure. Studies of the factors controlling the distribution of bedrock and alluvial channels have hitherto been limited to anthropogenic badlands. Here we investigate the distribution of channel types in forested mountain drainage basins, and show that the occurrence of bedrock and alluvial channels can be described by a threshold model relating local sediment transport capacity to sediment supply. In addition, we find... ©MACMILLAN MAGAZINES LTD 1996 All rights reserved.

Distribution of Uranium-238 in Environmental Samples From a Residential Area Impacted by Mining and Milling Activities McConnell, M. A. Sadagopa Ramanujam, V. M. Alcock, N. W. Gabehart, G. J. Au, W. W. ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY 1998 VOL 17; NUMBER 5 , page(s) 841-850 PERGAMON PRESS 0730-7268. The northern region of Karnes County, Texas, USA, has been the site of extensive mining/milling of uranium for over 30 years. A previous study in our laboratory indicates that residents living near these facilities have increased chromosomal aberrations and a reduced DNA repair capacity. In this study, the long-lived radionuclides uranium-238 (^2^3^8U) and thorium-232 (^2^3^2Th) were measured in order to evaluate the extent of contamination from mining/milling facilities. ^2^3^2Th was quantified simultaneously and served as a reference. Soil samples (n = 70) were collected from the yards of previously studied households and adjacent areas near former mining and mining/milling sites at the surface and 30 cm

subsurface. Additionally, samples from drinking water wells (n = 6) were collected f... ©PERGAMON PRESS 1998 All rights reserved.

Drainage networks in soils. A concept to describe bypass-flow pathways Deurer, M. Green, S. R. Clothier, B. E. Bottcher, J. Duijnisveld, W. H. JOURNAL OF HYDROLOGY -AMSTERDAM- 2003 VOL 272; NUMBER 1-4 , page(s) 148-162 Elsevier Science B.V., Amsterdam. 0022-1694. By using linear scaling factors of water characteristic functions we have been able to reconstruct a probable long-term drainage network through a sandy soil under coniferous forest in the north of Germany. The topology of the drainage network closely resembles one of mountainous streams. The fractional area of the entire profile occupied by the network was found to decrease exponentially with depth. For solutes preferentially travelling through such a network, the transport volume will therefore decrease exponentially with depth, and so the effective velocity should increase correspondingly. Assuming one-dimensional (1D), piston-flow through this effective transport volume of the network, we have been able to predict how much cumulative infiltration is, on average, needed for inert solute... ©Elsevier Science B.V., Amsterdam. 2003 All rights reserved.

Ecological Functions of Riparian Buffers and Effects of Pasture Development on Riparian Ecosystem Yamada, H. Nakamura, F. GRASSLAND SCIENCE 2003 VOL 48; PART 6 , page(s) 548-556 JAPANESE SOCIETY OF GRASSLAND SCIENCE 0447-5933.

Ecotones and fluvial regimes in arctic lotic environments Power, G. Power, M. HYDROBIOLOGIA -THE HAGUE- 1995 VOL 303; NUMBER 1/3 , page(s) 111 KLUWER ACADEMICS 0018-8158.

Effect of Riparian Buffer Width and Vegetation Type on Shallow Groundwater Quality in the Middle Coastal Plain of North Carolina Dukes, M. D. Evans, R. O. Gilliam, J. W. Kunickis, S. H. TRANSACTIONS- AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS 2002 VOL 45; PART 2 , page(s) 327-336 ASAE AMERICAN SOCIETY OF AGRICULTURAL 0001-2351.

Effects of a Managed Three Zone Riparian Buffer System on Shallow Groundwater Quality in the Southeastern Coastal Plain Lowrance, R. Hubbard, R. K. Williams, R. G. JOURNAL OF SOIL AND WATER CONSERVATION -USA- 2000 VOL 55; PART 2 , page(s) 212-219 SOIL CONSERVATION SOCIETY OF AMERICA 0022-4561.

EFFECTS OF INTERACTION BETWEEN SURFACE WATER AND GROUNDWATER ON GROUNDWATER FLOW AND QUALITY BENEATH URBAN AREAS Grischek, T. Foley, A. Schoenheinz, D. Gutt, B. NATO SCIENCE SERIES SUB SERIES IV EARTH AND ENVIRONMENTAL SCIENCES Current problems of hydrogeology in urban areas, urban agglomerates, and industrial centres 2002 VOL 8 , page(s) 201-220 Dordrecht; Boston; Kluwer Academic Publishers; 2002 1402006004.

Effects of natural and anthropogenic factors on nitrogen fluxes in agricultural soils: a modelling study in the Saale River basin (central Europe) Krysanova, V. Haberlandt, U. Osterle, H. Hattermann, F. IAHS PUBLICATION Impact of human activity on groundwater dynamics 2001 NO 269 , page(s) 331-338 Wallingford, Oxfordshire; IAHS; 2001 0144-7815 1901502562.

Effects of Pocket Gopher Burrowing on Cesium-133 Distribution on Engineered Test Plots Gonzales, G. J. Saladen, M. T. Hakonson, T. E. JOURNAL OF ENVIRONMENTAL QUALITY 1995 VOL 24; NUMBER 6 , page(s) 1056-1062 AMERICAN SOCIETY OF AGRONOMY 0047-2425. Very low levels of radionuclides exist on soil surfaces from atmospheric fallout following weapons testing or from stack discharges, and from exposure of some of the older waste storage and disposal sites worldwide. Biological factors including vegetation and animal burrowing can influence the fate of these surface contaminants. Animal burrowing introduces variability in radionuclide migration that confounds estimation of nuclide migration pathways, risk assent, and assessment of waste burial performance. A field study on the surface and subsurface erosional transport of surface-applied ^1^3^3Cs as affected by pocket gopher (Thomomys bottae) burrowing was conducted on simulated waste landfill caps at the Los Alamos National Laboratory in north central New Mexico. Surface loss of Cs, adhere... ©AMERICAN SOCIETY OF AGRONOMY 1995 All rights reserved.

Effects of slope vegetation removal on the diurnal variations of a small mountain stream Bren, L. J. WATER RESOURCES RESEARCH 1997 VOL 33; NUMBER 2 , page(s) 321-331 AGU AMERICAN GEOPHYSICAL UNION 0043-1397. The effect on removal of lower, mid, and upper slope vegetation on the diurnal variation in streamflow from a 46-ha catchment was observed. The diurnal variation in streamflow of the small stream was measurable during the late-spring-to-late-autumn period. The amplitude in streamflow variation reached a maximum in early summer and declined during autumn. Observation of diurnal variations during the periods of higher flow in winter and spring showed that they may occur but were masked by much larger variations associated with storm runoff. Simulation of the characteristics of the flow measurement system showed that diurnal variations can only be studied using V-notch weirs and float recorders during periods of low flow. No effect of the clearing of slope vegetation on the phase of the outfl... ©AGU AMERICAN GEOPHYSICAL UNION 1997 All rights reserved.

Effects of uranium mining on radioactive contamination in the kletno region in poland Chrusciel, E. Jodlowski, P. Kalita, S. J. Pieczonka, J. Piestrzynski, A. JOURNAL OF RADIOANALYTICAL AND NUCLEAR CHEMISTRY 1996 VOL 212; NUMBER 4 , page(s) 259-268 ELSEVIER SEQUOIA SA 0236-5731. In the Lower Silesia region, in the vicinity of Kletno town (near Klodzko), there are remainders of uranium ores being mined there, such as dump sites, abandoned pits and the like. Extensive research has indicated an increase in radioactivity there. The present research was aimed at defining the radioactive contamination in the neighborhood of Kletno. The research involved gauging the radiation background, especially at the mine dumps and measuring the concentration of natural radioactive isotopes and Cs in the rocks and soil. Besides, the concentration of radium isotopes in waters was determined. Two spots only were found with higher radiation

levels. A method for dealing with radiation hazards is proposed. Water analyses have indicated that flushing of radium isotopes from the rock-mass ... ©ELSEVIER SEQUOIA SA 1996 All rights reserved.

Electrical Conductivity Used for Evaluation of Competing Ion Effects on Radionuclide Uptake by Plant Roots Yasuda, H. ENVIRONMENTAL TECHNOLOGY -LONDON- 1995 VOL 16; NUMBER 2 , page(s) 197 SELPER PUBLICATIONS 0959-3330.

Enhancement of natural radioactivity in soils and salt-marshes surrounding a non-nuclear industrial complex Bolivar, J. P. Garcia-Tenorio, R. Garcia-Leon, M. SCIENCE OF THE TOTAL ENVIRONMENT Environment Radiochemical Analysis 1995 VOL 173/174; NUMBER COM , page(s) 125-136 ELSEVIER SCIENCE DIVISION 0048-9697. The existence of a very high extension (about 1000 ha) of phosphogypsum piles, sited in the estuary formed by the mouths of the Tinto and Odiel rivers (SW Spain), produce a quite local, but unambiguous radioactive impact in the surrounding salt-marshes. In these piles the main by-product formed in the manufacture of phosphoric acid is stored. The radioactive impact is generated by the deposition and accumulation of radionuclides from the uranium series that previously had been mainly leached or dissolved from the piles by waters that temporally can cover or cross them. Other means of impact, especially through the atmosphere, have been evaluated as negligible or not detectable. ©ELSEVIER SCIENCE DIVISION 1995 All rights reserved.

Environmental radioactivity at the Venezuelan Institute for Scientific Research (IVIC) LaBrecque, J. J. Rosales, P. A. JOURNAL OF RADIOANALYTICAL AND NUCLEAR CHEMISTRY 1997 VOL 220; NUMBER 1 , page(s) 59-64 ELSEVIER SEQUOIA SA 0236-5731. The concentration of ^1^3^7Cs, potassium, thorium and uranium for 6 monitoring sites and 32 other sites at the Venezuelan Institute for Scientific Research (IVIC) were presented, as well as, the estimated air dose and exposure rates for each site. The concentration ^1^3^7Cs was found to be much higher at many sites at IVIC in respect to the average estimated value of ^1^3^7Cs in Venezuela. But, this was determined to be due to a natural cause, the cloud forest which surrounds the higher elevations. The values of potassium, thorium and uranium were compared to values from other parts of northern Venezuela and were found to agree for sites at similar elevations. They were also shown to be shoot two to three times higher than global estimates. Thus, the air dose and exposure rates were corres... ©ELSEVIER SEQUOIA SA 1997 All rights reserved.

Estimating the Potential Impact of Climate Change on Streamflow in the Oldman River Basin, Alberta: An Analogue Approach Nkemdirim, L. C. Purves, H. CANADIAN WATER RESOURCES JOURNAL 1994 VOL 19; NUMBER 2 , page(s) 141 CANADIAN WATER RESOURCES ASSOCIATION 0701-1784.

Estimation of stream flow depletion and uncertainty from discharge measurements in a small alluvial stream Nyholm, T. Rasmussen, K. R. Christensen, S. JOURNAL OF HYDROLOGY -AMSTERDAM- 2003 VOL 274; NUMBER 1-4 , page(s) 129-144 Elsevier Science B.V., Amsterdam. 0022-1694. Hydrographs were recorded at three discharge stations at a small alluvial stream during the summers of 1997 and 1998. A method of analysis was set up so that the temporal variations in discharge resulting from natural hydrological processes can be distinguished from the influence from ground water being periodically abstracted approximately 60m from the stream. Thus, evapotranspiration from the riparian zone resulted in diurnal variations in streamflow with maximum amplitude of 3-5l/s, whereas heavy rainfall resulted in intense short-term surface/subsurface flow from the riparian zone. The magnitude of peak-flow was of the order of 2-3 times baseflow and such events typically disturbed the hydrograph for one to three days. Baseflow increased from about 35l/s to about 70l/s over the studied... ©Elsevier Science B.V., Amsterdam. 2003 All rights reserved.

Evaluation of chloride and pesticide transport in a fractured clayey till using large undisturbed columns and numerical modeling Joergensen, P. R. McKay, L. D. Spliid, N. H. WATER RESOURCES RESEARCH 1998 VOL 34; NUMBER 4 , page(s) 539-553 AGU AMERICAN GEOPHYSICAL UNION 0043-1397. Saturated groundwater flow and tracer experiments using fluorescent dye, chloride, and the herbicides mecoprop and simazine were carried out in the laboratory using three large-diameter (0.5 m) undisturbed columns of fractured clayey till. Hydraulic conductivity of the columns ranged from 10^-^5 m/s in the shallowest column (1 m depth) to 10^-^7 m/s in the deepest column (4 m depth) and were similar to field-measured values for these deposits. Results of the tracer experiments are consistent with a conceptual model of advective transport along the fractures combined with diffusion into the fine-grained matrix between the fractures. Arrival of the chloride tracer in the effluent was highly retarded relative to fracture flow velocities calculated on the basis of the cubic law and measured va... ©AGU AMERICAN GEOPHYSICAL UNION 1998 All rights reserved.

Experimental Study of Small-Scale Spatial Variation in Filtration Coefficient Using Tracer Method Usyarov, O. G. COLLOID JOURNAL C/C OF KOLLOIDNYI ZHURNAL 2003 VOL 65; NUMBER 1 , page(s) 100-104 Kluwer Academic Publishers 1061-933X. The procedure for studying the nonuniformity of filtration flows in capillary-porous media was developed. Time dependences of local filtration coefficients averaged over the area and their spatial variation during the flow of water and aqueous electrolyte solutions were studied on soil samples of undisturbed structure using tracer method. It was found that the transformation of a pore space structure accompanied with reverse variations in pore sizes occurs because of the action of disjoining pressure in thin films depending on the ion nature. Relaxation times corresponding to the times necessary to attain equilibrium within interlayer gaps of clay minerals were determined. The conclusion was made that if the system volume is constant, the variations in the pore space structure take place b... ©Kluwer Academic Publishers 2003 All rights reserved.

Factors regulating the spatial and temporal distribution of solute concentrations in a major river system in NE Scotland Smart, R. P. Soulsby, C. Neal, C. Wade, A. Cresser, M. S. Billett, M. F. Langan, S. J. Edwards, A. C. Jarvie, H. P. Owen, R. SCIENCE OF THE TOTAL ENVIRONMENT 1998 VOL 221; ISSUE 2-3 , page(s) 93-110 ELSEVIER SCIENCE DIVISION 0048-9697. The River Dee in NE Scotland, an oligotrophic soft water system, has a catchment area of approx. 2100 km^2, its source in the Cairngorm mountains being approx. 140 km from its outlet to the North Sea at Aberdeen. A

comprehensive sampling strategy and analytical programme, commensurate with the size and nature of the Dee system, have been established for major water quality determinands to identify the controls on, and origins of, dissolved species throughout the system at a range of catchment scales and over a range of flow regimes. Fifty-nine sites covering a range of catchment types and scales were therefore sampled bi-weekly for 1 year. At the basin scale, there is a general downstream increase in determinand concentrations. This produces strong linear relationships between many determi...

Fate of phosphate, nitrate and other elements during short-term flooding of a riparian meadow Hoffmann, C. C. NERI TECHNICAL REPORT Erosion and delivery, transport and fate of sediments and sediment-associated nutrients in watersheds: Sediment and phosphorus 1996 NUMBER 178, page(s) 135-142 Ministry of Environment and Energy; 1996 0905-815X 8777722981.

Flow and transport processes in a macroporous subsurface-drained glacial till soilI: Field investigations Villholth, K. G. Jensen, K. H. Fredericia, J. JOURNAL OF HYDROLOGY -AMSTERDAM- 1998 VOL 207; ISSUE 1-2 , page(s) 98-120 ELSEVIER SCIENCE DIVISION 0022-1694. The qualitative and quantitative effects of macropore flow and transport in an agricultural subsurface-drained glacial till soil in eastern Denmark have been investigated. Three controlled tracer experiments on individual field plots (each approximately 1000m^2) were carried out by surface application of the conservative chloride ion under different application conditions. The subsequent continuous long-term monitoring of the rate and chloride concentration of the drainage discharge represented an integrated and large-scale approach to the problem. In addition, point-scale determination of macropore structure and hydraulic efficiency, using image analysis and tension infiltration, and of soil water content, level of groundwater table, and chloride content of soil water within the soil prof...

Generic performance assessment for a deep repository for low and intermediate level waste in the UK-a case study in assessing radiological impacts on the natural environment Jones, S. R. Patton, D. Copplestone, D. Norris, S. O`Sullivan, P. JOURNAL OF ENVIRONMENTAL RADIOACTIVITY 2003 VOL 66; NUMBER 1-2 , page(s) 89-119 Elsevier Science B.V., Amsterdam. 0265-931X. Concentrations of radionuclides in soil and surface water, taken from a generic performance assessment of a repository for low and intermediate level radioactive waste, assumed to be located in the UK, have been used as the basis for a case study in assessing radiological impacts on the natural environment. Simplified descriptions of the terrestrial and aquatic ecosystem types likely to be impacted have been developed.A scoping assessment has identified 226Ra, 210Po, 234U, 230Th and 238U as having the highest potential for impact, with doses from internally incorporated alpha emitters as being potentially of particular importance. These nuclides, together with 36Cl and 129I (which have proved to be of importance in radiological risk assessments for humans) were included in a more detailed ...

GEOCHEMICAL AND ISOTOPIC MAPPING OF GROUNDWATER IN THE COASTAL AQUFIER: THE INFLUENCE OF ANTHROPOGENIC COMPONENTS ON THE WATER QUALITY Velder, O. Vengosh, A. Ayalon, A. ABSTRACTS-ISRAEL GEOLOGICAL SOCIETY , page(s) 126 Israel Geological Society NONE-XXXX.

Geochemical controls on arsenic distribution in the Baccu Locci stream catchment (Sardinia, Italy) affected by past mining Frau, F. Ardau, C. APPLIED GEOCHEMISTRY 2003 VOL 18; NUMBER 9 , page(s) 1373-1386 Elsevier Science B.V., Amsterdam. 0883-2927. The Baccu Locci stream catchment (Sardinia, Italy) is affected by serious As contamination as a consequence of past mining. The presence of both point and widespread sources of contamination (waste-rock dumps and flotation tailings, respectively) strongly affects surface water chemistry, and produces high As concentrations (hundreds of mg l-1) in stream waters. Water chemistry of the Baccu Locci stream changes considerably over a distance of about 10 km as a consequence of various, locally concomitant, processes acting along the stream course: (1) mixing with metal-rich SO4 waters; (2) dissolution/precipitation of metal-bearing phases; (3) mixing with HCO3-dominated lake waters; (4) gypsum dissolution coupled with calcite precipitation; (5) mixing with dilute surface and/or ground waters. ...

Geogenic and anthropogenic impacts on the groundwater resources in southwest of Berlin Wurl, J. Sommer-von Jarmerstedt, C. Pekdeger, A. ZEITSCHRIFT- DEUTSCHEN GEOLOGISCHEN GESELLSCHAFT 1995 VOL 146; NUMBER 1 , page(s) 243 W. FR. KAESTNER GMBH & CO. 0012-0189.

Global Radioactive Contamination Background in Terrestrial Ecosystems 13 Years after the Chernobyl Accident Pokarzhevskii, A. D. Uspenskaya, E. Y. Filimonova, Z. V. RUSSIAN JOURNAL OF ECOLOGY C/C OF EKOLOGIIA 2003 VOL 34; NUMBER 2 , page(s) 73-79 Kluwer Academic Publishers 1067-4136. The contents of 137Cs in the soil, plant, and animal samples collected in the ecosystems of protected areas from the White Sea to the Black Sea in 1999 slightly differ from those in the period between 1980 and 1984. As a result of global fallout after the Chernobyl accident, the content of radioactive cesium in the soil has increased only on the territory of the Biological Station of Moscow State University at the White Sea, whereas that in the litter and plants has increased in virtually all areas studied. The isotope content in animals is actually equal to that recorded between 1980 and 1984. The mobility of 137Cs in the soil-plant link has increased, which may be due to fallout after the accident. The duration of a complete radionuclide cycle in ecosystems decreases from 10 half-life pe...

Groundwater Chemistry in Southeastern Mecklenburg-Western Pomerania - A report from the field for differentiating between anthropogenic and geogenic influences Deibel, K. WASSERWIRTSCHAFT WASSERTECHNIK 1995 ISSUE 6 , page(s) 35 VERLAG FUER BAUWESEN 0043-0986.

Groundwater Circulations between Alluvial Aquifer and Underlying Senonian Chalk in the Seine Valley Weng, P. Coudrain-Ribstein, A. Talbi, A. Bendjoudi, H. PHYSICS AND CHEMISTRY OF THE EARTH PART B HYDROLOGY OCEANS AND ATMOSPHERE 1999 VOL 24; NUMBER 1-2 , page(s) 151-154 1464-1909

Groundwater Nitrate Concentrations in the Riparian Zones of Two Southern Ontario Streams Martin, T. L. Kaushik, N. K. Whiteley, H. R. Cook, S. Nduhiu, J. W. CANADIAN WATER RESOURCES JOURNAL 1999 VOL 24; PART 2 , page(s) 125-138 CANADIAN WATER RESOURCES ASSOCIATION 0701-1784.

Groundwater nitrate depletion in a swine lagoon effluent-irrigated pasture and adjacent riparian zone Sloan, A. J. Gilliam, J. W. Parsons, J. E. Mikkelsen, R. L. Riley, R. C. JOURNAL OF SOIL AND WATER CONSERVATION -USA- 1999 VOL 54; PART 4 , page(s) 651-656 SOIL CONSERVATION SOCIETY OF AMERICA 0022-4561.

Groundwater Nitrate Dynamics in Grass and Poplar Vegetated Riparian Buffer Strips during the Winter Haycock, N. E. Pinay, G. JOURNAL OF ENVIRONMENTAL QUALITY 1993 VOL 22; NUMBER 2 , page(s) 273 AMERICAN SOCIETY OF AGRONOMY 0047-2425.

Groundwater phosphate dynamics in a river riparian zone: effects of hydrologic flowpaths, lithology and redox chemistry Carlyle, G. C. Hill, A. R. JOURNAL OF HYDROLOGY -AMSTERDAM- 2001 VOL 247; NUMBER 3-4 , page(s) 151-168 ELSEVIER SCIENCE DIVISION 0022-1694.

Groundwater Record of Halocarbon Transport by the Danube River Boehlke, J. K. Revesz, K. Busenberg, E. Deak, J. Deseoe, E. Stute, M. ENVIRONMENTAL SCIENCE AND TECHNOLOGY -WASHINGTON DC- 1997 VOL 31; NUMBER 11 , page(s) 3293-3299 ACS AMERICAN CHEMICAL SOCIETY 0013-936X. Groundwater dating studies have supported the concept that aquifers with low coefficients of dispersion may contain coherent records of past conditions in recharge areas. Groundwater records can provide unique information about natural or anthropogenic changes in the atmosphere and hydrosphere where long-term monitoring data are not available. Here we describe a 40-year record of halocarbon contamination in the Danube River that was retrieved from a shallow aquifer in northwest Hungary. The time scale is based on ^3H and He isotope dating of groundwaters that were recharged by the Danube River and moved horizontally away from the river in a surficial gravel aquifer with minor dispersion at a maximum rate of at least 500 m/yr. Analyses of dated groundwaters along a flow path indicate that t...

Groundwater-surface water interactions in headwater forested wetlands of the Canadian Shield Devito, K. J. Hill, A. R. Roulet, N. JOURNAL OF HYDROLOGY -AMSTERDAM- 1996 VOL 181; NUMBER 1/4 , page(s) 127-147 ELSEVIER SCIENCE DIVISION 0022-1694. Groundwater and surface water interaction in two conifer swamps located in headwater catchments with contrasting till depth, typical of the southern Canadian Shield, were studied from June 1990 to August 1992. Both swamps had little influence on the regulation or attenuation of seasonal runoff response in the catchment. The two valley bottom swamps were connected to local aquifers but the upland-wetland connection was continuous in the catchment with deeper till and ephemeral in the catchment with thin till-rock ridges. Groundwater movement through the wetlands was restricted mainly to the surface peat layer in both wetlands, because a large portion of inputs from shallow soil layers and stream inflows enter near the peat surface. However, differences in upland-wetland connections resulted...

Hydraulic Gradients and Flow Rates of a Shallow Coastal Plain Aquifer in a Forested Riparian Buffer Bosch, D. D. Sheridan, J. M. Lowrance, R. R. TRANSACTIONS- AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS 1996 VOL 39; NUMBER 3 , page(s) 865-872 ASAE AMERICAN SOCIETY OF AGRICULTURAL 0001-2351. Water table gradients were measured and saturated flow rates estimated for a hillslope consisting of a tilled upland field and a downslope riparian forest buffer system located in the Gulf-Atlantic Coastal Plain Tifton-Vidalia Uplands. Three years of water table measurements and estimates of saturated hydraulic conductivity were used to evaluate and quantify saturated water flow gradients, directions, and rates. Forest treatments consisting of clear cutting, thinning, and no cutting were examined. The gradient of the water table from the top of the landscape to the bottom varied from 0.9 to 0.2%, less than the 1.5% land slope. The direction of groundwater flow generally followed the land slope. However, during summer months the hydraulic gradient within the forested buffer reversed directi...

Hydrogen and Oxygen Isotope Ratios of Groundwaters in Shallow Aquifers beneath the Alluvial Fan Mizutani, Y. Satake, H. Yamabe, A. Miyachi, H. Mase, N. Yamamura, K. JOURNAL OF GROUNDWATER HYDROLOGY 2001 VOL 43; PART 1 , page(s) 3-12 UNKNOWN 0913-4182

Hydrological Flowpaths and Nitrate Removal Rates Within a Riparian Floodplain Along a Fourth-Order Stream in Brittany (France) Clement, J.-C. Aquilina, L. Bour, O. Plaine, K. Burt, T. P. Pinay, G. HYDROLOGICAL PROCESSES 2003 VOL 17; PART 6 , page(s) 1177-1196 JOHN WILEY & SONS LTD 0885-6087.

Hysteresis of the Solute Concentration/Discharge Relationship in Rivers During Storms House, W. A. Warwick, M. S. WATER RESEARCH 1998 VOL 32; NUMBER 8 , page(s) 2279-2290 PERGAMON PRESS 0043-1354. Hysteresis of dissolved calcium, silicon, nitrate, nitrite, ammonium and phosphorus fractions, i.e. soluble reactive phosphorus, total dissolved phosphorus and total phosphorus, in river waters during a major storm event in the R. Swale catchment in Yorkshire (U.K.), are quantified using a semi-empirical model. The model separates point and base-flow contributions of the chemical determinants from diffuse inputs. The magnitude of the diffuse inputs is related to river water discharge so that the size and rotation of the hysteresis loop is characterized by a single parameter. The approach is applied to chemical and water

discharge data collected at 2 h intervals from three river sites in the catchment over a complete storm hydrograph. The results illustrate hysteresis effects for all the de... ©PERGAMON PRESS 1998 All rights reserved.

Identifying Riparian Sinks for Watershed Nitrate using Soil Surveys Rosenblatt, A. E. Gold, A. J. Stolt, M. H. Groffman, P. M. Kellogg, D. Q. JOURNAL OF ENVIRONMENTAL QUALITY 2001 VOL 30; PART 5 , page(s) 1596-1603 AMERICAN SOCIETY OF AGRONOMY 0047-2425.

Image analysis and water tracing methods for examining runoff pathways, soil properties and residence times in the continuous permafrost zone Quinton, W. L. Marsh, P. IAHS PUBLICATION Integrated Methods in Catchment Hydrology - Tracer, Remote Sensing and New Hydrometric Techniques 1999 ISSUE 258 , page(s) 257-264 IAHS PRESS - INTERN ASSOC HYDROLOGICAL SCIENC 0144-7815.

Impact of flooding on the water use of semi-arid riparian eucalypts Akeroyd, M. D. Tyerman, S. D. Walker, G. R. Jolly, I. D. JOURNAL OF HYDROLOGY -AMSTERDAM- 1998 VOL 206; ISSUE 1-2 , page(s) 104-117 ELSEVIER SCIENCE DIVISION 0022-1694. The water use strategy of Eucalyptus largiflorens (F. Muell.) was investigated in response to flooding on the Chowilla Anabranch, a semi-arid floodplain of the Murray River, South Australia. Water use was measured using the heat pulse technique at six sites that varied in flood duration from 0 to 78 days. Soil chloride, plant water potential and surface root mass were also measured. Suppression of tree water use did not occur during flooding regardless of flood length and site health, suggesting that sufficient oxygen had been available to the trees. Increases in tree water use occurred at some sites after the flood because of increases in water availability due to leaching of salt from the soil profile. The soils with a higher clay content incurred little leaching of salts and therefore l... ©ELSEVIER SCIENCE DIVISION 1998 All rights reserved.

Improved understanding of groundwater flow dynamics and risk assessment through use of anthropogenic trace substances Drenkard, S. Schlosser, P. Umweltschutz: Moglichkeiten und Grenzen der Reinigung kontaminierter Grundwasser , page(s) 475-490 Frankfurt am Main; Deutsche Gesellschaft fur Chemisches Apparatewesen, Chemische Technik und Biotechnologie; 1997 3926959800

Influence of an artificial groundwater lake on the surrounding porous aquifer traced by means of hydrochemical and isotope investigations Yehdegho, B. Zojer, H. Rozanski, K. Stichler, W. NATIONAL CONFERENCE PUBLICATION-INSTITUTION OF ENGINEERS AUSTRALIA NCP 1994 NUMBER 10//1 , page(s) 211-216 INSTITUTION OF ENGINEERS, AUSTRALIA 0313-6922. Hydrogeochemical and isotopic investigations have been carried out in a small Quaternary basin in the province of Styria, Austria, with the aim of determining the exchange between small dredging lakes and the surrounding groundwater field. The mineralization continuously evolves, due to natural hydrochemical processes and anthropogenic influences, as groundwater flows from the western boundary of the basin to the center. The opening of the groundwater induces the decrease of the concentration of most of the physico-chemical parameters as a result of the combined effect of dilution and the different geochemical and biochemical processes taking place in the artificial groundwater lakes. The concentration of most chemical species increases with the distance from the lakes in the downgradient ... ©INSTITUTION OF ENGINEERS, AUSTRALIA 1994 All rights reserved.

Influence of Natural and Anthropogenic Ligands on Metal Transport during Infiltration of River Water to Groundwater Nowack, B. Xue, H. Sigg, L. ENVIRONMENTAL SCIENCE AND TECHNOLOGY -WASHINGTON DC- 1997 VOL 31; NUMBER 3 , page(s) 866-872 ACS AMERICAN CHEMICAL SOCIETY 0013-936X. The behavior of dissolved metals, the anthropogenic ligands EDTA and NTA, and the natural ligands for Cu and Zn during infiltration of river water to the adjacent aquifer was investigated at the Glatt River field site (Switzerland). The speciation of EDTA was determined by a combination of experimental methods and of equilibrium calculations. The speciation of EDTA that behaves conservatively with respect to its total concentration changes on the infiltration path. The main EDTA species in the river water are Zn-EDTA, Ca-EDTA, and Fe(III)-EDTA and in some of the groundwaters Mn(II)-EDTA. The speciation of EDTA is strongly influenced by the presence of natural organic ligands for Cu and Zn that bind a large fraction of these metals, even in groundwater. Ni-EDTA is a less significant species... ©ACS AMERICAN CHEMICAL SOCIETY 1997 All rights reserved.

Influence of plant roots upon the mobility of radionuclides in soil, with respect to location of contamination below the surface Harvey, N. W. Shaw, G. Bell, N. J. B. JOURNAL OF RADIOANALYTICAL AND NUCLEAR CHEMISTRY 1997 VOL 226; NUMBER 1/2 , page(s) 159-173 ELSEVIER SEQUOIA SA 0236-5731. The movement of ^8^5Sr, ^1^3^7Cs, ^5^4Mn and ^6^0Co in the 50 cm soil profile was studied with and without the presence of plant roots (triticum aestivum) in order to investigate the influence of roots and depth contamination upon the migration of radionuclides. The water table was maintained manually at 3 cm from the bottom. The physiochemical characteristics (E~h Fe^-^2, NH^+~4, pH and moisture content) as well as the total and extractable radioactivity were investigated. In the discrete contamination, where the location of contamination varied within the soil profile (0-5, 25-30 or 45-50 cm from the top), the influence of location upon the movement of these radionuclides was also studied. It was found that the changes in the soil physicochemical characteristics influenced the mobility o... ©ELSEVIER SEQUOIA SA 1997 All rights reserved.

Influence of predictive contamination to agricultural products due to dry and wet processes during an accidental release of radionuclides Hwang, W. T. Kim, E. H. Suh, K. S. Jeong, H. J. Han, M. H. Lee, C. W. ANNALS OF NUCLEAR ENERGY 2003 VOL 30; NUMBER 14 , page(s) 1457-1471 Elsevier Science B.V., Amsterdam. 0306-4549. The influence of predictive contamination to agricultural products due to the wet processes as well as dry processes from radioactive air concentration during a nuclear emergency is comprehensively analyzed. The previous dynamic food chain model DYNACON considering Korean agricultural and environmental conditions, in which the initial input parameter was radionuclide concentrations on the ground, is improved so as to evaluate radioactive contamination to agricultural products from either radioactive air concentrations or radionuclide concentrations on the ground. As for the results, wet deposition is a

more dominant mechanism than dry deposition in contamination on the ground. While, the contamination levels of agricultural products are strongly dependent on radionuclide and precipitation ... ©Elsevier Science B.V., Amsterdam. 2003 All rights reserved.

Influences of the stream groundwater hydrology on nitrate concentration in unsaturated riparian area bounded by an intermittent Mediterranean stream (DOI 10.1029/2001WR001260) Butturini, A. Bernal, S. Nin, E. Hellin, C. Rivero, L. Sabater, S. Sabater, F. WATER RESOURCES RESEARCH 2003 VOL 39; PART 4 , page(s) SBH 12 AGU AMERICAN GEOPHYSICAL UNION 0043-1397.

Interactive Effects of Controlled Drainage and Riparian Buffers on Shallow Groundwater Quality Dukes, M. D. Evans, R. O. Gilliam, J. W. Kunickis, S. H. JOURNAL OF IRRIGATION AND DRAINAGE ENGINEERING 2003 VOL 129; PART 2 , page(s) 82-92 ASCE AMERICAN SOCIETY OF CIVIL ENGINEERS 0733-9437.

INVESTIGATION OF ANALYTICAL AND NUMERICAL MODELS FOR SIMULATING SURFACE WATER/GROUNDWATER INTERACTION Fox, G. A. Durnford, D. S. PROCEEDINGS OF THE ANNUAL AGU HYDROLOGY DAYS Hydrology days 2001 21ST , page(s) 58-69 Colorado State University, Civil Engineering Department; 2001.

Investigation of the Over-Exploitation of a Major Alluvial Aquifer in Thessaly, Greece Marinos, P. G. Kavvadas, M. J. Perleros, V. HYDROLOGICAL SCIENCE AND TECHNOLOGY Gambling with groundwater: physical, chemical, and biological aspects of aquifer-stream relations 1998 VOL 14; NO 1-4 , page(s) 29-38 American Institute of Hydrology; 1998 0887-686X

Isotopic constraints on radionuclide transport at Pe¤a Blanca No author Natural Analogue Working Group: Seventh EC natural analogue working group meeting , page(s) 113-122 European Commission; 1997 9282811905.

Isotopic imaging of surface water/groundwater interactions, Sacramento Valley, California Criss, R. E. Davisson, M. L. JOURNAL OF HYDROLOGY -AMSTERDAM- 1996 VOL 178; NUMBER 1/4 , page(s) 205-222 ELSEVIER SCIENCE DIVISION 0022-1694. Groundwater isotope data across the Sacramento Valley, California establish two types of groundwater mining: (1) overdraft of ancient groundwater with limited recharge by surface waters, producing cones of depression; (2) ancient groundwater withdrawal followed by rapid recharge of irrigation water, reducing groundwater quality. The first type occurs in the Sacramento metropolitan area, where meteoric runoff is unnaturally high and 40 years of pumping have depressed water levels to 25 m below sea-level, inducing recharge from losing reaches of the Sacramento and American rivers. Lateral migration rates are quantified by the binary mixing between river water (ë^1^8O = -10.8) and natural groundwater (ë^1^8O = -7.0). The second type of mining occurs in agricultural regions to the west, where ... ©ELSEVIER SCIENCE DIVISION 1996 All rights reserved.

Issues of Uranium and Radioactivity in Natural Mineral Waters Sparovek, R. B. M. Fleckenstein, J. Schnug, E. LANDBAUFORSCHUNG VOLKENRODE 2001 VOL 51; PART 4 , page(s) 149-158 REDAKTION IM SELBSTVERLAG DER 0458-6859.

Kinetics and Temperature Dependence of Potential Denitrification in Riparian Soils Maag, M. Malinovsky, M. Nielsen, S. M. JOURNAL OF ENVIRONMENTAL QUALITY 1997 VOL 26; NUMBER 1 , page(s) 215-223 AMERICAN SOCIETY OF AGRONOMY 0047-2425. We studied factors influencing potential denitrification activity (PDA) in anaerobic soil samples amended with NO~3^- from a riparian meadow with agricultural uplands, and a reedswamp receiving nitrate-containing creek water at two loading rates. Both sites had high levels of PDA (3-28 mg N kg^-^1 h^-^1), which decreased exponentially with depth. High correlations were seen between PDA and mineralizable and water soluble C. At the meadow site, high apparent K~m values (29-51 æM N) were found in the upper 150 cm of the soil profile due to a lateral flow of nitrate-rich water. Below this depth, K~m values were 10 to 30 times lower due to the influence of nutrient poor groundwater. In the 0- to 10-cm profile of the reedswamp soil, the highest apparent K~m (89 æM N) was found on the high load ... ©AMERICAN SOCIETY OF AGRONOMY 1997 All rights reserved.

Lake sediments, erosion and landscape change during the Holocene in Britain and Ireland Edwards, K. J. Whittington, G. CATENA -GIESSEN THEN AMSTERDAM- Landscape sensitivity; Landscape sensitivity 2001 VOL 42; NO 2-4 , page(s) 143-174 Elsevier; 2001 0341-8162.

Landscape Attributes as Controls on Ground Water Nitrate Removal Capacity of Riparian Zones Gold, A. J. Groffman, P. M. Addy, K. Kellogg, D. Q. Stolt, M.; Rosenblatt, A. E. JOURNAL- AMERICAN WATER RESOURCES ASSOCIATION 2001 VOL 37; PART 6 , page(s) 1457-1464 1093-474X.

Lichens as biomonitors of uranium in the Balkan area Loppi, S. Riccobono, F. Zhang, Z. H. Savic, S. Ivanov, D. Pirintsos, S. A. ENVIRONMENTAL POLLUTION -LONDON THEN BARKING- 2003 VOL 125; NUMBER 2 , page(s) 277-280 Elsevier Science B.V., Amsterdam. 0269-7491. The contribution of the conflict of 1999 to the environmental levels of uranium in the Balkan area was evaluated by means of lichens used as biomonitors. The average U concentration found in lichens in the present study was in line with the values reported for lichens from other countries and well below the levels found in lichens collected in areas with natural or anthropogenic sources of U. Measurement of isotopic ratios 235U/238U allowed to exclude the presence of depleted uranium. According to these results, we could not detect widespread environmental contamination by depleted uranium in the Balkan area. ©Elsevier Science B.V., Amsterdam. 2003 All rights reserved.

Linking an ecosystem model and a landscape model to study forest species response to climate warming He, H. S. Mladenoff, D. J. Crow, T. R. ECOLOGICAL MODELLING 1998 VOL 114; ISSUE 2-3 , page(s) 213-233 ELSEVIER

SCIENCE DIVISION 0304-3800. No single model can address forest change from single tree to regional scales. We discuss a framework linking an ecosystem process model (linkages) with a spatial landscape model (landis) to examine forest species responses to climate warming for a large, heterogeneous landscape in northern Wisconsin, USA. Individual species response at the ecosystem scale was simulated with linkages, which integrates soil, climate and species data, stratified by ecoregions. Individual species biomass results, simulated by linkages at year 10, were quantified using an empirical equation as species establishment coefficients (0.0-1.0). These coefficients were used to parameterize landis, thus integrating ecosystem dynamics with large-scale landscape processes such as seed dispersal and fire disturbance. Spe...

Long-term Effects of localised Accumulation of Anthropogenic Materials on the Groundwater Golwer, A. ZEITSCHRIFT-DEUTSCHEN GEOLOGISCHEN GESELLSCHAFT 1995 VOL 146; NUMBER 1 , page(s) 191 W. FR. KAESTNER GMBH & CO. 0012-0189.

Marine Isotope Stage 11 as an analogue for the present interglacial Loutre, M. F. Berger, A. GLOBAL AND PLANETARY CHANGE 2003 VOL 36; NUMBER 3 , page(s) 209-217 Elsevier Science B.V., Amsterdam. 0921-8181. Past analogues for our present interglacial or even warmer periods have been sought in order to better understand our present and future climate. Marine Isotope Stage (MIS) 5, more precisely substage 5e, has long been considered to be a good candidate. However, there were some elements against this analogy in the data themselves [Kukla et al. Quat. Sci. Rev. 16 (6) (1997) 605], as well as in the mechanisms [Berger, 1989 Response of the climate system to CO2 and astronomical forcings. In: Paleo-Analogs, IPCC Working Group I, Bath, 20-21 November 1989] and forcing related to both periods. Here we suggest that the period from 405 to 340 ka before present (BP), including a large part of Marine Isotope Stage 11, could be a good analogue for future climate. The insolation over this interval show...

Measurement of bromide ion used as a solute-transport monitor via epithermal neutron activation analysis Kazemi, H. V. Morris, J. S. Anderson, S. H. Gantzer, C. J. Buyanovsky, G. A. JOURNAL OF RADIOANALYTICAL AND NUCLEAR CHEMISTRY 1998 VOL 235; NUMBER 1/2 , page(s) 249-254 ELSEVIER SEQUOIA SA 0236-5731. In soil science (ca 1970), bromide ion (Br^-) in various forms (e.g., KBr, NaBr, SrBr~2) was introduced as a non-reactive stable tracer in solute transport studies normally moving freely with the flux of water without substantial chemical or physical interactions with the soil: Typically, Br^- is extracted from soil and quantified using either a bromide selective electrode (sensitivity is -10 æg/ml) or by high-performance liquid chromatography (sensitivity is -0.010 æg/ml). Where the sensitivity is adequate, the selective conductivity method, which is simple, affordable and fast, is preferred. More recently (ca. 1990), workers have reported that 20% of Br^- tracers, at low groundwater pH, may be adsorbed by iron oxides and kaolinite when present in the alluvial aquifer. We investigated the...

Mechanisms for the Formation of a Perched Water Zone in Fractured Tuff: A Natural Analogue Study Woodhouse, E. G. Bassett, R. L. MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS Scientific Basis for Nuclear Waste Management XX 1997 VOL 465 , page(s) 1161-1168 MATERIALS RESEARCH SOCIETY 0272-9172. Perched water zones have been identified in the fractured, welded tuff in the semi-arid to and environments of Yucca Mountain, Nevada and near Superior, Arizona. An understanding of the formation of such zones is necessary in order to predict where future perched water might form at Yucca Mountain, the proposed site of a high-level nuclear waste repository. The formation or growth of a perched zone near a repository is one of the factors to be considered in the risk assessment of the Yucca Mountain site. The Apache Leap Research Site near Superior, Arizona is a natural analog to the Yucca Mountain site in terms of geology, hydrology, and climate. Information used to study possible mechanisms for the formation of the perched zone included data regarding isotopic and geochemical properties o...

Microbial Nitrate Processing in Shallow Groundwater in a Riparian Forest Groffman, P. M. Howard, G. Gold, A. J. Nelson, W. M. JOURNAL OF ENVIRONMENTAL QUALITY 1996 VOL 25; NUMBER 6 , page(s) 1309-1316 AMERICAN SOCIETY OF AGRONOMY 0047-2425. We measured denitrification, immobilization, and respiration in microcosms that simulated groundwater conditions in a riparian forest in Rhode Island. Measured rates were compared with rates of NO^-~3 removal measured in a companion study using a groundwater monitoring well network and 10-mo injection of NO^-~3 and a bromide tracer to groundwater in the same riparian forest. Limiting factors for denitrification were assessed, and microbial and root biomass and potential net N mineralization and nitrification were compared in aquifer material exposed to the 10 mo of NO^-~3 dosing and unexposed control material. While there was significant variation in water table levels, dissolved oxygen, dissolved organic C, and total C within the aquifer in the riparian forest, there was little spatial va...

Microbial role in immobilization of technetium in soil under waterlogged conditions Tagami, K. Uchida, S. CHEMOSPHERE 1996 VOL 33; NUMBER 2 , page(s) 217-225 PERGAMON PRESS 0045-6535. Technetium behaviour in soil depends upon its chemical forms. The nuclide is expected to be in a soluble form of pertechnetate (TcO~4^-) under an aerobic condition, however, this changes through a combination of factors such as a redox condition and microbial activity. In this study, a radiotracer experiment was carried out to clarify the influence of microbial activity on plant available Tc under waterlogged condition. Air-dried soil with 0, 0.05, 0.5% glucose contents and sterile soil were used to compare the effect of microbial activity. The soils were waterlogged with ^9^5^mTc or ^9^9Tc solution and kept at room temperature. Relative activities of the bottom solutions which had collected 1 hour after waterlogging indicated high correlations with the amounts of total-C, total-N, active-...

Mining Relics as Sources of Natural Radioactivity - Release of Radon from Uranium Mill Tailings Baraniak, L. Mende, A. FACHVERBAND FUR STRAHLENSCHUTZ EIGENTRAGENER VEREIN -PUBLIKATIONEN- FS ALL SERIES

International Radiation Protection Association: Fachverband fur Strahlenschutz; Umweltradioaktivitat Radiookologie Strahlenwirkungen 1993 BAND 1 , page(s) 76-78 Verlag TUV Rheinland; 1993 3824901692.

Mobilization of radionuclides from uranium mill tailings and related waste materials in anaerobic environments Landa, E. R. JOURNAL OF RADIOANALYTICAL AND NUCLEAR CHEMISTRY 2003 VOL 255; NUMBER 3 , page(s) 559-563 Kluwer Academic Publishers 0236-5731. Specific extraction studies in our laboratory have shown that iron and manganese oxide- and alkaline earth sulfate minerals are important hosts of radium in uranium mill tailings. Iron- and sulfate-reducing bacteria may enhance the release of radium (and its analog barium) from uranium mill tailings, oil field pipe scale [a major technologically enhanced naturally occurring radioactive material (TENORM) waste], and jarosite (a common mineral in sulfuric acid processed-tailings). These research findings are reviewed and discussed in the context of nuclear waste forms (such as barium sulfate matrices), radioactive waste management practices, and geochemical environments in the Earths surficial and shallow subsurface regions. ©Kluwer Academic Publishers 2003 All rights reserved.

Model of Radionuclide Uptake by Marine Sediments Hulbert, M. H. Bennett, R. H. Burkett, P. J. ENVIRONMENTAL GEOTECHNOLOGY -INTERNATIONAL SYMPOSIUM- Environmental geotechnology 1996 3rd , page(s) 363-374 Technomic Pub. Co; 1996 1566764629.

Modeling of Neptunium(V), Plutonium(IV) and Americium(III) Sorption on Soils in the Presence of Humic Acid Tanaka, T. Sakamoto, Y. Muraoka, S. JAERI CONF NUCEF: safety research and development of base technology on nuclear fuel cycle 1999 NUMBER 4/1 , page(s) 662-673 Japan Atomic Energy Research Institute; 1999.

Modelling contaminant transport at catchment or regional scale Addiscott, T. M. Mirza, N. A. AGRICULTURE ECOSYSTEMS AND ENVIRONMENT Long-Term Perspectives for Effects of Rural Land Use Changes on Soil Contaminants 1998 VOL 67; NUMBER 2/3 , page(s) 211-221 ELSEVIER SCIENCE DIVISION 0167-8809. Most models for contaminant transport have been developed and tested at the scale of the field plot, the lysimeter or even the laboratory soil column. Modelling at the scale of the catchment or region therefore brings some interesting new challenges. The interaction between non-linearity in a model and variance in one of its parameters can cause errors in modelling even small areas of land; the reasons are explained and a test for non-linearity given. It is necessary to know whether this problem will intensify as the area modelled increases, and it is suggested that the variogram provides a means of answering this question. The intrinsic variability of the soil is only one of the factors that have to be considered at catchment or regional scale. At these scales, land use is likely to be th... ©ELSEVIER SCIENCE DIVISION 1998 All rights reserved.

Modelling Long-Term Contaminant Migration in A Catchment at Fine Spatial and Temporal Scales Using the UP System Sloan, W. T. Ewen, J. HYDROLOGICAL PROCESSES 1999 VOL 13; NUMBER 6 , page(s) 823-846 JOHN WILEY & SONS LTD 0885-6087.

Modelling nitrate transport in the Slapton Wood catchment using SHETRAN Birkinshaw, S. J. Ewen, J. JOURNAL OF HYDROLOGY -AMSTERDAM- 2000 VOL 230; NUMBER 1-2 , page(s) 18-33 ELSEVIER SCIENCE DIVISION 0022-1694.

Modelling Solute and Sediment Transport at Different Spatial and Temporal Scales Bogena, H. R. Diekkruger, B. EARTH SURFACE PROCESSES AND LANDFORMS Linking Sediment Delivery from Hillslope to Catchment Scale 2002 VOL 27; PART 13 , page(s) 1475-1490 WILEY 0197-9337.

Modelling studies for determining unsaturated flow components in a sandy soil dual tracer test Nutzmann, G. Maciejewski, S. DEVELOPMENTS IN WATER SCIENCE International conference on computational methods in water resources 2002 VOL 47; NO 1 , page(s) 33-40 Amsterdam; Oxford; Elsevier; 2002 0444509755.

Modelling the long-term behaviour of radioactive substances in fresh water systems: role of migration from catchment basins and of radionuclide exchange between water and sediment Bergstrom, U. Boardman, J. Heling, R. Van der Steen, J. STUDIES IN ENVIRONMENTAL SCIENCE Freshwater and estaurine radioecology 1997 VOL 68 , page(s) 433-440 Amsterdam; Oxford; Elsevier; 1997 0444825339.

Modelling the time evolution of water-quality parameters in a river: Yarra River, Australia Sokolov, S. Black, K. P. JOURNAL OF HYDROLOGY -AMSTERDAM- 1996 VOL 178; NUMBER 1/4 , page(s) 311-335 ELSEVIER SCIENCE DIVISION 0022-1694. Analyses of water-quality variables for the Yarra River in South-Eastern Australia have shown that the relationship between species concentrations in the river and the river discharge is time dependent and non-linear. A simple dynamic model relating the time evolution of the total mass of chemical element in the catchment area to chemical loading in the river provides high-accuracy predictions of absolute and time-integrated values of the latter. Because the chemical loads in the river are controlled by the total mass of chemical element in the catchment area, the relationship between chemical concentration in stream water and river discharge reveals a hysteresis. A balance between chemical loads in the river and the loads into the catchment area determines the direction of rotation of the... ©ELSEVIER SCIENCE DIVISION 1996 All rights reserved.

Movement of Bacteria in Unsaturated Soil Columns with Macropores Abu-Ashour, J. Joy, D. M. Lee, H. Whiteley, H. R. Zelin, S. TRANSACTIONS- AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS 1998 VOL 41; NUMBER 4 , page(s) 1043-1050 ASAE AMERICAN SOCIETY OF AGRICULTURAL 0001-2351. Rapid movement of bacteria through the soil has been observed after applications of manure to agricultural fields. Preferential flow through macropores has been suggested as the main reasons for these observations. Experiments with repacked soil columns were used to study the effect of artificially created macropores, soil type, soil water content, and simulated rain application on movement of a tracer bacterium, nalidixic acid-resistant Escherichia coli. Results form these experiments showed a significant increase in the number of biotracer cells passing through a soil column when macropores were present and the soil was wet. There was no

passage of biotracer cells through a dry soil with macropores. No biotracer cells were eluted from columns without macropores even when the soils were w... ©ASAE AMERICAN SOCIETY OF AGRICULTURAL 1998 All rights reserved.

Natural analogue studies of the role of colloids, natural organics and microorganisms on radionuclide transport McCarthy, J. NUCLEAR SCIENCE AND TECHNOLOGY 6th Meeting , page(s) 195-210 CEC; 1996 1018-5593 9282761606.

Natural analogue studies: present status and performance assessment implications Smellie, J. A. T. Karlsson, F. Alexander, W. R. JOURNAL OF CONTAMINANT HYDROLOGY Migration 95: selected papers from the fifth international conference on chemistry and migration behaviour of actinides and fission products in the geosphere... 1997 VOL 26; NUMBER 1/4 , page(s) 3-18 Elsevier; 1997 0169-7722

Natural and anthropogenic factors controlling spring water quality in the southern part of the Malopolska Upland (southern Poland) Chelmicki, W. Siwek, J. IAHS PUBLICATION Impact of human activity on groundwater dynamics 2001 NO 269 , page(s) 317-322 Wallingford, Oxfordshire; IAHS; 2001 0144-7815 1901502562.

Natural and Anthropogenic Nitrate Contamination of Groundwater in a Rural Community, California Williams, A. E. Lund, L. J. Johnson, J. A. Kabala, Z. J. ENVIRONMENTAL SCIENCE AND TECHNOLOGY -WASHINGTON DC- 1998 VOL 32; NUMBER 1 , page(s) 32-39 ACS AMERICAN CHEMICAL SOCIETY 0013-936X. Contamination of small basins impacts the quality of groundwater resources and the health of residents dependent on local, limited water supplies. Understanding contaminant sources is crucial not only to planning mitigation and cleanup but also to the rural community, who must participate in any scientific or regulatory effort. Groundwaters, rock, and soil samples representative of the Sierra Pelona Valley in an arid, "Mediterranean" climate region of southern California indicate significant anthropogenic nitrate contamination. Groundwater nitrate from diverse sources can be differentiated on the basis of chemical and isotopic compositions. Samples analyzed for dissolved or leachable ion concentrations as well as ë^1^5N provide both chemical and isotopic signatures that distinguish between... ©ACS AMERICAN CHEMICAL SOCIETY 1998 All rights reserved.

Natural Constraints on Radionuclide Release Rates Curtis, D. B. Fabryka-Martin, J. Dixon, P. Nuclear science and technology , page(s) 211-218 CEC; 1994 9282670910.

Neptunium Uptake on Boom Clay - Time Dependence and Association of Np with Fine Particles Hart, K. P. Payne, T. E. Robinson, B. J. Van Iseghem, P. RADIOCHIMICA ACTA 1994 VOL 66/67; NUMBER COM , page(s) 19 R OLDENBOURG VERLAG GMBH 0033-8230.

Nitrate Depletion During Within-Stream Transport: Effects of Exchange Processes Between Streamwater, the Hyporheic and Riparian Zones Grimaldi, C. Chaplot, V. WATER AIR AND SOIL POLLUTION 2000 VOL 124; PART 1/2 , page(s) 95-112 KLUWER ACADEMIC PUBLISHERS GROUP 0049-6979.

Nitrate Dynamics in Relation to Lithology and Hydrologic Flow Path in a River Riparian Zone Devito, K. J. Fitzgerald, D. Hill, A. R. Aravena, R. JOURNAL OF ENVIRONMENTAL QUALITY 2000 VOL 29; PART 4 , page(s) 1075-1084 AMERICAN SOCIETY OF AGRONOMY 0047-2425.

Nitrate Dynamics in Riparian Forests: Groundwater Studies Simmons, R. C. Gold, A. J. Groffman, P. M. JOURNAL OF ENVIRONMENTAL QUALITY 1992 VOL 21; NUMBER 4 , page(s) 659 AMERICAN SOCIETY OF AGRONOMY 0047-2425.

Nitrate in groundwater and water sources used by riparian trees in an agricultural watershed: A chemical and isotopic investigation in southern Minnesota Komor, S. C. Magner, J. A. WATER RESOURCES RESEARCH 1996 VOL 32; NUMBER 4 , page(s) 1039-1050 AGU AMERICAN GEOPHYSICAL UNION 0043-1397. This study evaluates processes that affect nitrate concentrations in groundwater beneath riparian zones in an agricultural watershed. Nitrate pathways in the upper 2 m of groundwater were investigated beneath wooded and grass-shrub riparian zones next to cultivated fields. Because trees can be important components of the overall nitrate pathway in wooded riparian zones, water sources used by riparian trees and possible effects of trees on nitrate concentrations in groundwater were also investigated. Average nitrate concentrations in shallow groundwater beneath the cultivated fields were 5.5 mg/L upgradient of the wooded riparian zone and 3.5 mg/L upgradient of the grass-shrub zone. Shallow groundwater beneath the fields passed through the riparian zones and discharged into streams that had... ©AGU AMERICAN GEOPHYSICAL UNION 1996 All rights reserved.

Nitrate movement and removal along a shallow groundwater flow path in a riparian wetland within a sheep-grazed pastoral catchment: results of a tracer study Burns, D. A. Nguyen, L. NEW ZEALAND JOURNAL OF MARINE AND FRESHWATER RESEARCH 2002 VOL 36; PART 2 , page(s) 371-386 EUROSPAN LTD 0028-8330.

Nitrate removal in a regularly flooded riparian meadow Hoffmann, C. C. PROCEEDINGS- INTERNATIONAL ASSOCIATION OF THEORETICAL AND APPLIED LIMNOLOGY International Association of Theoretical and Applied Limnology 1996 /1998; VOL 26; NUMBER 3 , page(s) 1352-1358 Stuttgart; E Schweizerbart'sche Verlagsbuchhandlung; 1996-1998 0368-0770 3510540441; 3510540476.

Nitrate removal in riparian wetland soils: effects of flow rate, temperature, nitrate concentration and soil depth Willems, H. P. L. Rotelli, M. D. Berry, D. F. Smith, E. P. Reneau, R. B. Mostaghimi, S. WATER RESEARCH 1997 VOL 31; NUMBER 4 , page(s) 841-840 PERGAMON PRESS 0043-1354. Riparian zones, located adjacent to intensely managed agricultural fields, are thought to play an important role in removal of nutrient contaminants including NO^-~3 from groundwater. We studied the effect of flow rate, NO^-~3 concentration and temperature on NO^-~3 removal in soil columns under saturated-flow conditions. Bibb (coarse-loamy, siliceous, acid thermic Typic Fluvaquent) sandy loam soil was collected from a riparian forest located in Nomini Creek Watershed, Virginia. Soils included in the study were a permanently inundated

surface horizon, a seasonally saturated surface horizon, a shallow subsurface horizon and a deep subsurface horizon. Soil columns were infiltrated with NO^-~3 amended groundwater at concentrations from 14 to 36 mg NO^-~3-N L^-^1. Column operating temperatures... ©PERGAMON PRESS 1997 All rights reserved.

Nitrate Removal in Stream Riparian Zones Hill, A. R. JOURNAL OF ENVIRONMENTAL QUALITY 1996 VOL 25; NUMBER 4 , page(s) 743-755 AMERICAN SOCIETY OF AGRONOMY 0047-2425. This review considers the role of stream riparian zones in regulating the transport of nitrate (NO^-~3) in groundwater flow from uplands to streams. The current consensus is that most riparian zones effectively remove NO^-~3 from subsurface water. However, research has not focused on the relationship between hydrology and chemistry within the context of the riparian zone hydrogeologic setting. Most riparian zones that remove NO^-~3 occur in landscapes with impermeable layers near the ground surface. In this setting, small amounts of groundwater follow shallow horizontal flow paths that increase water residence time and contact with vegetation roots and organic-rich riparian soils. Limited research suggests that riparian zones have less effect on NO^-~3 transport in hydrogeologic settings w... ©AMERICAN SOCIETY OF AGRONOMY 1996 All rights reserved.

Nitrogen and phosphorus variation in shallow groundwater and assimilation in plants in complex riparian buffer zones Kuusemets, V. Mander, U. Lohmus, K. Ivask, M. WATER SCIENCE AND TECHNOLOGY Wetland systems for water pollution control 2001 VOL 44; NOS 11-12 , page(s) 615-622 IWA; 2000 0273-1223 1843394073.

Nitrogen Assimilation by Riparian Buffer Systems Receiving Swine Lagoon Wastewater Hubbard, R. K. Newton, G. L. Davis, J. G. Lowrance, R. Vellidis, G. Dove, C. R. TRANSACTIONS- AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS 1998 VOL 41; NUMBER 5 , page(s) 1295-1304 ASAE AMERICAN SOCIETY OF AGRICULTURAL 0001-2351. A three-year study was conducted to determine the feasibility of using riparian buffer systems to assimilate nitrogen (N) from swine lagoon effluent. Replicated 30x4 m plots were established at the interface of a pasture and riparian forest. Wastewater from the third lagoon of the University of Georgia Coastal Plain Experiment Station main swine research unit was applied to each plot by overland flow from tanks at the top end of each plot. The wastewater, which contained an average N concentration of 160 mg L^-^1 N, primarily as ammonium (NH~4-N), was applied to the plots at two different rates (either once per week [1x, 1285 L/plot] or twice per week [2x, 2570 L/plot]). Three different vegetative buffer treatments were evaluated: (1) 10 m grass buffer draining into 20 m existing riparian ... ©ASAE AMERICAN SOCIETY OF AGRICULTURAL 1998 All rights reserved.

Nitrogen dynamics in the shallow groundwater of a riparian wetland zone of the Garonne, SW France: nitrate inputs, bacterial densities, organic matter supply and denitrification measurements Sanchez-Perez, J. M. Vervier, P. Garabetian, F. Sauvage, S. Loubet, M. Rols, J. L. Bariac, T. Weng, P. HYDROLOGY AND EARTH SYSTEM SCIENCES Understanding hydrological processes in wetlands to improve management 2003 VOL 7; NUMB 1 , page(s) 97-108 EUROPEAN GEOPHYSICAL SOCIETY 1027-5606.

Nitrogen isotope ratios of natural and anthropogenic nitrate in the subsurface Rolston, D. E. Fogg, G. E. Decker, D. L. Louie, D. T. NATIONAL CONFERENCE PUBLICATION- INSTITUTION OF ENGINEERS AUSTRALIA NCP Vol 2B; Groundwater Papers 1994 NUMBER 14//2B , page(s) 451-457 The Institute; 1994 0313-6922 858256207.

Nitrogen transformation component for SHETRAN catchment nitrate transport modelling Birkinshaw, S. J. Ewen, J. JOURNAL OF HYDROLOGY -AMSTERDAM- 2000 VOL 230; NUMBER 1-2 , page(s) 1-17 ELSEVIER SCIENCE DIVISION 0022-1694.

Non-point pollution of groundwater in urban areas Trauth, R. Xanthopoulos, C. WATER RESEARCH 1997 VOL 31; NUMBER 11 , page(s) 2711-2718 PERGAMON PRESS 0043-1354. Within a pilot project, a monitoring network for the description of the non-point sources of groundwater pollution in urban areas was implemented and operated for 3 years. The main concept of the network lay in the collection of consistent series of time data for the description of groundwater quality and the description of the relationship between the non-point sources of anthropogenic pollutants in the urban areas and the measured concentration in groundwater. The impairment of the groundwater quality due to non-point sources of pollution could be demonstrated and described. Supporting information on hydrology, geology and land-use has been used in addition to the measured data. The results show the significant impact of the urban non-point sources on the groundwater quality. In particul... ©PERGAMON PRESS 1997 All rights reserved.

Nuclide Concentration Factors for Freshwater Biota Bird, G. A. Schwartz, W. TECHNICAL RECORD- ATOMIC ENERGY OF CANADA LIMITED TR 1996 ISSUE 703 , page(s) ALL SCIENTIFIC DOCUMENT DISTRIBUTION OFFICE 1207-5426.

Nutrient dynamics at interface between surface waters and groundwaters Dahm, C. N. Grimm, N. B. Marmonier, P. Maurice Valett, H. Vervier, P. FRESHWATER BIOLOGY Rivers in the landscape: riparian and groundwater ecology 1998 VOL 40; NUMBER 3 , page(s) 427-452 BLACKWELL SCIENTIFIC PUBLICATIONS 0046-5070.

Oklo as a Natural Analogue for Radionuclide Transfer Processes in a Waste Geological Repository: Present Status of the Program Blanc, P. L. Nuclear science and technology , page(s) 157-162 CEC; 1994 9282670910.

Oklo-Natural Analogue: Hydrochemical Constraints on the Radionuclide Transport Modelling at Bagombe Louvat, D. Ledoux, E. Winberg, A. Use of hydrogeochemical information in testing groundwater flow models , page(s) 169-174 OECD; 1999 9264161538.

Overview of inert tracer experiments in key Belgian soil types: Relation between transport and soil morphological and hydraulic properties (Paper 2000WR000110) Vanderborght, J. Vanclooster, M. Timmerman, A. Seuntjens, P.; Mallants, D.

Kim, D.-J. Jacques, D. Hubrechts, L. Gonzalez, C.; Feyen, J. WATER RESOURCES RESEARCH 2001 VOL 37; PART 12 , page(s) 2873-2888 AGU AMERICAN GEOPHYSICAL UNION 0043-1397.

Palaeoclimate versus vegetation reconstruction - palynological investigations on the Oligocene sequence of the Sava Basin, Slovenia Bruch, A. A. Mosbrugger, V. REVIEW OF PALAEOBOTANY AND PALYNOLOGY 2002 VOL 122; NUMBER 3-4 , page(s) 117-141 Elsevier Science B.V., Amsterdam. 0034-6667. An Oligocene succession from the Slovenian Sava Basin (Zasavje) was analysed to reconstruct climate and vegetation of the interval. Independent quantitative approaches were applied on a detailed palynological data set to reconstruct both parameters separately allowing for a synthesis and interpretation. The reconstruction of palaeoclimate is based on the coexistence approach and documents an equal, warm-temperate, humid climate with low annual variation. Quantitative results indicate values of mean annual temperature of 16-19degreeC, with winter temperatures of 6-9degreeC and summer temperatures of 25-28degreeC, and a mean annual precipitation ranging between 1100 and 1300 mm. In contrast to the very homogeneous climatic signal, the vegetational reconstruction based on multivariate statist...

PANEL-People and riparian ecosystem: Past, present, and future Periman, R. D. Raish, D. UNITED STATES DEPARTMENT OF AGRICULTURE FOREST SERVICE GENERAL TECHNICAL REPORT RM Desired future conditions for Southwestern riparian ecosystems: Bringing interests and concerns together 1995 ISSUE 272 , page(s) 237 US DEPARTMENT OF AGRICULTURE 0277-5786.

Paraglacial geomorphology Ballantyne, C. K. QUATERNARY SCIENCE REVIEWS 2002 VOL 21; NUMBER 18-19 , page(s) 1935-2017 Elsevier Science B.V., Amsterdam. 0277-3791. Paraglacial geomorphology is the study of earth-surface processes, sediments, landforms, landsystems and landscapes that are directly conditioned by former glaciation and deglaciation. The withdrawal of glacier ice exposes landscapes that are in an unstable or metastable state, and consequently liable to modification, erosion and sediment release at rates greatly exceeding background denudation rates. This paper (1) reviews research on paraglacial processes, landforms and landscape change in a range of geomorphological settings; (2) explores the importance of paraglacial landscape modification and sediment recycling as a component of alternating glacial/nonglacial landscape evolution; (3) assesses the nature and significance of paraglacial facies in Quaternary stratigraphic sequences; and ...

Partitioning and Availability of Uranium and Nickel in Contaminated Riparian Sediments Sowder, A. G. Bertsch, P. M. Morris, P. J. JOURNAL OF ENVIRONMENTAL QUALITY 2003 VOL 32; PART 3 , page(s) 885-898 AMERICAN SOCIETY OF AGRONOMY 0047-2425.

Patterns of Nitrate Attenuation in Riparian Wetlands Cosandey, A.-C. Maitre, V. Guenat, C. Vedy, J.-C. WETLANDS AND REMEDIATION International conference on wetlands and remediation; Wetlands and remediation II 2002 2ND , page(s) 347-354 Columbus, OH; Battelle Press; 2002 1574771221.

Pedogenic evolution of paddy soils in different soil landscapes Zhang, G. L. Gong, Z. T. GEODERMA 2003 VOL 115; NUMBER 1-2 , page(s) 15-29 Elsevier Science B.V., Amsterdam. 0016-7061. Paddy soils are Hydragric Anthrosols and are an important soil resource for food production. They are widely distributed in China and Asia. Soils that can be used for paddy cultivation vary considerably but basically are grouped into three kinds of landscape, i.e., well-drained sloping uplands, alluvial plains with groundwater fluctuation, and poorly drained polder areas with a near-surface water table. Typical soil chronosequences were studied to clarify the pedogenic changes after wetland rice cultivation, especially in relation to management practices. All of them are in important rice production regions of China. The study focussed on redox condition and iron oxides dynamics. On alluvial plains, the soil conditions range from continuously reducing controlled by high groundwater to alte...

Performance of conceptual rainfall-runoff models in low-yielding ephemeral catchments Ye, W. Bates, B. C. Viney, N. R. Sivapalan, M. Jakeman, A. J. WATER RESOURCES RESEARCH 1997 VOL 33; NUMBER 1 , page(s) 153-166 AGU AMERICAN GEOPHYSICAL UNION 0043-1397. Low-yielding catchments with ephemeral streams involve highly nonlinear relationships between rainfall and runoff, and there is much less documentation and appreciation of the ability to predict streamflow in these very difficult cases than in humid catchments. The predictions of three conceptual rainfall-runoff models are assessed in three low-yielding, emphemeral streams over a 10-year period. The models are a simple conceptual model, Generalized Surface infiltration Baseflow (GSFB; eight parameters), a hybrid metric/conceptual model, Identification of Hydrographs and Components from Rainfall, Evaporation and Streamflow data (IHACRES; six parameters), and a complex conceptual model, the Large Scale Catchment Model (LASCAM; 22 parameters). The Salmon (0.82 km^2), Stones (15 km^2), and Can...

Pesticide contamination of water resources: a case study - the rivers in the Paris region Tisseau, M. Fauchon, N. Cavard, J. Vandevelde, T. WATER SCIENCE AND TECHNOLOGY Water Quality International '96: Part 4 1996 VOL 34; NUMBER 7//8 , page(s) 147-152 PERGAMON PRESS 0273-1223. For a number of years, the Compagnie Generale des Eaux has been studying pesticide contamination of surface water in order to better understand the origins and the main transfer mechanisms of these pollutants into water resources. Sampling campaigns are being carried out on the three main rivers of the Paris area to monitor a number of products from the triazine and urea families. This monitoring has confirmed the extension of agricultural non-point source pollution. The products being sought are present in the three rivers and, in most cases, in significant concentrations. Atrazine is the most important contaminant. Measured concentrations exceed the value of 100 ng/l most of the time, thus proving that the aquifers drained by the three rivers are contaminated. For a period of several mon...

Physiological and Growth Responses of Riparian Sedge Transplants to Groundwater Depth Steed, J. E. DeWald, L. E. Kolb, T. E. INTERNATIONAL JOURNAL OF PLANT SCIENCES 2002 VOL 163; PART 6 , page(s) 925-936 THE UNIVERSITY OF CHICAGO PRESS 1058-5893.

Preferential Transport of a Bromide Tracer Applied in a Pulse of Ponded Water Timlin, D. J. Ahuja, L. R. Heathman, G. C. JOURNAL OF ENVIRONMENTAL QUALITY 1998 VOL 27; NUMBER 3 , page(s) 505-514 AMERICAN SOCIETY OF AGRONOMY 0047-2425. The objective of this study was to quantify relations between preferential transport of a solute and initial water content, infiltration rate, and porosity in a field soil where preferential transport was mainly due to soil heterogeneity. We measured the horizontal and vertical distribution of a tracer chemical applied with ponded water to study the flow paths of the tracer. The soil at the site is a Bosville fine sandy loam (fine-mixed, thermic Albaquic Paleudalfs). Strontium bromide (SrBr~2) tracer was applied with a dye (methylene blue) in a 100 or 50-mm pulse of water to soil within eight double ring infiltrometers. After 48 h the soil in each infiltrometer was sampled to 0.7 m. Twelve horizontally oriented, continuous soil samples 0.1 m long were collected at each depth. There were ve...

Quality of underground water and its contribution towards selenium enrichment of the soil-plant system for a seleniferous region of northwest India Dhillon, K. S. Dhillon, S. K. JOURNAL OF HYDROLOGY -AMSTERDAM- 2003 VOL 272; NUMBER 1-4 , page(s) 120-130 Elsevier Science B.V., Amsterdam. 0022-1694. Quality of underground water drawn from 90 tubewells located in the seleniferous region of northwestern India was evaluated on the basis of Se content, electrical conductivity and residual sodium carbonate (RSC). All the water samples were found to be suitable for irrigation on the basis of total dissolved salts. With respect to RSC ratings, 86% of the samples were marginally fit and 12% of the samples were unfit for irrigation purposes. Selenium content of tubewell waters at or near the toxic sites ranged between 0.25 and 69.5mgl-1 with an average value of 4.7mgl-1. The maximum contamination level (MCL) of 10mgSel-1 for drinking purposes was exceeded by 11.1% of the tubewell waters and the maximum permissible level (MPL) of 20mgSel-1 for irrigation purposes was exceeded by 4.4% of the wat...

Quantification of mass fluxes and natural attenuation rates at an industrial site with a limited monitoring network: a case study Bockelmann, A. Zamfirescu, D. Ptak, T. Grathwohl, P. Teutsch, G. JOURNAL OF CONTAMINANT HYDROLOGY 2003 VOL 60; NUMBER 1-2 , page(s) 97-121 Elsevier Science B.V., Amsterdam. 0169-7722. At many "real world" field sites, the number of available monitoring wells is limited due to economic or geological reasons. Under such restricted conditions, it is difficult to perform a reliable field investigation and to quantify primary lines of evidence for natural attenuation (NA), like the documentation of a decrease of contaminant mass flux in flow direction. This study reports the results of a groundwater investigation at a former manufactured gas plant situated in a Quaternary river valley in southwest Germany. The location, infrastructure and aquifer setting are typical of many industrial sites in Germany. Due to difficult drilling conditions (coarse glaciofluvial gravel deposits and an anthropogenic fill above the aquifer), only 12 monitoring wells were available for the invest...

Quantifying groundwater discharge to a small perennial stream in southern Ontario, Canada Cey, E. E. Rudolph, D. L. Parkin, G. W. Aravena, R. JOURNAL OF HYDROLOGY -AMSTERDAM- 1998 VOL 210; ISSUE 1-4 , page(s) 21-37 ELSEVIER SCIENCE DIVISION 0022-1694. A study of the interaction between groundwater and surface water was undertaken within a small agricultural watershed in southern Ontario, Canada. Groundwater contributions to streamflow were measured along a section of stream during baseflow conditions and during rainfall events. Four techniques were used to estimate the contribution of groundwater to the stream along a 450m reach (three during baseflow and one during stormflow conditions). Under baseflow conditions, streamflow measurements using the velocity-area technique indicated that the net groundwater flux to the stream during the summer months was asymptotically equal to10mls^-^1m^-^1. Hydrometric measurements (i.e. hydraulic gradient and hydraulic conductivity) taken using mini-piezometers installed in the sediments beneath the s...

Quantifying long-term catchment changes of alluvial fan systems Mather, A. E. Harvey, A. M. Stokes, M. GEOLOGICAL SOCIETY OF AMERICA BULLETIN 2000 VOL 112; PART 12 , page(s) 1825-1833 GEOLOGICAL SOCIETY OF AMERICA 0016-7606.

Quantitative evaluation of forest floor evaporation and transpiration revealed by soil water content observation in humid temperate pine forests Shimada, J. Yonesaka, T. Qi You Zhou IAHS PUBLICATION Integrated Methods in Catchment Hydrology - Tracer, Remote Sensing and New Hydrometric Techniques 1999 ISSUE 258 , page(s) 29-36 IAHS PRESS - INTERN ASSOC HYDROLOGICAL SCIENC 0144-7815.

Radioactive and Stable Isotopes in Abiotic and Biotic Components of Antarctic Ecosystems Surrounding the Italian Base Triulzi, C. Nonnis Marzano, F. Casoli, A. Mori, A. Vaghi, M. INTERNATIONAL JOURNAL OF ENVIRONMENTAL ANALYTICAL CHEMISTRY 1995 VOL 61; NUMBER 3 , page(s) 225-230 GORDON & BREACH / HARWOOD ACADEMIC PUBLISHING 0306-7319. Results concerning the analysis of natural (K-40, Th-232, U-238) and anthropogenic (Sr-90, Cs- 137, Pu-238, Pu-239, 240) radioactivity determined in samples collected during the PNRA (National Program for Antarctic Research) 1990-91 and 1991-92 Scientific Expeditions, are presented. The data refer to samples of the terrestrial, lacustrine and marine ecosystems surrounding the Italian Base in the Terra Nova Bay (Ross Sea) territory with special emphasis on the Cs-137 biogeochemical behaviour. In particular, the role of the organic substance in the radionuclide transfer has been evaluated through statistical correlation analysis between the Cs-137 concentrations and organic matter, organic carbon and nitrogen contents determined in samples of marine and lacustrine sediments.

Radioactivity Levels in the Red Sea Coastal Environment of Sudan Adam Khatir Sam Ahamed, M. M. O. El Khangi, F. A. El Nigumi, Y. O. Holm, E. MARINE POLLUTION BULLETIN 1998 VOL 36; NUMBER 1 , page(s) 19-26 PERGAMON 0025-326X. Measurements of natural and fallout radionuclides in marine surface sediments, seagrass and algae collected from the Sudanese coastal waters of the Red Sea have been made using high resolution gamma-spectrometry, radiochemical separation and à-spectrometry. Activity levels of uranium isotopes, thorium isotopes, ^2^2^6Ra, ^2^1^0Po, ^4^0K and ^1^3^7Cs were determined in the samples. Comparison of the data on natural radionuclides from coastal marine sediments with those collected from 30 km offshore (Sanganeb atoll) reveals that both anthropogenic and terrestrial influx from the hinterland is negligible. However, values for ^2^2^6Ra and ^2^1^0Po are higher in the sediments of Port Sudan harbour relative to those from the adjacent fringing reefs. Uranium content is higher in shallow-water sed...

Radionuclide release rates from spent fuel for performance assessment modelling Curtis, D. NUCLEAR SCIENCE AND TECHNOLOGY 6th Meeting , page(s) 145-154 CEC; 1996 1018-5593 9282761606.

Radionuclide uptake by red deer (cervus elaphus) on mountain grazing McGee, E. J. Synnott, H. J. O'Keefe, C. Colgan, P. A. BRITISH VETERINARY JOURNAL 1995 VOL 151; NUMBER 6 , page(s) 671-682 BAILLIERE TINDALL 0007-1935.

Radionuclide uptake by some Herbaceous food crops Fasae, P. K. Ajayi, O. S. Ajayi, I. R. JURNAL FIZIK MALAYSIA 1997 VOL 18; NUMBER 1 , page(s) 25-30 MALAYSIAN INSTITUTE OF PHYSICS 0128-0333.

Radionuclides in the Lichen-Caribou-Human Food Chain Near Uranium Mining Operations in Northern Saskatchewan, Canada Thomas, P. A. Gates, T. E. ENVIRONMENTAL HEALTH PERSPECTIVES 1999 VOL 107; NUMBER 7 , page(s) 527-538 NAT INST OF ENVIRON HEALTH SCIENCES 0091-6765.

Radon and radon progeny outdoors in a valley of enhanced natural radioactivity Pressyanov, D. S. Guelev, M. G. Sharkov, B. G. ATMOSPHERIC ENVIRONMENT 1995 VOL 29; NUMBER 23 , page(s) 3433 PERGAMON PRESS INC 1352-2310. Results of a pilot study of ^2^2^2Rn and ^2^2^2Rn progeny outdoors and indoors in a valley of enhanced radioactivity, affected by uranium mining and milling have been summarized. Diurnal and spatial variations have been followed, and ^2^2^2Rn concentrations in soil-gas have been determined. High outdoor concentrations of radon progeny during nights and at early mornings have been observed under the conditions of high air stagnation. The indoor concentrations were greater than the outdoor ones, however in most of the studied houses, the contribution of outdoor radon to the total exposure was found to be dominating. The cumulative exposure (for over 90% of the inhabitants) due to outdoor radon was estimated to be about 0.9 WLM per annum. These results reveal that lung-cancer risk excess by a...

Radon exhalation from uranium mill tailings: experimental validation of a 1-D model Ferry, C. Richon, P. Beneito, A. Robe, M.-C. JOURNAL OF ENVIRONMENTAL RADIOACTIVITY Technologically enhanced natural radiation; Natural radioactivity, technological enhancement, detection and migration 2001 VOL 54; NO 1 , page(s) 99-108 Elsevier; 2001 0265-931X.

Radon-222, Radium-226, and Uranium in Georgia Piedmont Well Water Butler, A. Kahn, B. GEORGIA WATER RESOURCES CONFERENCE Georgia water resources conference 1995 , page(s) 401-404 Carl Vinson Institute of Government; 1995 0935835040.

Recent advances in understanding the interaction of groundwater and surface water Winter, T. C. REVIEWS OF GEOPHYSICS -RICHMOND VIRGINIA- THEN WASHINGTON- 21st General assembly 1995 VOL 33; NUMBER SUP//PT2 , page(s) 985-994 American Geophysical Union; 1995 8755-1209.

Reconciliation of Experimental and Modelling Concepts in a Natural Analogue of Radionuclide Migration Suksi, J. Rasilainen, K. MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS Scientific Basis for Nuclear Waste Management XX 1997 VOL 465 , page(s) 1169-1176 MATERIALS RESEARCH SOCIETY 0272-9172. One of the major problems in testing radionuclide transport models with a natural analogue is the potential discrepancy between experimental and modelling concepts. In the matrix diffusion studies at Palmottu the measured U-series concentration profiles and mathematical simulations showed disagreement, suggesting discrepancy in respective concepts of radionuclide attachment on the rock pores. Here, the discrepancy was approached by studying uranium fixation in more detail within the most loosely-bound fraction.

Regional groundwater discharge: phreatophyte mapping, groundwater modelling and impact analysis of land-use change Batelaan, O. De Smedt, F. Triest, L. JOURNAL OF HYDROLOGY -AMSTERDAM- 2003 VOL 275; NUMBER 1-2 , page(s) 86-108 Elsevier Science B.V., Amsterdam. 0022-1694. The relationship between groundwater recharge and discharge is one of the most important aspects in the protection of ecologically valuable areas. Knowledge of groundwater systems is therefore a pre-requisite for up-to-date integrated land and water management. A methodology is presented for assessing the relative importance of different recharge-discharge systems, with respect to ecological status or development, including mapping of regional groundwater systems, and recharge and discharge areas. This methodology is applied to a land-use planning project in the Grote-Nete basin, Belgium. Discharge regions are delineated on the basis of their spatial discharge contiguity, position in the landscape and alkalinity of the plants habitat. The simulated discharge areas are verified by field map...

Relationships Between Surface, Subsurface, and Groundwater Components in a Stream-Sandbar Interaction System Ahmed, A. M. M. M. Sumi, T. Tsujimoto, T. Ground water / surface water interactions , page(s) 359-364 American Water Resources Assn; 2002 1882132572.

REMM: The Riparian Ecosystem Management Model Lowrance, R. Altier, L. S. Williams, R. G. Inamdar, S. P. Sheridan, J. M. Bosch, D. D. Hubbard, R. K. Thomas, D. L. JOURNAL OF SOIL AND WATER CONSERVATION -USA- 2000 VOL 55; PART 1 , page(s) 27-34 SOIL CONSERVATION SOCIETY OF AMERICA 0022-4561.

Resolving Superimposed Ground-Water Contaminant Plumes Characterized by Chromium Nitrate, Uranium, and Technetium-99 Hall, S. H. GROUNDWATER MANAGEMENT Ground water geochemistry 1990 VOL 2 , page(s) 251-266 Water Well Journal Publishing Co; 1990 0267-1990.

Restoration and management of riparian ecosystems: a catchment perspective Wissmar, R. C. Beschta, R. L. FRESHWATER BIOLOGY Rivers in the landscape: riparian and groundwater ecology 1998 VOL 40; NUMBER 3 , page(s) 571-585 BLACKWELL SCIENTIFIC PUBLICATIONS 0046-5070.

Riparian Trees and Flow Paths between the Hyporheic Zone and Groundwater in the Oberer Seebach, Austria Wagner, F. H. Bretschko, G. INTERNATIONAL REVIEW OF HYDROBIOLOGY 2003 VOL 88; NUMB 2 , page(s) 129-138 WILEY - VCH 1434-2944.

Riparian Zone Attributes Affecting Nitrogen Removal in Shallow Groundwater Addy, K. Gold, A. J. Kellogg, D. Q. Rosenblatt, A. E. ANNUAL FORUM- GROUND WATER PROTECTION COUNCIL Ground Water Protection Council 1999 , page(s) 195-206 GWPC; 1999.

Riparian Zone Vegetation Effects on Nitrate Concentrations in Shallow Groundwater James, B. Bagley, B. Gallagher, P. CRC PUBLICATION New perspectives in the Chesapeake system: a research and management partnership 1991 NUMBER 137 , page(s) 605-612 Chesapeake Research Consortium; 1991.

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Risks from Radionuclide Migration to Groundwater in the Chernobyl 30-KM Zone Bugai, D. A. Waters, R. D. Dzhepo, S. P. Skal'skij, A. S. HEALTH PHYSICS 1996 VOL 71; NUMBER 1 , page(s) 9-18 WILLIAMS AND WILKINS 0017-9078. Remediation of contaminated groundwater in the Chernobyl 30-km evacuation zone is frequently identified as a priority by technical experts and Chernobyl site officials in Ukraine. In order to evaluate the health risk basis for this groundwater remediation, we have estimated both on-site and off-site health risks caused by radionuclide migration to the groundwater and compared these risks with those from exposure to radioactive contamination on the ground surface. A simple and conservative analytical model was developed to assess radionuclide transport to the groundwater from the soil surface contaminated by radioactive fallout. ^9^0Sr, the primary radioactive contaminant of concern for the groundwater-migration exposure pathway, was evaluated in the analysis. The estimated health risk to h... ©WILLIAMS AND WILKINS 1996 All rights reserved.

River/land ecotones: scales and patterns Bretschko, G. HYDROBIOLOGIA -THE HAGUE- 1995 VOL 303; NUMBER 1/3 , page(s) 83 KLUWER ACADEMICS 0018-8158. On a continental scale a river system itself is an ecotone, mediating between the terrestrial system and the sea. On the landscape scale, ecotones appear between terrestrial and river systems. At decreasing scales, the number and diversity of ecotones increases. Ecotone processes are discussed in relation to the entire 'river' ecosystem, on scales ranging from the activity range of fish fry up to that of adult fish. The introduction of patch theory into the River Continuum Concept (RCC) allows for the proper consideration of hydraulics and time. The relationships between stream order and patch distribution, patch size and lifetime and age diversity of patches are described. This 'combination model' is much better adjusted to the situations occurring in nature than the original, very abstra... ©KLUWER ACADEMICS 1995 All rights reserved.

Rock Matrix Diffusion as a Mechanism of Radionuclide Retardation: A Natural Analogue Study of El Berrocal Granite, Spain Heath, M. J. Montoto, M. Rodriguez Rey, A. De Argando¤a, V. G. R. RADIOCHIMICA ACTA 1992 VOL 58/59; NUMBER 2 , page(s) 379 R OLDENBOURG VERLAG GMBH 0033-8230.

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Seasonal biogeochemical patterns in surface water, subsurface hyporheic, and riparian ground water in a temperate stream ecosystem Hendricks, S. P. White, D. S. ARCHIV FUR HYDROBIOLOGIE 1995 VOL 134; NUMBER 4 , page(s) 459 SCHWEIZERBART'SCHE VERLAGSBUCHHANDLUNG 0003-9136.

Seasonal groundwater nitrate dynamics and nitrogen isotope discrimination in a riparian zone Dhondt, K. Boeckx, P. Van Cleemput, O. Hofman, G. De Troch, F. MEDEDELINGEN- FACULTEIT LANDBOUWKUNDIGE EN TOEGEPASTE BIOLOGISCHE WETENSCHAPPEN 2001 VOL 66; PART 4 , page(s) 157-160 Universiteit Gent; 1999 NONE-XXXX.

Seasonal groundwater nitrate dynamics in a riparian buffer zone Dhondt, K. Boeckx, P. Van Cleemput, O. Hofman, G. de Troch, F. AGRONOMIE -PARIS- Nitrogen 2002 VOL 22; NO 7-8 , page(s) 747-754 EDP; 2002 0249-5627.

SEDIMENT DEPOSITION RATES AND CARBON CONTENT IN THE SOILS OF AN AGRICULTURAL RIPARIAN ECOSYSTEM Ritchie, J. C. McCarty, G. W. PROCEEDINGS OF THE FEDERAL INTERAGENCY SEDIMENTATION CONFERENCE Federal inter-agency sedimentation conference 2001 7TH; VOL 2 , page(s) IX-41-IX-46 [Washington?]; The Subcommittee; [2001].

Seepage of Groundwater Nitrate from a Riparian Agroecosystem into the Wye River Estuary Staver, K. W. Brinsfield, R. B. ESTUARIES 1996 VOL 19; NUMBER 2//B , page(s) 359-370 ESTUARIES 0160-8347.

Selective extractions in uranium migration studies - findings from a natural analogue study at Palmottu, southern Finland Suksi, J. Ruskeeniemi, T. Saarinen, L. JOURNAL OF CONTAMINANT HYDROLOGY Migration 93 1996 VOL 21; NUMBER 1/4 , page(s) 47-58 0169-7722.

Selenium Remobilization Due to Destruction of Wetlands in Orange County, California Hibbs, B. Lee, M. Walker, J. Riparian ecology and management in multi-land use watersheds , page(s) 149-154 American Water Resources Association; 2000 1882132513.

Separating the natural and anthropogenic components of spring flood pH decline: A method for areas that are not chronically acidified (Paper 2000WR900030) Bishop, K. H. Laudon, H. Kohler, S. WATER RESOURCES RESEARCH 2000 VOL 36; PART 7 , page(s) 1873-1884 AGU AMERICAN GEOPHYSICAL UNION 0043-1397.

SHETRAN: Distributed River Basin Flow and Transport Modeling System Ewen, J. Parkin, G. O'Connell, P. E. JOURNAL OF HYDROLOGIC ENGINEERING 2000 VOL 5; PART 3 , page(s) 250-258 AMERICAN SOCIETY OF CIVIL ENGINEERS 1084-0699.

Simulation of Interaction Between Ground Water in an Alluvial Aquifer and Surface Water in a Large Braided River Leake, S. Lilly, M. R. Groundwater management , page(s) 325-330 New York, NY; American Society of Civil Engineers; 1995 0784401071.

Soil-to-plant transfer factors for natural radionuclides and stable elements in a Mediterranean area Vera Tome, F. Blanco Rodriguez, M. P. Lozano, J. C. JOURNAL OF ENVIRONMENTAL RADIOACTIVITY 2003 VOL 65; NUMBER 2 , page(s) 161-175 Elsevier Science B.V., Amsterdam. 0265-931X. The transfer factors (TF) for natural uranium isotopes (238U and 234U), thorium isotopes (232Th, 230Th and 228Th) , and 226Ra were obtained in plant samples (grass-pasture) growing in granitic and alluvial soils around a disused uranium mine located in the Extremadura region in the south-west of Spain. Affected and non-affected areas of the mine presented large differences in the activity concentrations of radionuclides of the uranium series. We also determined transfer factors for several stable elements (essential and non-essential). A set of statistical tests were applied to validate the data. The results showed that the transfer factors for both the natural radionuclides and the stable elements are independent of the two substrate types involved and also of the two areas considered in ...

Solid Radioactive Waste Disposal in England and Wales: The use and application of natural and anthropogenic analogue studies Duerden, S. L. Yearsley, R. A. Knight, J. L. Humphreys, P. Natural analogue working group meeting , page(s) 73-84 European Commission; 2002 9282843890

Solute channeling in unsaturated heterogeneous porous media Birkholzer, J. Tsang, C.-F. WATER RESOURCES RESEARCH 1997 VOL 33; NUMBER 10 , page(s) 2221-2238 AGU AMERICAN GEOPHYSICAL UNION 0043-1397. Numerical simulations have been performed to study flow and solute transport phenomena in strongly heterogeneous, variably saturated porous media. Different saturation scenarios were applied varying from fully saturated to highly unsaturated conditions, corresponding to different infiltration rates into the soil. It was found that the solute travels along preferred flow paths, which may be called channels. The degree of channeling, the location of channels, and the hydraulic properties along channels are a function of the mean saturation in the flow domain. Strong channeling effects were obtained in both fully saturated and in low-saturation cases. At intermediate saturation values, channeling effects are less significant, and the system exhibits a more homogeneous flow pattern. The disper...

Solute Provenance, Transport and Denudation in a High Arctic Glacierized Catchment Hodgkins, R. Tranter, M. Dowdeswell, J. A. HYDROLOGICAL PROCESSES 1997 VOL 11; NUMBER 14 , page(s) 1813-1832 JOHN WILEY & SONS LTD 0885-6087.

Solute Transport and Filtering Through a Riparian Forest Hubbard, R. K. Lowrance, R. R. TRANSACTIONS-AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS 1996 VOL 39; NUMBER 2 , page(s) 477-488 ASAE AMERICAN SOCIETY OF AGRICULTURAL 0001-2351. A two and a half year study was conducted to determine the fate of solutes applied to the landscape position just above the upper edge of a forested riparian zone. Nitrate (NO~3-N) and bromide (Br) sources were applied to an 18 x 18 m killed grass sod area at the rates of 188 and 336 kg ha^-^1 N and Br, respectively. Soil samples were collected four times during the study to determine vertical and lateral transport within the treatment area. Shallow groundwater wells were installed at transect positions 13 and 6 m upslope, and 2, 7, 12, 17, and 22 m downslope from the grass sod-riparian forest interface. There were two sets of wells at each transect position in the treatment area, and three sets of wells at each transect position in the forested riparian zone. The well depths for each set ...

Some principles behind the selection of crops to minimize radionuclide uptake from soil Smolders, E. Merckx, R. SCIENCE OF THE TOTAL ENVIRONMENT Relative Effectiveness of Agricultural Countermeasure Techniques-REACT 1993 VOL 137; NUMBER COM , page(s) 135 ELSEVIER SCIENCE DIVISION 0048-9697.

Sorption Kinetics of Uranium-238, Neptunium-237, Caesium-134, and Strontium-85 on a Glacial Deposit Moyes, L. N. Bunker, D. J. Smith, J. T. Livens, F. R. Hughes, C. R. Hilton, J. Braithwaite, A. Richardson, S. MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS Scientific Basis for Nuclear Waste Management XXI 1998 VOL 506 , page(s) 757-764 MATERIALS RESEARCH SOCIETY 0272-9172. Batch sorption experiments have been used to assess the

sorption behaviour of four radionuclides, important in the context of low-level waste disposal, on a glacial substrate. Data for sorption of ^2^3^8U, ^2^3^7Np, ^1^3^4Cs and ^8^5Sr are compared and agree well with independent studies. A series of well-established kinetic models have been used to describe the individual uptake mechanisms and rate parameters reported. Sorption occurs via both equilibrium and kinetically controlled pathways, with neptunium sorption being under kinetic control to the greatest extent.

Source processes of the thermal waters from the Phlegraean Fields (Naples, Italy) by means of the study of selected minor and trace elements distribution Valentino, G. M. Stanzione, D. CHEMICAL GEOLOGY 2003 VOL 194; NUMBER 4 , page(s) 245-274 Elsevier Science B.V., Amsterdam. 0009-2541. The geochemical characteristics of hydrothermal waters from the Phlegraean Fields (P.F.) (Naples, Italy) were analysed for minor and trace elements, selectively mobilised in hydrothermal systems such as B, F, Hg, As, Pb and Tl.The water samples, collected from a shallow aquifer likely to be fed by deeper fluids, showed various geochemical features, resulting from the mixing of three components: (1) surface waters of meteoric origin; (2) hot deep waters deriving from water-rock interaction and including deep waters of marine origin; (3) magmatic fluids rising from the local magma chamber, lying a few kilometres below the town of Pozzuoli.This setting, although very complex, provides a reliable means of studying the distribution of the investigated trace elements. In particular, within the P...

Spatial and Temporal Variation in Groundwater Nitrate Removal in a Riparian Forest Nelson, W. M. Gold, A. J. Groffman, P. M. JOURNAL OF ENVIRONMENTAL QUALITY 1995 VOL 24; NUMBER 4 , page(s) 691 AMERICAN SOCIETY OF AGRONOMY 0047-2425

Spatial and Temporal Variations in Nitrate Contamination of a Rural Aquifer, California Williams, A. E. Johnson, J. A. Lund, L. J. Kabala, Z. J. JOURNAL OF ENVIRONMENTAL QUALITY 1998 VOL 27; NUMBER 5 , page(s) 1147-1157 AMERICAN SOCIETY OF AGRONOMY 0047-2425. The quality of groundwater in the Sierra Pelona watershed, California is examined as an example of a small rural groundwater basin in a mountainous area of arid climate. Water quality in this region has been seriously impacted by nitrate (NO~3) contamination with 42% of wells sampled exceeding the EPA public drinking water maximum contaminant level (MCL) of 10 mg/L as NO~3-N at some point during 1992-1993. High NO~3-N concentrations reported from this region suggest degradation of water quality due to anthropogenic activity. Dissolved ion concentrations, particularly NO~3, chloride and calcium varied radically in 55% of well waters sampled prior to, following, and months after an unusually wet winter. Our extensive well sampling program, chemical results and delineation of spatial and temp...

Speciation of rare earth elements in natural terrestrial waters: assessing the role of dissolved organic matter from the modeling approach Tang, J. Johannesson, K. H. GEOCHIMICA ET COSMOCHIMICA ACTA 2003 VOL 67; NUMBER 13 , page(s) 2321-2339 Elsevier Science B.V., Amsterdam. 0016-7037. Humic Ion-Binding Model V, which focuses on metal complexation with humic and fulvic acids, was modified to assess the role of dissolved natural organic matter in the speciation of rare earth elements (REEs) in natural terrestrial waters. Intrinsic equilibrium constants for cation-proton exchange with humic substances (i.e., pKMHA for type A sites, consisting mainly of carboxylic acids), required by the model for each REE, were initially estimated using linear free-energy relationships between the first hydrolysis constants and stability constants for REE metal complexation with lactic and acetic acid. pKMHA values were further refined by comparison of calculated Model V "fits" to published data sets describing complexation of Eu, Tb, and Dy with humic substances. A subroutine that allows ...

Stable lead isotopes, contaminant metals and radionuclides in upper Hudson River sediment cores: implications for improved time stratigraphy and transport processes Chillrud, S. N. Hemming, S. Shuster, E. L. Simpson, H. J. Bopp, R. F. Ross, J. M. Pederson, D. C. Chaky, D. A. Tolley, L. R. Estabrooks, F. CHEMICAL GEOLOGY 2003 VOL 199; NUMBER 1-2 , page(s) 53-70 Elsevier Science B.V., Amsterdam. 0009-2541. Radionuclide, stable lead isotope and trace metal analyses on fine-grained sediment cores collected along a 24-mile reach of the upper Hudson River were used to establish temporal trends of contaminant loadings, to establish stable lead isotopes as an additional stratigraphic tool, and as tracers for resolving particle transport fluxes over periods of decades. Very large contaminant inputs of Cd, Sb, Pb and Cr were evident in the sediment record. One potential large source for these metals was from a pigment manufacturing facility in Glens Falls, NY. The total range in stable lead isotope ratios observed in well-dated cores from about 15 miles downstream of the potential metal inputs was large (e.g., maximum difference in 206Pb/207Pb is 10%) and characterized by four major shifts occurring...

Statistical and analytical study of the propagation of flood-induced groundwater rise in an alluvial aquifer Vekerdy, Z. Meijerink, A. M. J. JOURNAL OF HYDROLOGY -AMSTERDAM- 1998 VOL 205; ISSUE 1-2 , page(s) 112-125 ELSEVIER SCIENCE DIVISION 0022-1694. The propagation of stage rises of the river Danube in an adjoining alluvial aquifer (Kisalfold, NW Hungary) has been studied by preparing a map which shows the lag times corresponding to maximum correlation values between the hydrographs of groundwater observation wells and the river stages. As expected, the lag times for the unconfined aquifer generally exceed those for the semi-confined part. The complex pattern suggests that other rivers in the area also play a role and that transmissivities and resistances of a cover layer are not sufficiently well known, despite the presence of a relatively dense network of bore holes. A systematic increase of the lag times with the distance from the river was noted at two sections. Nine flood events have been selected to study how well observed head ...

Stream Channel Changes Associated with Mining and Grazing in the Great Basin Sidle, R. C. Sharma, A. JOURNAL OF ENVIRONMENTAL QUALITY 1996 VOL 25; NUMBER 5 , page(s) 1111-1121 AMERICAN SOCIETY OF AGRONOMY 0047-2425. Characteristics of channel morphology and streambed sediment were sampled at 5- and 10-m intervals, respectively, along a 6.4-km reach of Birch Creek in 1989 and 1992. In this case study we evaluate changes in

these channel features using kernel regression analysis. The watershed is located high in the Toiyabe Mountains of central Nevada and has experienced historical grazing and more recent (1986-1989) mining for gold. Exclusion of grazing in the incised lower 1 km of the channel since 1990 did not lead to substantial geomorphic recovery by 1992. The bankfull width did decrease a bit in the grazing exclosure, but baseflow width increased. In both years, bankfull width was about 4 m greater in the exclosure compared with the upstream reaches, reflecting the long-term grazing influences. Th...

Studying Nitrate-N Leaching with a Bromide Tracer in an Irrigated Silt Loam Soil Wright, J. L. Westermann, D. T. Lehrsch, G. A. PROCEEDINGS FROM THE USCID WATER MANAGEMENT CONFERENCE USCID water management conference; Best management practices for irrigated agriculture and the environment 1997 , page(s) 229-242 Denver, CO; The Committee; 1998 1887903046.

Studying Solute and Particulate Sediment Transfer in a Small Mediterranean Mountainous Catchment Subject to Land Abandonment Llorens, P. Queralt, I. Plana, F. Gallart, F. EARTH SURFACE PROCESSES AND LANDFORMS 1997 VOL 22; NUMBER 11 , page(s) 1027-1036 WILEY 0197-9337.

Surface Water/Groundwater Interaction Research in Natural Protected Areas as a Management Tool for Environmental Policies in Spain Coleto, C. Groundwater ecology; tool for management of water resources , page(s) 351-356 European Commission; 2001 9289416394.

Surface water-groundwater interactions in an alluvial plain: Chemical and isotopic systematics Negrel, P. Petelet-Giraud, E. Barbier, J. Gautier, E. JOURNAL OF HYDROLOGY -AMSTERDAM- 2003 VOL 277; NUMBER 3-4 , page(s) 248-267 Elsevier Science B.V., Amsterdam. 0022-1694. Our work on the Loire River forms part of a French National Research Program dedicated to wetlands and aims to better understand the global functioning of the system from the hydrological, geochemical, ecological and sociological aspects. The present study, using a coupled hydrological and geochemical (stable and Sr isotopes) approach, focuses on the `Soulangy' site with its secondary anastomosing channels just below the confluence of the Loire and Allier rivers, and also on the `Dorna``nt' site with two unconnected oxbow lakes 50 km upstream of the confluence. The stable isotopes of water (d18O, d2H) show that the alluvial (or riverbank) aquifer feeds the Loire River during the summer, but is not recharged by the river during flood periods in the winter; the alluvial groundwater thus has ...

Survey of arsenic and other heavy metals in food composites and drinking water and estimation of dietary intake by the villagers from an arsenic-affected area of West Bengal, India Roychowdhury, T. Tokunaga, H. Ando, M. SCIENCE OF THE TOTAL ENVIRONMENT 2003 VOL 308; NUMBER 1-3 , page(s) 15-35 Elsevier Science B.V., Amsterdam. 0048-9697. An investigation of arsenic, copper, nickel, manganese, zinc and selenium concentration in foodstuffs and drinking water, collected from 34 families and estimation of the average daily dietary intake were carried out in the arsenic-affected areas of the Jalangi and Domkal blocks, Murshidabad district, West Bengal where arsenic-contaminated groundwater (mean: 0.11 mg/l, n=34) is the main source for drinking. The shallow large diameter tubewells, installed for agricultural irrigation contain an appreciable amount of arsenic (mean: 0.094 mg/l, n=10). So some arsenic can be expected in the food chain and food cultivated in this area. Most of the individual food composites contain a considerable amount of arsenic. The mean arsenic levels in food categories are vegetables (20.9 and 21.2 mg/kg), ...

Swedish investigations on the Bagombe reactor zone, U-series desequilibrium and time-scale of radionuclide mobilization processes Bros, R. Andersson, P. Roos, P. Claesson, S. NUCLEAR SCIENCE AND TECHNOLOGY OKLO-Natural Analogue Phase II project: behaviour of nuclear reaction products in natural environment , page(s) 187-196 European Commission; 1998 928283610X.

Symposium on the Effects of Agriculture on the Riparian Ecosystem Willms, W. D. CANADIAN JOURNAL OF PLANT SCIENCE 1998 VOL 78; NUMBER 2 , page(s) 179-180 AGRICULTURAL INSTITUTE OF CANADA 0008-4220.

Testing geochemical models of radionuclide solubility and speciation in natural analogue studies Bruno, J. NUCLEAR SCIENCE AND TECHNOLOGY 6th Meeting , page(s) 185-192 CEC; 1996 1018-5593 9282761606.

The areas of high natural radioactivity and TENORM wastes Paschoa, A. S. Godoy, J. M. INTERNATIONAL CONGRESS SERIES -AMSTERDAM- EXCERPTA MEDICA THEN ELSEVIER SCIENCE- 2002 VOL 1225 , page(s) 3-8 Elsevier Science B.V., Amsterdam. 0531-5131. There are many areas of high natural radioactivity (HINAR) throughout the world. To mention a few, the monazite-bearing sands in the Kerala coast in India and in the coastal regions of the states Espirito Santo and Rio de Janeiro in Brazil; the mineralized volcanic intrusives in the Brazilian states of Minas Gerais and Goias; the hot springs in Ramsar, Iran; the primitive, granitic, schistous and sandstone areas of France; and selected areas in Zaire. Some HINAR areas are such that there are sources of economically feasible ores geologically associated with naturally occurring radioactive materials (NORM). In Brazil, the main technologically enhanced naturally occurring radioactive materials (TENORM) waste-producing ores are the rare earth-rich monazite sands; phosphate rocks; and gold, le...

The boundaries of river systems: the metazoan perspective Ward, J. V. Bretschko, G. Brunke, M. Danielopol, D. Gibert, J. Gonser, T. Hildrew, A. G. FRESHWATER BIOLOGY Rivers in the landscape: riparian and groundwater ecology 1998 VOL 40; NUMBER 3 , page(s) 531-570 BLACKWELL SCIENTIFIC PUBLICATIONS 0046-5070.

The distribution and history of nuclear weapons related contamination in sediments from the Ob River, Siberia as determined by isotopic ratios of plutonium and neptunium Kenna, T. C. Sayles, F. L. JOURNAL OF ENVIRONMENTAL RADIOACTIVITY 2002 VOL 60; NUMBER 1-2 , page(s) 105-137 0265-931X.

The Earth's Climate in the Next Hundred Thousand years (100 kyr) Berger, A. Loutre, M. F. Crucifix, M. SURVEYS IN GEOPHYSICS 2003 VOL 24; NUMBER 2 , page(s) 117-138 Kluwer Academic Publishers 0169-3298. One of the most striking features of the Quaternary paleoclimate records remains the so-called 100-kyr cycle which is undoubtedly linked to the future of our climate. Such a 100-kyr cycle is indeed characterised by long glacial periods followed by a short-interglacial (10-15 kyr long). As we are now in an interglacial, the Holocene, the previous one (the Eemian, which corresponds quite well to Marine Isotope Stage 5e, peaking at 125 kyr before present, BP) was assumed to be a good analogue for our present-day climate. In addition, as the Holocene is 10 kyr long, paleoclimatologists were naturally inclined to predict that we are quite close to the next ice age. Simulations using the 2-D climate model of Louvain-la-Neuve show, however, that the current interglacial will most proba...

The geochemical environment of nuclear fuel waste disposal Gascoyne, M. CANADIAN JOURNAL OF MICROBIOLOGY 1996 VOL 42; NUMBER 4 , page(s) 401-409 NATIONAL RESEARCH COUNCIL CANADA 0008-4166. The concept for disposal of Canada's nuclear fuel waste in a geologic environment on the Canadian Shield has recently been presented by Atomic Energy of Canada Limited (AECL) to governments, scientists, and the public, for review. An important part of this concept concerns the geochemical environment of a disposal vault and includes consideration of rock and groundwater compositions, geochemical interactions between rocks, groundwaters, and emplaced vault materials, and the influences and significance of anthropogenic and microbiological effects following closure of the vault. This paper summarizes the disposal concept and examines aspects of the geochemical environment. The presence of saline groundwaters and reducing conditions at proposed vault depths (500-1000 m) in the Canadian Shield...

The hydrogeomorphic approach to functional assessment of riparian wetlands: evaluating impacts and mitigation on river floodplains in the U.S.A. Richard Hauer, F. Daniel Smith, R. FRESHWATER BIOLOGY Rivers in the landscape: riparian and groundwater ecology 1998 VOL 40; NUMBER 3 , page(s) 517-530 BLACKWELL SCIENTIFIC PUBLICATIONS 0046-5070.

The impact of contamination from a municipal solid waste landfill (Zagreb, Croatia) on underlying soil Ahel, M. Mikac, N. Cosovic, B. Prohic, E. Soukup, V. WATER SCIENCE AND TECHNOLOGY 1998 VOL 37; NUMBER 8 , page(s) 203-210 PERGAMON PRESS 0273-1223. The present study was conducted on the main landfill of the city of Zagreb which contains about 5 million tons of waste disposed of directly onto highly permeable alluvial sediments. The investigations were aimed at assessing the impact of contamination from the landfill on underlying soil and comprised the determination of a broad spectrum of inorganic and organic constituents in the samples (size fractions <2 mm) of solid waste, soil and aquifer sediments. Both the total content of various contaminants as well as their part which is readily leachable with water were determined in the examined samples. Compound classes identified in the landfill can be classified into the two main categories: (1) markers of biological waste and of its microbial transformation (ammonia, dissolved organic c...

The impact of tailings dam spills and clean-up operations on sediment and water quality in river systems: the Rollar, Spain Hudson-Edwards, K. A. Macklin, M. G. Jamieson, H. E. Brewer, P. A.; Coulthard, T. J. Howard, A. J. Turner, J. N. APPLIED GEOCHEMISTRY 2003 VOL 18; NUMBER 2 , page(s) 221-239 Elsevier Science B.V., Amsterdam. 0883-2927. The Aznalcollar tailings dam at Boliden Apirsa's Aznalcollar/Los Frailes Ag-Cu-Pb-Zn mine 45 km west of Seville, Spain, was breached on 25 April 1998, flooding approximately 4600 hectares of land along the Rollar open pit during clean-up work undertaken immediately after the spill until January 1999. Detailed geomorphological and geochemical surveys of the post-clean-up channel, floodplain and valley floor, and sediment and water sampling, were carried out in January and May 1999 at 6 reaches representative of the types of river channel and floodplain environments in the Rio Guadiamar catchment affected by the spill. The collected data show that the clean-up operations removed enough spill-deposited sediment to achieve pre-spill metal (Ag, As, Cd, Cu, Pb, Sb, Tl, Zn) concentrations in surf...

The Impact of the October-November 2000 Floods on Contaminant Metal Dispersal in the River Swale Catchment, North Yorkshire, UK Dennis, I. A. Macklin, M. G. Coulthard, T. J. Brewer, P. A. HYDROLOGICAL PROCESSES 2003 VOL 17; PART 8 , page(s) 1641-1658 JOHN WILEY & SONS LTD 0885-6087.

The Importance of Surface Water/Groundwater Interaction in Contaminant Plume Assessment Close, E. R. Interdisciplinary approaches in hydrology and hydrogeology , page(s) 209-221 The Institute; 1993.

The influence of a coal-fired power plant operation on radionuclide concentrations in soil Flues, M. Moraes, V. Mazzilli, B. P. JOURNAL OF ENVIRONMENTAL RADIOACTIVITY 2002 VOL 63; NUMBER 3 , page(s) 285-294 Elsevier Science B.V., Amsterdam. 0265-931X. Fifty-two soil samples in the vicinity of a coal-fired power plant (CFPP) in Figueira (Brazil) were analyzed. The radionuclide concentration for the uranium and thorium series in soils ranged from -1. The range of 40K concentration in soils varied from -1. The CFPP (10 MWe) has been operating for 35 years and caused a small increment in natural radionuclide concentration in the surroundings. This technologically enhanced natural radioactivity (TENR) was mainly due to the uranium series (234Th, 226Ra and 210Pb) and was observable within the first kilometer from the power plant. The CFPP influence was only observed in the 0-25 cm soil horizon. The soil properties prevent the radionuclides of the 238U-series from reaching deeper soil profiles. The same behavior was observed for 40K as well. N...

The influence of artificial macropores on water and solute transport in laboratory soil columns Buttle, J. M. Leigh, D. G. JOURNAL OF HYDROLOGY -AMSTERDAM- 1997 VOL 191; NUMBER 1/4 , page(s) 290-314 ELSEVIER SCIENCE DIVISION 0022-1694. The role of macropores in infiltration through a sandy loam was studied using laboratory columns

pretreated with water possessing a ^1^8 O signature of-8.7%o and 15 mg l^-^1 Cl-. A simulated snow-melt pulse of ë^1^8O-depleted water containing 1100 mg l^-^1 Cl- was added to a control column and two columns containing a single vertical macropore, one continuous and the other discontinuous. Macropores were formed in situ by disintegration of a biodegradable foam thread inserted during column packing. Macropores were 2 mm in:diameter, which has been suggested to be the threshold for significant macropore flow given the soil's mean textural pore diameter of 0.41 mm. Meltwater was flushed from the columns by adding two pore volumes of isotopically enriched water containing 15 mg 1^-^1 CI- at a r...

The influence of parent material on small-scale spatial changes in streamwater chemistry in Scottish upland catchments Billett, M. F. Lowe, J. A. H. Black, K. E. Cresser, M. S. JOURNAL OF HYDROLOGY -AMSTERDAM- 1997 VOL 187; NUMBER 3/4 , page(s) 311-331 ELSEVIER SCIENCE DIVISION 0022-1694. Spatial changes in streamwater chemistry in seven upland catchments in NE Scotland have been studied using samples collected at 250 m intervals from the stream source to the catchment outlet. The catchments contain a number of different parent materials including granites and diorite from the Lochnagar Complex, and metasediments and metabasites from the Argyll and Appin Groups of the Dalradian Supergroup. Samples were collected under low flow conditions between June 1989 and January 1990 and ten component ions were determined; this paper concentrates on pH, Ca, Mg, Na and K. All seven catchments show major changes in stream solute concentrations along their length. Samples collected immediately downstream of the source typically show a rapid increase in pH with distance, reflecting degassi...

The influence of vegetation and organic debris on flood-plain sediment dynamics: case study of a low-order stream in the New Forest, England Jeffries, R. Darby, S. E. Sear, D. A. GEOMORPHOLOGY -AMSTERDAM- 2003 VOL 51; NUMBER 1-3 , page(s) 61-80 Elsevier Science B.V., Amsterdam. 0169-555X. The presence of large woody debris (LWD) has important implications for the physical and ecological behaviour of rivers, and these aspects have been researched extensively in recent years. However, this research has so far focused primarily on interactions between LWD and in-channel processes, and the role of LWD in flood-plain genesis is still poorly understood. Established conceptual models of flood-plain evolution are, therefore, lacking because they neglect the complex interaction between water, sediment, and vegetation in systems with accumulations of LWD. This study examines the effect of LWD on patterns of sediment deposition within a small area of forest flood plain along the Highland Water, S. England. In-channel debris dams locally increase the frequency and extent of overbank fl...

THE INTERRELATION BETWEEN GROUNDWATER AND STREAMFLOW-QUANTITATIVE AND QUALITATIVE PROBLEMS AND ANTHROPOGENIC INFLUENCES, EASTERN SLOVAKIA Fendekova, M. Nemethy, P. Zenisova, Z. Krcmar, D. Flakova, R. Gambling with groundwater: physical, chemical, and biological aspects of aquifer-stream relations , page(s) 689-696 American Institute of Hydrology; 1998.

The long-term control of vegetation and woody debris on channel and flood-plain evolution: insights from a paired catchment study in southeastern Australia Brooks, A. P. Brierley, G. J. Millar, R. G. GEOMORPHOLOGY -AMSTERDAM- 2003 VOL 51; NUMBER 1-3 , page(s) 7-29 Elsevier Science B.V., Amsterdam. 0169-555X. Numerous case studies have demonstrated that alluvial and semi-alluvial rivers in SE Australia have undergone dramatic metamorphosis in historical times. However, very few studies place these changes within a long-term evolutionary context. As a consequence, the magnitude of, and ultimate controls on, the changes to river form and processes are not fully appreciated. In this study, a paired catchment analysis is undertaken between two moderate-sized sand-bed rivers in East Gippsland, Australia. From the Thurra River, direct insight is gained into the predisturbance control exerted by riparian vegetation and wood in a lowland alluvial river. This river is effectively in the same condition today as it was at the time of the arrival of Europeans in Australia. In contrast, the adjacent Cann Ri...

The role of the European Commission in the support of Natural Analogue Studies von Maravic, H. Natural analogue working group meeting , page(s) 15-16 European Commission; 2002 9282843890

The quest for more powerful validation of conceptual catchment models Mroczkowski, M. Raper, G. P. Kuczera, G. WATER RESOURCES RESEARCH 1997 VOL 33; NUMBER 10 , page(s) 2325-2335 AGU AMERICAN GEOPHYSICAL UNION 0043-1397. The power of a validation strategy (that is, its ability to discriminate between good and bad model hypotheses) depends on what kind of data are available and how the data are used to challenge the hypothesis. Several validation strategies are examined from the perspective of power and practical applicability. It is argued that validation using multiresponse data in a catchment experiencing a shift in hydrologic regime due to disturbance or extreme climatic inputs is a considerably more powerful strategy than traditional split-sample testing using streamflow data alone in undisturbed catchments. A case study testing two model hypotheses is presented using paired catchments for which multiple-response data in the form of streamflow, stream chloride, and groundwater levels were available. Th...

The Relationship Between Stream Chemistry and Watershed Land Cover Data in the Mid-Atlantic Region, U.S. Herlihy, A. T. Stoddard, J. L. Johnson, C. B. WATER AIR AND SOIL POLLUTION Ecosystem behavior: Biogeochemical investigations at watershed, landscape, and regional scales 1998 VOL 105; NUMBER 1/2 , page(s) 377-386 Kluwer; 1998 0049-6979.

The Riparian Ecosystem Management Model (REMM): Evaluation of the Hydrology Component Inamdar, S. Sheridan, J. Williams, R. Bosch, D. Lowrance, R. Altier, L. S. Thomas, D. PROCEEDINGS OF THE FEDERAL INTERAGENCY HYDROLOGIC MODELING CONFERENCE Federal interagency hydrologic modeling conference 1ST; VOL 2 , page(s) 7-17-24 [Reston, Va.]; The Subcommittee; 1998.

The role of flood plain sedimentation in catchment sediment and contaminant budgets Walling, D. E. Owens, P. N. IAHS PUBLICATION International Symposium on the Structure, Function and Management Implications of Fluvial Sedimentary Systems 2002 NO 276 , page(s) 407-416 Wallingford; IAHS; 2002 0144-7815 1901502961.

The Role of Landscape Setting in Riparian Groundwater Nitrate Removal Gold, A. J. Groffman, P. M. Addy, K. Kellogg, D. Q. Rosenblatt, A. E. Riparian ecology and management in multi-land use watersheds , page(s) 113-118 American Water Resources Association; 2000 1882132513.

The role of micro-organisms in the ecological connectivity of running waters Pusch, M. Fiebig, D. Brettar, I. Eisenmann, H. Ellis, B. K. Kaplan, L. A. Lock, M. A. Naegeli, M. W. Traunspurger, W. FRESHWATER BIOLOGY Rivers in the landscape: riparian and groundwater ecology 1998 VOL 40; NUMBER 3 , page(s) 453-496 BLACKWELL SCIENTIFIC PUBLICATIONS 0046-5070.

The sensitivity of Scottish rivers and upland valley floors to recent environmental change Werritty, A. Leys, K. F. CATENA -GIESSEN THEN AMSTERDAM- Landscape sensitivity; Landscape sensitivity 2001 VOL 42; NO 2-4 , page(s) 251-274 Elsevier; 2001 0341-8162.

THE SIGNIFICANCE OF PROTECTING ALLUVIAL AQUIFERS AS NEW POTENTIAL WATER-SUPPLY ZONES ALONG THE SAVA IN AN AGRICULTURAL REGION, YUGOSLAVIA Rasula, G. Gambling with groundwater: physical, chemical, and biological aspects of aquifer-stream relations , page(s) 661-666 American Institute of Hydrology; 1998

The transport of U- and Th-series nuclides in sandy confined aquifers Reynolds, B. C. Wasserburg, G. J. Baskaran, M. GEOCHIMICA ET COSMOCHIMICA ACTA 2003 VOL 67; NUMBER 11 , page(s) 1955-1972 Elsevier Science B.V., Amsterdam. 0016-7037. Abundances of 238U, 234U, 232Th, 226Ra, 228Ra, 224Ra, and 222Rn were measured in groundwaters of the Ojo Alamo aquifer in northwest New Mexico. This is an arid area with annual precipitation of 22 cm. The purpose was to investigate the transport of U-Th series nuclides and their daughter products in an old, slow-moving groundwater mass as a means of understanding water-rock interactions and to compare the results with a temperate zone aquifer. It was found that 232Th is approximately at saturation and supports the view of that Th is precipitated irreversibly upon weathering, leaving surface coatings of 232Th and 230Th on aquifer grains. Uranium in the aquifer waters has very high [234U/238U] 9 and low 238U concentrations. These levels can be explained by low weathering rates in the aquif...

The water use of two dominant vegetation communities in a semiarid riparian ecosystem Scott, R. L. James Shuttleworth, W. Goodrich, D. C. Maddock III, T. AGRICULTURAL AND FOREST METEOROLOGY -AMSTERDAM- ELSEVIER- 2000 VOL 105; NUMBER 1-3 , page(s) 241-256 ELSEVIER 0168-1923.

Theoretical basis of estimation of different factors influence on radionuclide uptake by plants and prediction of their accumulation in yield Bondar, P. F. RADIATSIONNAIA BIOLOGIIA RADIOEKOLOGIIA 1998 VOL 38; NUMBER 2 , page(s) 274-282 NAUKA MOSCOW 0869-8031.

Three-dimensional mapping of geomorphic controls on flood-plain hydrology and connectivity from aerial photos Poole, G. C. Stanford, J. A. Frissell, C. A. Running, S. W. GEOMORPHOLOGY -AMSTERDAM- 2002 VOL 48; NUMBER 4 , page(s) 329-347 Elsevier Science B.V., Amsterdam. 0169-555X. The Nyack flood plain of the Middle Fork Flathead River, MT, USA is a 9-km anastomosed alluvial montane flood plain. Upstream from the flood plain, the river is unregulated and the catchment virtually pristine. A patchy mosaic of vegetation and channels exists on the flood-plain surface. The surface and subsurface geomorphic structures of the flood plain facilitate high hydrologic connectivity (water flux between the channel and flood plain) marked by complex seasonal patterns of flood-plain inundation, extensive penetration of channel water laterally into the alluvial aquifer, and springbrooks formed by ground water erupting onto the flood-plain surface. After delineating and classifying flood-plain "elements" (vegetation patches and channel reaches) on the flood plain, we analyzed field-...

Tillage Effects on Surface and Groundwater Quality in Loessial Upland Soybean Watersheds Schreiber, J. D. Cullum, R. F. TRANSACTIONS- AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS 1998 VOL 41; NUMBER 3 , page(s) 607-614 ASAE AMERICAN SOCIETY OF AGRICULTURAL 0001-2351. Evaluation of tillage practices on surface and subsurface water quality is essential for conserving and protecting the nation's soil and water resources. The objective of this research was to evaluate the water quality of perched groundwater (0.15 to 3.04 m) and surface runoff from a 2.13 ha no-till and a 2.10 ha conventional-till soybean watershed for plant nutrients during the 1990-1993 water years. Mean nitrate-N concentrations for all groundwater depths and sites of the no-till and conventional-till watersheds were 4.81 and 5.98 mgùL^-^1, respectively. Shallow groundwater NO~3-N concentrations for some storms exceeded U.S. Drinking Water Standards. However, in a forested riparian zone, only 61 m down slope from the conventional-till watershed, the mean NO~3-N concentration in groundwat...

Total Content of Arsenic, Antimony and Selenium in Groundwater Samples from Western Poland Niedzielski, P. Siepak, J. Siepak, M. POLISH JOURNAL OF ENVIRONMENTAL STUDIES 2001 VOL 10; PART 5 , page(s) 347-350 HARD Publishing; 1999 1230-1485.

Total mercury concentrations in an industrialized catchment, the Thur River basin (north-eastern France): geochemical background level and contamination factors Remy, S. Prudent, P. Hissler, C. Probst, J. L. Krempp, G. CHEMOSPHERE - OXFORD- 2003 VOL 52; NUMBER 3 , page(s) 635-644 Elsevier Science B.V., Amsterdam. 0045-6535. River bottom sediments and soils were collected from the industrialized Thur River basin (north-eastern France) to assess mercury contamination. The regional geochemical background level of total mercury was evaluated to calculate mercury contamination factors (Fc) in soils and river bottom sediments. Our estimate of the mean background mercury levels in river

sediments and soils, not affected by human activities, was 232 ngg-1 (range: 27-406 ngg-1). Sediments contaminated by the effluent from a chlor-alkali plant yielded the highest contamination factors (Fc=1784). Contamination factors of surficial soils within 1 km of the industrial site range from 6.3 to 43.6. This contamination is attributed to diffuse atmospheric deposition from this local plant. However, even upstream from this indu...

Transfer of lead, cadmium and mercury in the system soil - plant - animal Kralovec, J. Slavik, L. ROSTLINNA VYROBA 1997 VOL 43; NUMBER 6 , page(s) 257-262 CESKOSLOVENSHA AKADEMIE ZEMEDELSKA 0370-663X.

Transport modelling in the natural analogue study of the Cigar Lake uranium deposit (Saskatchewan, Canada) Liu, J. Yu, J.-W. Neretnieks, I. JOURNAL OF CONTAMINANT HYDROLOGY Migration 93 1996 VOL 21; NUMBER 1/4 , page(s) 19-34 0169-7722.

Transport of in Situ Mobilized Colloidal Particles in Packed Soil Columns Grolimund, D. Elimelech, M. Borkovec, M. Barmettler, K. Kretzschmar, R. Sticher, H. ENVIRONMENTAL SCIENCE AND TECHNOLOGY -WASHINGTON DC- 1998 VOL 32; NUMBER 22 , page(s) 3562-3569 ACS AMERICAN CHEMICAL SOCIETY 0013-936X. A systematic investigation of the transport behavior of in situ mobilized soil colloidal particles in their parent soil matrix medium is presented. Particle advection, dispersion, and deposition kinetics were studied by analysis of particle breakthrough curves as a response to short-pulse particle injections to the inlet of packed soil columns. The transport of the heterogeneous soil particles was compared to the transport of monodisperse carboxyl latex particles to further understand the various particle transport mechanisms. Results show that colloidal particles travel much faster than a conservative tracer (nitrate) due to size exclusion effects, whereby mobile colloidal particles are excluded from small pores within the soil medium. Dispersivity of the natural and latex particles was c...

Transport of multiple tracers in variably saturated humid region structured soils and semi-arid region laminated sediments Mayes, M. A. Jardine, P. M. Mehlhorn, T. L. Bjornstad, B. N. Ladd, J. L. Zachara, J. M. JOURNAL OF HYDROLOGY - AMSTERDAM- 2003 VOL 275; NUMBER 3-4 , page(s) 141-161 Elsevier Science B.V., Amsterdam. 0022-1694. The processes governing physical nonequilibrium (PNE)-coupled preferential flow and matrix diffusion-are diverse between humid and semi-arid regions, and are directly related to climate and rock/sediment type, and indirectly related to subsequent soil profile development. The fate and transport of contaminants in these variably saturated undisturbed media is largely a function of the influence of PNE processes. Large cores of laminated silts and sands were collected from the US Department of Energy Pacific Northwest National Laboratory (PNNL) in semi-arid south central Washington. Additional cores of weathered, fractured interbedded limestone and shale saprolite were collected from the Oak Ridge National Laboratory (ORNL) in humid eastern Tennessee. PNNL cores were collected parallel (FBP)...

TRANSPORT OF PARTICULATE MATTER IN GROUNDWATER DEPENDING ON NATURAL AND ANTHROPOGENIC HYDRAULIC VARIATIONS Schafer, T. Knoke, H. Schenk, D. Gambling with groundwater: physical, chemical, and biological aspects of aquifer-stream relations , page(s) 541-548 American Institute of Hydrology; 1998.

Uncertainties in the definition of critical groups to chronic exposure scenarios Rochedo, E. R. Amaral, E. C. Hacon, S. S. INTERNATIONAL CONGRESS SERIES -AMSTERDAM- EXCERPTA MEDICA THEN ELSEVIER SCIENCE- 2002 VOL 1225 , page(s) 25-31 Elsevier Science B.V., Amsterdam. 0531-5131. At the moment of the licensing of the uranium mining and milling installation at Pocos de Caldas, MG, critical groups have been defined according to the local land and water uses by the surrounding population. It was verified that all critical groups are now, about 12 years later, different from those previously defined, mainly because of a change in the occupation pattern of a previous remote area, as infrastructure such as roads and energy became available. The same situation can be foreseen for a new uranium mining, in an area that can be presently considered as being remote, as infrastructure provided by the installation will create new opportunities in the region. There already exist in Brazil several examples related to remote degraded areas that were abandoned, containing toxic or r...

Unforced Oscillations in a Freeboard and Basin Model: Analogue to Glacial/Climate Oscillators? Gaffin, S. R. JOURNAL OF GEOLOGY -CHICAGO- 1992 VOL 100; NUMBER 6 , page(s) 717 UNIVERSITY OF CHICAGO PRESS 0022-1376.

Uranium and other natural radionuclides in drinking water and risk of leukemia a case-cohort study in Finland Auvinen, A. Kurttio, P. Pekkanen, J. Pukkala, E. Ilus, T. Salonen, L. CANCER CAUSES AND CONTROL 2002 VOL 13; NUMBER 9 , page(s) 825-829 Kluwer Academic Publishers 0957-5243. Objective We assessed the effect of natural uranium and other radionuclides in drinking water on risk of leukemia. Methods The subjects (n = 144,627) in the base cohort had lived outside the municipal tapwater system during 1967-1980. A subcohort was formed as a stratified random sample of the base cohort and subjects using drinking water from drilled wells prior to 1981 were identified. A case-cohort design was used comparing exposure among cases with leukemia (n = 35) with a stratified random sample (n = 274) from the subcohort. Activity concentrations of uranium, radium-226, and radon in the drinking water were analyzed using radiochemical and alpha-spectrometric methods. Results The median activity concentration of uranium in well water was 0.08 Bq/L for the leukemia cases and 0.06 Bq/...

Uranium and Thorium Series Radionuclides in Drinking Water from Drilled Bedrock Wells: Correlation to Geology and Bedrock Radioactivity and Dose Estimation Salih, M. M. I. Pettersson, B. L. Lund, E. RADIATION PROTECTION DOSIMETRY 2003 VOL 102; PART 3 , page(s) 249-258 NUCLEAR TECHNOLOGY PUBLISHING 0144-8420.

Uranium in the food chain of animal and man in Germany Anke, M. Seeber, O. Leiterer, M. PROCEEDINGS - SOCIETY OF NUTRITION PHYSIOLOGY Society of Nutrition Physiology; Berichte der Gesellschaft fur Ernahrungsphysiologie 2002 BD. 11 , page(s) 71 DLG; 2002 3769040953.

Uranium transport around the reactor zone at Bangombe and Okelobondo (Oklo): examples of hydrogeological and geochemical model integration and data evaluation Gurban, I. Laaksoharju, M. Made, B. Ledoux, E. JOURNAL OF CONTAMINANT HYDROLOGY 2003 VOL 61; NUMBER 1/4 , page(s) 247-264 Elsevier Science B.V., Amsterdam. 0169-7722. The sites at Bangombe and Okelobondo (Oklo) in Gabon provide a unique opportunity to study the behaviour of products from natural nuclear reactions in the vicinity of reactor zones which were active around two billion years ago. The Commission of the European Communities initiated the Oklo Natural Analogue Programme. One of the principal aims was to study indications of present time migration of elements from the reactor zones under ambient conditions. The hydrogeological and hydrochemical data from the Oklo sites were modelled in order to better understand the geochemical behaviour of radionuclides in the natural system, by using independent models and by comparing the modelling outcome. Two modelling approaches were used: M3 code (hydrochemical mixing and mass balance model), developed b...

Uranium-series radionuclide and element migration around the Sanerliu granite-hosted uranium deposit in southern China as a natural analogue for high-level radwaste repositories Min, M. Z. Zhai, J. P. Fang, C. Q. CHEMICAL GEOLOGY 1998 VOL 144; ISSUE 3-4 , page(s) 313-328 ELSEVIER 0009-2541. The Sanerliu uranium deposit located in Hunan Province, South China, has a number of features analogous to aspects considered in the performance assessment of concepts for the disposal of high-level radwaste deep in granite. The deposit is hosted by medium- to coarse-grained porphyritic granite with a Rb-Sr isochron age of 215.2ñ6.3 Ma. The orebodies have a burial depth of more than 160-400 m under the surface of the ground. The major uranium mineralizations have U-Pb ages (pitchblende) of 103.2ñ0.6, 88.3ñ0.5 and 51.2ñ0.4 Ma and a hydrothermal origin. The isotopic data show that the Rb-Sr systems in the whole-rock samples of less- and un-fractured host granite around the orebodies have been little disturbed since the altered granite formed (132 Ma ago). Such samples have close to secular e...

Use of natural and anthropogenic tracers to identify sources of groundwater recharge in urban areas in Barcelona Vazquez-Sune, E. Castillo, O. Sanchez-Vila, X. Alberich, C. Carrera, J. IAHS PUBLICATION Tracers and modelling in hydrogeology 2000 NO 262 , page(s) 363-370 Wallingford; IAHS; 2000 0144-7815 190150221X.

Using a paired-catchment manipulation experiment to evaluate a catchment-scale biogeochemical model Cosby, B. J. Norton, S. A. Kahl, J. S. SCIENCE OF THE TOTAL ENVIRONMENT Modelling in Environmental Studies 1996 VOL 183; NUMBER 1/2 , page(s) 49-66 ELSEVIER SCIENCE DIVISION 0048-9697. Data from a paired-catchment manipulation experiment are used to evaluate a model of the biogeochemical responses of catchments to acidic deposition. The data are from the Watershed Manipulation Project at Bear Brook, Maine, USA. The model is MAGIC, (Model of Acidification of Groundwater In Catchments) which has been widely used in assessments of acidification effects. The catchment manipulation consisted of 3 years of application of dry ammonium sulfate to the catchment on a bimonthly schedule. The principal stream responses to treatment included increased concentrations of SO~4, NO~3, Ca, Mg, Na, K, Al and H, decreased alkalinity and dissolved organic carbon and essentially no change in the concentrations of Cl and Si. The model was calibrated to pre-treatment data on the manipulated cat...

Using unsupported lead-210 measurements to investigate soil erosion and sediment delivery in a small Zambian catchment Walling, D. E. Collins, A. L. Sichingabula, H. M. GEOMORPHOLOGY -AMSTERDAM- 2003 VOL 52; NUMBER 3-4 , page(s) 193-213 Elsevier Science B.V., Amsterdam. 0169-555X. Traditional techniques used to assemble information on rates of erosion and soil redistribution possess many important limitations. As a result, the use of environmental radionuclides, and more particularly 137Cs measurements, has attracted increasing attention in recent years as a means of obtaining spatially distributed information on rates of erosion and deposition. The application of the 137Cs approach is, however, hampered in some areas of the world where 137Cs inventories are low and the low concentrations of 137Cs found in soils and sediments cause problems for laboratory analysis. These problems will increase as time progresses due to the radioactive decay of the existing inventory, most of which was deposited as fallout ca. 40 years ago. This contribution explores the potential fo...

USING VIBRACORING AND MULTILEVEL WELLS TO EXAMINE THE HYPORHEIC ZONE WITHIN A RIPARIAN WETLAND Dunn, D. L. Dixon, K. L. Nichols, R. L. Gambling with groundwater: physical, chemical, and biological aspects of aquifer-stream relations , page(s) 155-160 American Institute of Hydrology; 1998.

Validation of catchment models for predicting land-use and climate change impacts. 2. Case study for a Mediterranean catchment Parkin, G. O'Donnell, G. Ewen, J. Bathurst, J. C. O'Connell, P. E. Lavabre, J. JOURNAL OF HYDROLOGY - AMSTERDAM- 1996 VOL 175; NUMBER 1/4 , page(s) 595-613 ELSEVIER SCIENCE DIVISION 0022-1694. Validation methods commonly used to test catchment models are not capable of demonstrating a model's fitness for making predictions for catchments where the catchment response is not known (including hypothetical catchments, and future conditions of existing catchments which are subject to land-use or climate change). This paper describes the first use of a new method of validation (Ewen and Parkin, 1996. J. Hydrol., 175: 583-594) designed to address these types of application; the method involves making 'blind' predictions of selected hydrological responses which are considered important for a particular application. SHETRAN (a physically based, distributed catchment modelling system) is tested on a small Mediterranean catchment. The test involves quantification of the uncertainty in four...

Valley-floor and Floodplain Processes Rumsby, B. T. British Geomorphological Research Group; Geomorphological processes and landscape change Britain in the last 1000 years , page(s) 90-115 Oxford; Malden, Mass., USA; Blackwell Publishers; 2001 0631222731.

Water and solute residence rimes in a catchment: Stochastic-mechanistic model interpretation of ^1^8O transport (Paper 1999WR900054) Simic, E. Destouni, G. WATER RESOURCES RESEARCH 1999 VOL 35; NUMBER 7 , page(s) 2109-2120 AGU AMERICAN GEOPHYSICAL UNION 0043-1397.

Water and solute transfer between a prairie wetland and adjacent uplands, 2. Chloride cycle Hayashi, M. Van der Kamp, G. Rudolph, D. L. JOURNAL OF HYDROLOGY -AMSTERDAM- 1998 VOL 207; ISSUE 1-2 , page(s) 56-67 ELSEVIER SCIENCE DIVISION 0022-1694. The quality of water in lakes and wetlands depends on the exchange of solutes with adjacent uplands. In many prairie wetlands, the input of water is dominated by snowmelt runoff and the output is dominated by groundwater flow. We use chloride as a tracer to quantify the mass transfer processes associated with surface runoff and groundwater flow between a wetland in Saskatchewan, Canada and the surrounding upland. Snowmelt runoff transports 4-5kgyr^-^1 of chloride from the upland to the wetland. Most of this chloride infiltrates under the wetland and moves laterally to the upland with shallow groundwater. Under the upland, chloride moves upward in the vadose zone with soil water, and accumulates near the surface as water is consumed by evapotranspiration. Part of this chloride mixes with sn...

Water and solute transfer between a prairie wetland and adjacent uplands, 1. Water balance Hayashi, M. Van der Kamp, G. Rudolph, D. L. JOURNAL OF HYDROLOGY -AMSTERDAM- 1998 VOL 207; ISSUE 1-2 , page(s) 42-55 ELSEVIER SCIENCE DIVISION 0022-1694. The hydrology and water quality of lakes and wetlands are controlled by the exchange of water and solutes with adjacent uplands. We studied a small catchment in Saskatchewan, Canada, to evaluate the mechanisms of water and solute transfer between the wetland and the surrounding upland. Detailed measurements of hydrologic processes (precipitation, runoff, evapotranspiration, and subsurface flow) and chloride distribution are combined to improve the estimate of the transfer flux. This paper describes hydrologic processes and Part 2 describes the solute transport processes. Large snowmelt runoff occurs in the catchment, which transfers 30-60% of winter precipitation on the upland into the wetland to form a pond in the center. Snowmelt water and summer precipitation infiltrate under the centra...

Water fluxes through clay and sandy soils: integration of tracing and soil water data Mosugu, M. Bradley, C. IAHS PUBLICATION Integrated Methods in Catchment Hydrology - Tracer, Remote Sensing and New Hydrometric Techniques 1999 ISSUE 258 , page(s) 143-150 IAHS PRESS - INTERN ASSOC HYDROLOGICAL SCIENC 0144-7815.

B. EXAMPLE OF CLIMATE ANALOGUE DATA AVAILABLE FOR USE IN SAFETY ASSESSMENTS (ORIGINAL DATA FROM THE CLIMATE RESEARCH UNIT AT THE UNIVERSITY OF EAST ANGLIA AND PROCESSED BY M.C. THORNE. PROVIDED BY UK NIREX AS CONTRIBUTION TO EC 5TH FRAMEWORK PROJECT BIOCLIM)

In order to provide input to the EC 5th Framework project BIOCLIM (Work Package 4, see www.andra.fr/bioclim) various analyses were undertaken of the climatic characteristics of various climate stations selected to be representative of the possible range of climate states that may characterise Central England over the next 200,000 years. The various analogue stations were chosen from each of the two-letter Köppen-Trewartha climate classes of relevance. The derivation of these classes is shown in Appendix B Annex 1. Due regard was taken to the geographic location of the analogue station (e.g. maritime or inland and its altitude) and some stations are clearly more representative than others. The most appropriate analogue climate stations and their associated Köppen-Trewartha classes are summarised in the following table.

Station	Country	Latitude	Longitude	Elevation (m)	Class
Mys Uelen	Russia	66.2	169.8	3	FT
Okhotsk	Russia	59.4	-143.2	5	EC
Reykyavik	Iceland	64.1	21.9	52	EO
Goeteborg	Sweden	57.8	-11.9	20	DC
Birmingham/Elmdon	UK	52.5	1.7	96	DO
Bordeaux/Merignac	France	44.8	0.7	47	Cr
Perpiganan	France	42.7	-2.9	42	Cs

The complete list of analogue stations and their locations are identified in Appendix B, Annex 2. They have reliable time-series records of temperature and precipitation that can be used as surrogates for information based on Central England during alternative climate states. The time-series data were aggregated and mean monthly values derived for temperature and precipitation. These are shown in Appendix B, Annex 3 as figures ABA3.1 to ABA3.8. In figures ABA3.9 and 10 the means of the mean values that have been calculated are shown.

This analogue information is of value in e.g. calculating water balances and dilution fluxes for potential repository locations under climatic conditions different to today.

Køppen-Trewartha Climate Classes

Rules for climate classification: taken from pages 84-85 of Rudloff, W., 1981: World-Climates, Wissenschaftliche Verlagsgesellschaft mbH, Stuttgart, 632pp, as summarised in BIOCLIM.

In order to derive a climate class the desert limit of precipitation has first to be calculated:

RW = 10(t-10) +300 Rs/R, where t is the mean annual temperature, R is the mean annual precipitation, and Rs is the mean precipitation in summer (April-September).

– The climate is BW if the mean precipitation R is less than RW.

- The climate is BM if the mean precipitation R is less than RW and the place is near the coast and has a high air humidity.

- The climate is BS if R is less than 2 RW.

- The class is not B if R is equal to or greater than 2 RW.

Secondly, one has to ask how many months are over 17°C. If all months are, the climate is A. Then one has to ask how many months have more than 59 mm precipitation.

- The climate is Ar if more than 9 months do: otherwise one has to calculate the value R' = 25(100-rn) where rn is the mean monthly precipitation of the driest month.

- The climate is Am if R is equal to or greater than R': otherwise

- The climate is Aw if winter is drier than summer, and

- The climate is As if summer is drier than winter.

If not all months, or none, are above 17°C, we have to ask how many months are over 9°C.

- The class of climate is F is there are no months over 9°C,

- The class of climate is E if there are 1-3 months over 9°C,

- The class of climate is D if there are 4-7 months over 9°C, and

- The class of climate is C if there are more than 7 months over 9°C.

- The climate is Cr if the class is C and the driest month of summer has more than 29 mm precipitation.

- The climate is Cs if the driest month is in summer with less than 30 mm and its precipitation is exceeded at least three times by the wettest month in winter, and R is less than 890 mm; otherwise the climate is Cr.

- The climate is Cw if the driest month is in winter and its precipitation is exceeded at least ten times by the wettest month in summer; otherwise the climate is Cr.

The foregoing procedure can also be applied to characterise D climates by means of r, s and w. s and w can also be applied without restriction to B, E and F climates.

The next question is how many months there are below 0°C:

- The climate is FI if the class is F and all months are below 0°C; otherwise the climate is FT.

- The climate is DO if the class is D and no month is below 0°C; otherwise the climate is DC.

- The climate is EO if the class is E and no month is below –9°C; otherwise the climate is EC.

The foregoing simple formula of a given place is prefixed by a G if the height of the place is between 500 m and below 2500 m, by an H if it is 2500 m or more. In addition to this all formulae are expanded by two code letters of the thermal standard scale indicating the warmth of summer and the cold of winter corresponding to the maximum and minimum of the mean monthly air temperature.

Universal Thermal Scale:

35°C	to …	severely hot	i
28°C	to 34°C	very hot	h
23°C	to 27°C	hot	a
18°C	to 22°C	warm	b
10°C	to 17°C	mild	l
0°C	to 9°C	cool	k
-9°C	to –1°C	cold	o
-24°C	to –10°C	very cold	c
-39°C	to –25°C	severely cold	d
Less than –40°C		excessively cold	e

Analogue Weather Stations for Central England Used in Analysis (BIOCLIM 2003)

FT STATIONS: NORTHERN HEMISPHERE

Stn-ID	Station name	Lat.	Long.	Elev.	Country		Series
425000	GODTHAAB	6417	-5175	70	GREENLAND		1
436000	AMMASALIK	6560	-3763	52	GREENLAND		2
2539900	MYS UELEN	6617	-16983	7	RUSSIAN FEDERATION		3
2559400	BUHTA PROVIDE	6442	-17323	17	RUSSIAN-FEDERATION		4
7030800	ST. PAUL	5715	-17022	9	UNITED STATES		5

EC STATIONS: NORTHERN HEMISPHERE

Stn-ID	Station name	Lat.	Long.	Elev.	Country		Series
2591300	MAGADAN	5955	15078	118	RUSSIAN FEDERATION		1
2923100	KOLPASEV	5830	8290	76	RUSSIAN FEDERATION	2	
2926300	ENISEJSK	5845	9215	79	RUSSIAN FEDERATION		3
2928200	BOGUCANY	5838	9745	134	RUSSIAN FEDERATION		4
3108800	OHOTSK	5937	14320	8	RUSSIAN FEDERATION		5
3241100	ICA	5558	15558	10	RUSSIAN FEDERATION		6
7032600	KING SALMON	5868	-15665	15	UNITED STATES	7	
7181600	GOOSE	5330	-6040	49	CANADA		8
7181800	CARTWRIGHT	5370	-5700	14	CANADA		9
7190600	FORT CHIMO	5810	-6840	37	CANADA		10

EO STATIONS: "GREATER" EUROPE ONLY

Stn-ID	Station name	Lat.	Long.	Elev.	Country	Series
401300	STYKKISHOLMUR	6508	-2273	17	ICELAND	1
403000	REYKJAVIK	6400	-2200	61	ICELAND	2
406300	AKUREYRI	6568	-1808	27	ICELAND	3
427000	IVIGTUT/NARSARSUAQ	6120	-4542	32	GREENLAND	4

DC STATIONS: "GREATER" EUROPE ONLY

Stn-ID	Station name	Lat.	Long.	Elev.	Country		Series
149200	OSLO BLINDERN	5995	1072	96	NORWAY		1
236100	HARNOSAND	6260	1800	8	SWEDEN		2
241800	KARLSTAD	5935	1347	55	SWEDEN	3	
251200	GOETEBORG/GAVE	5777	1188	53	SWEDEN		4
259000	VISBY AIRPORT	5767	1833	51	SWEDEN		5
261600	FALSTERBO	5538	1282	5	SWEDEN		6
267200	KALMAR	5673	1630	15	SWEDEN	7	
294300	TAMPERE	6150	2370	85	FINLAND		8
297200	TURKU	6052	2227	59	FINLAND		9
1018400	GREIFSWALD	5410	1340	6	GERMANY		10
1210500	KOSZALIN	5420	1615	34	POLAND		11
1229500	BIALYSTOK	5310	2320	151	POLAND		12
2603800	TALLIN	5942	2480	44	ESTONIA		13
2625800	PSKOV	5783	2835	45	RUSSIAN FEDERATION	14	
2647700	VELIKIE LUKI	5635	3062	106	RUSSIAN FEDERATION		15
2662900	KAUNAS	5488	2383	77	LITHUANIA		16
2673000	VIL'NJUS	5463	2528	189	LITHUANIA		17

Temperature and Precipitation Records for Alternative Climate States. Derived from Analogue Weather Stations (for Central England) (BIOCLIM 2003).

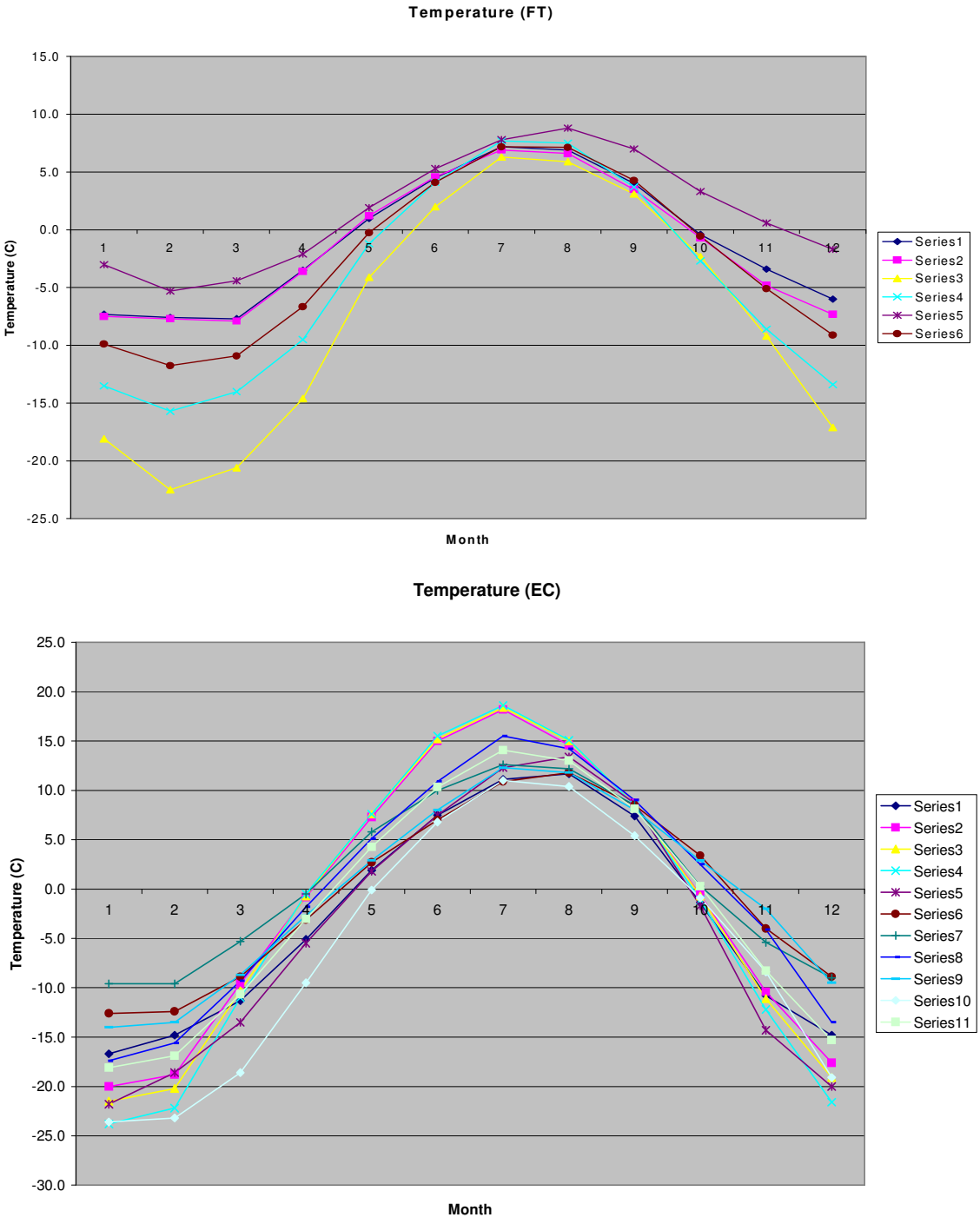

Figure ABA3.1: Temperature Data for Analogue Stations for Central England (FT, EC)

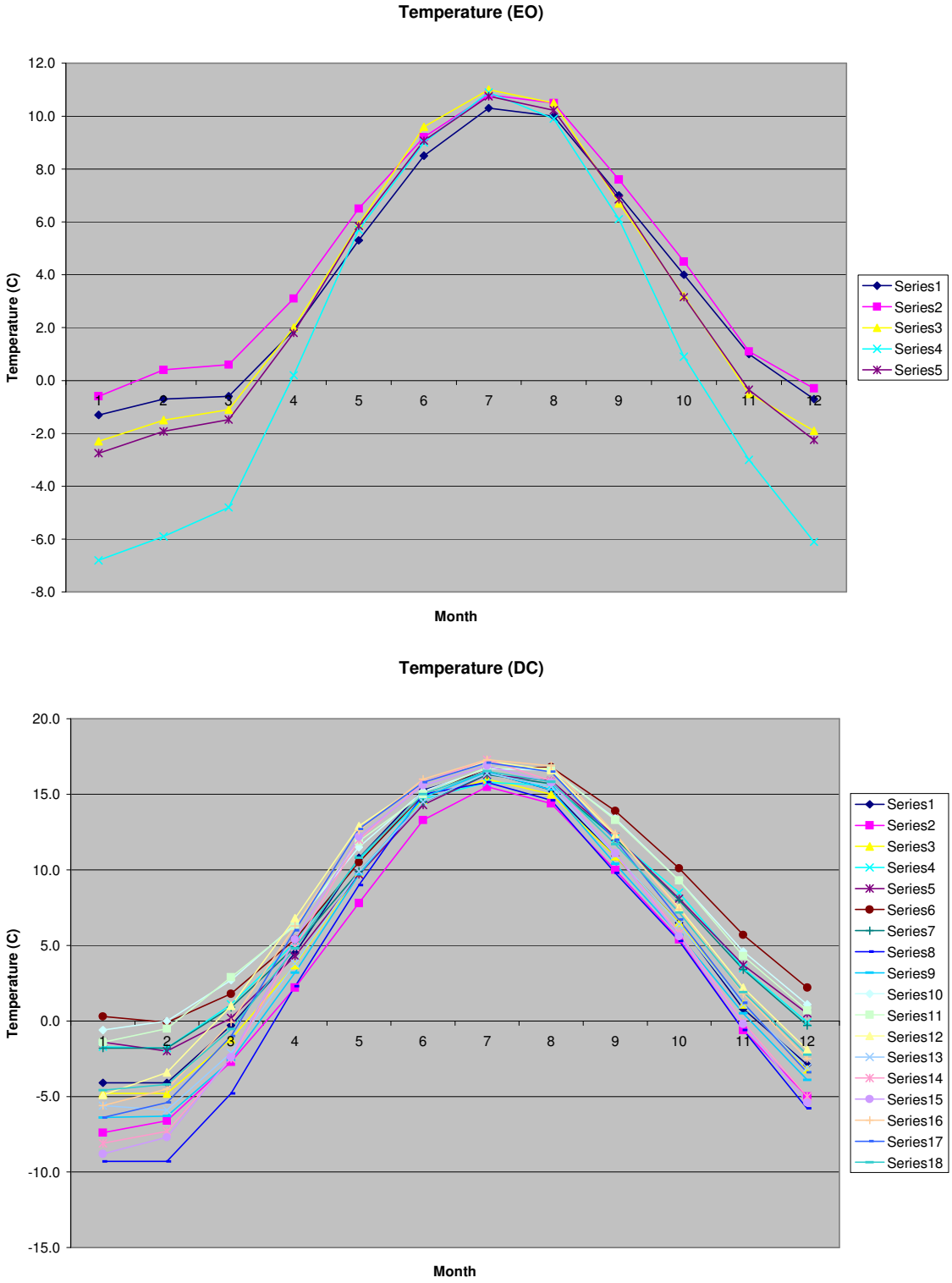

Figure ABA3.2: Temperature Data for Analogue Stations for Central England (EO, DC)

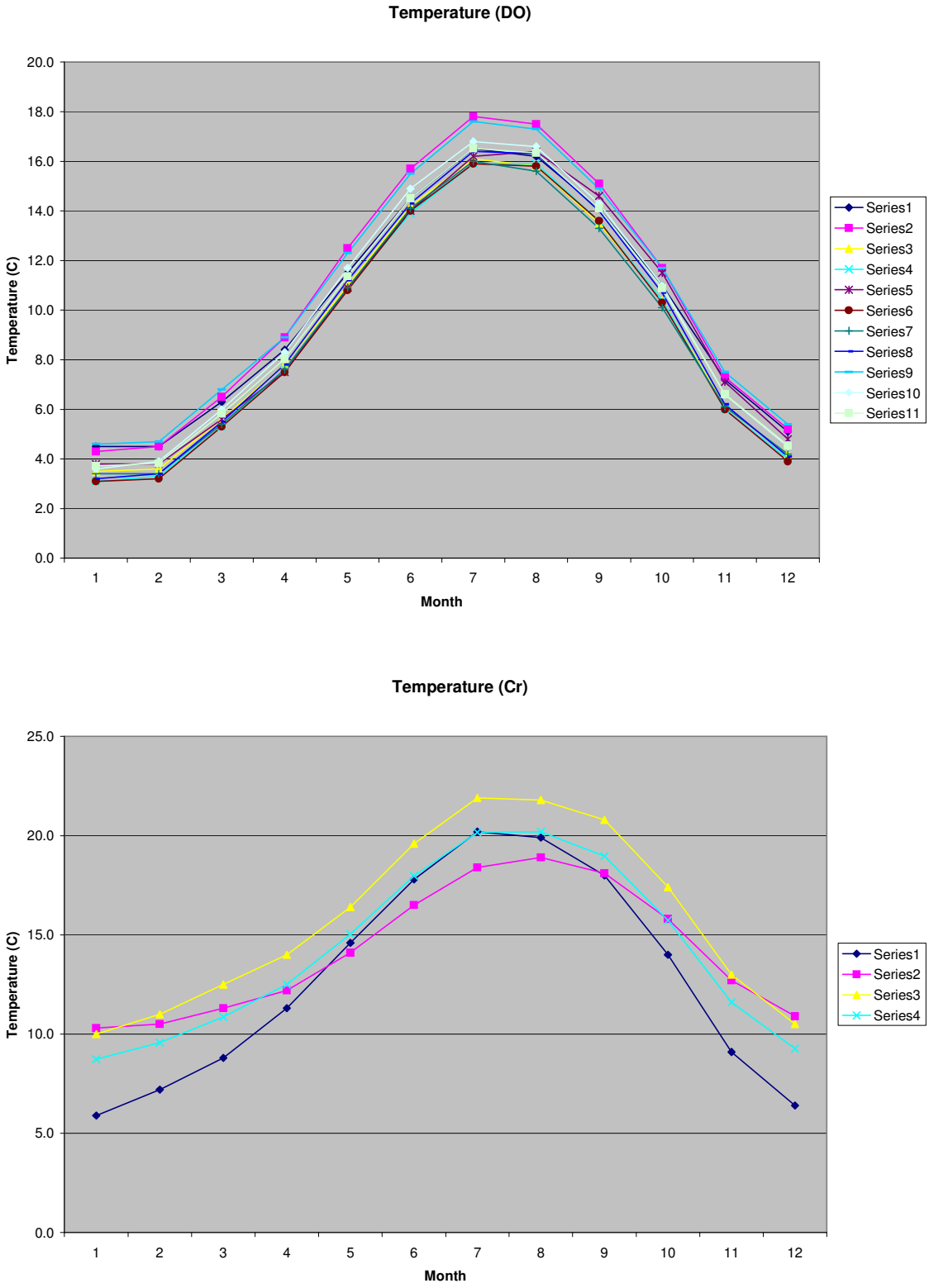

Figure ABA3.3: Temperature Data for Analogue Stations for Central England (DO, CR)

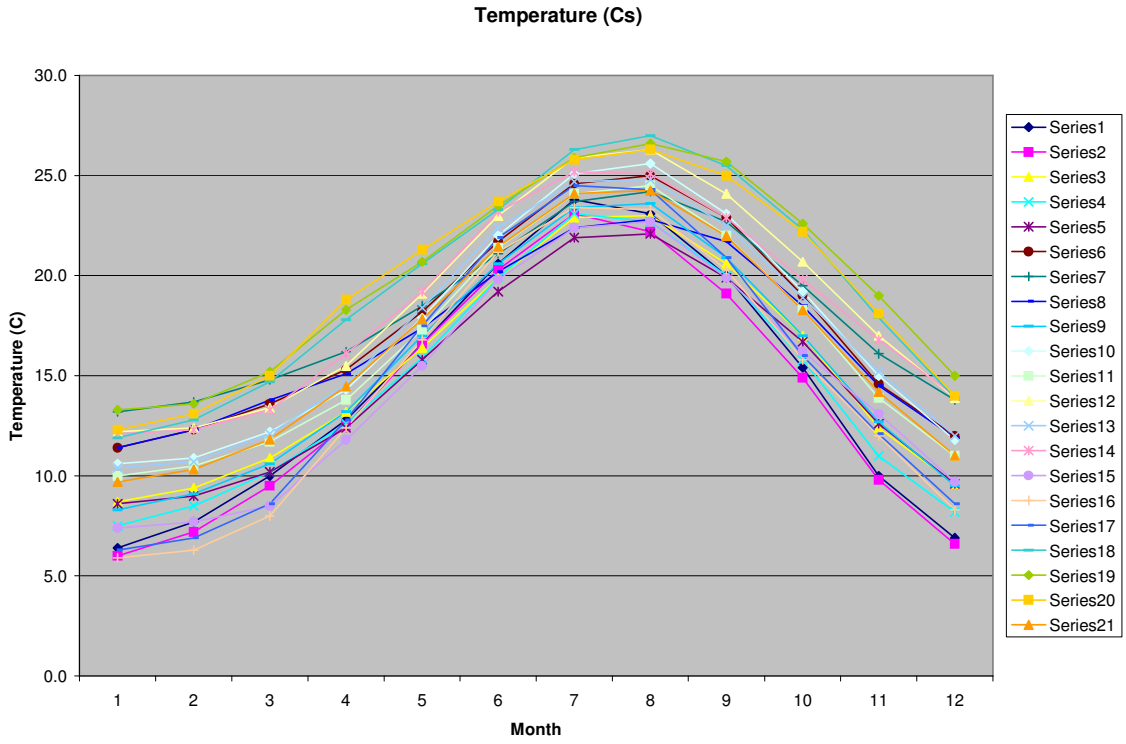

Figure ABA3.4: Temperature Data for Analogue Stations for Central England (Cs)

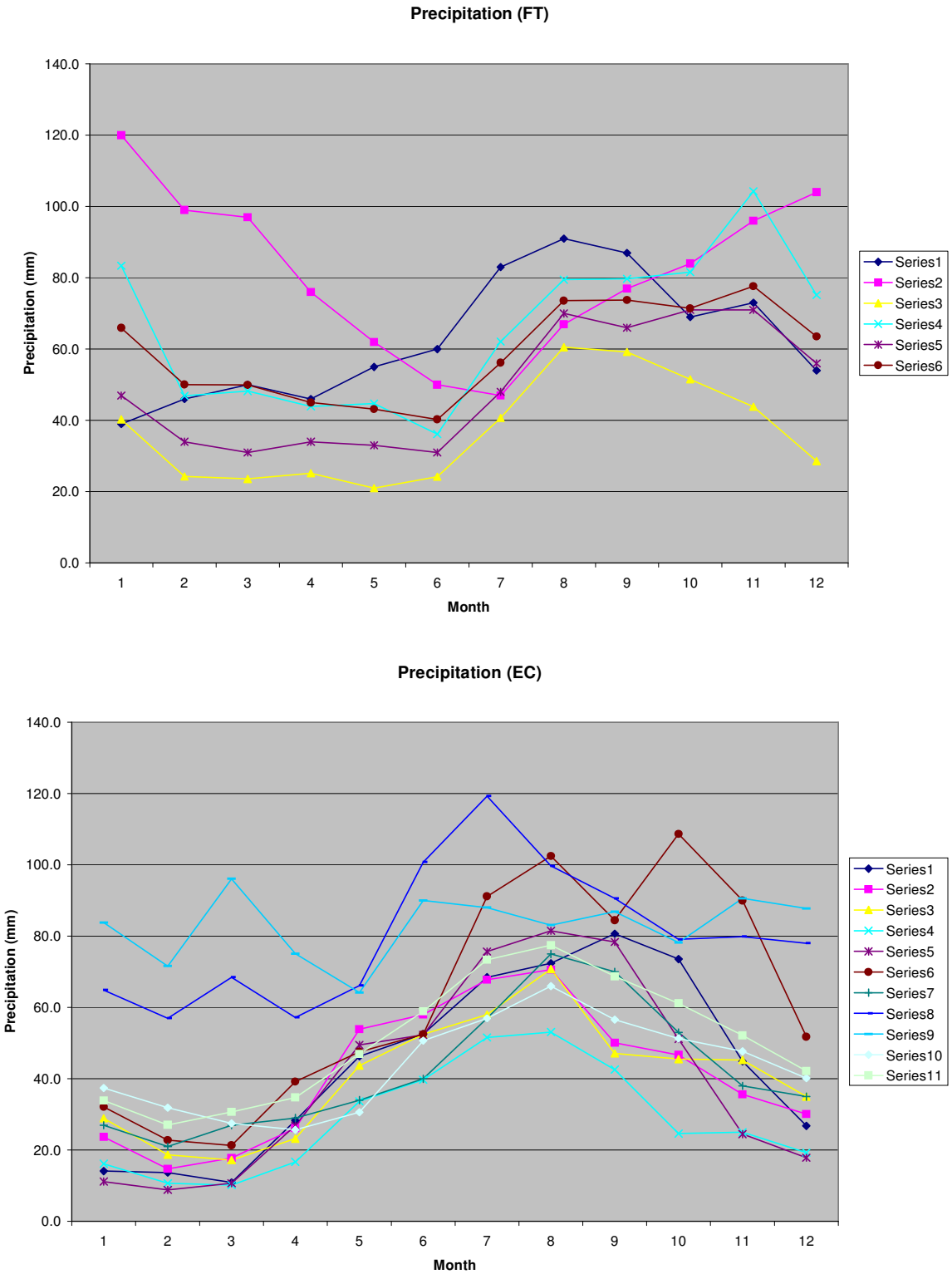

Figure ABA3.5: Precipitation Data for Analogue Stations for Central England (FT, EC)

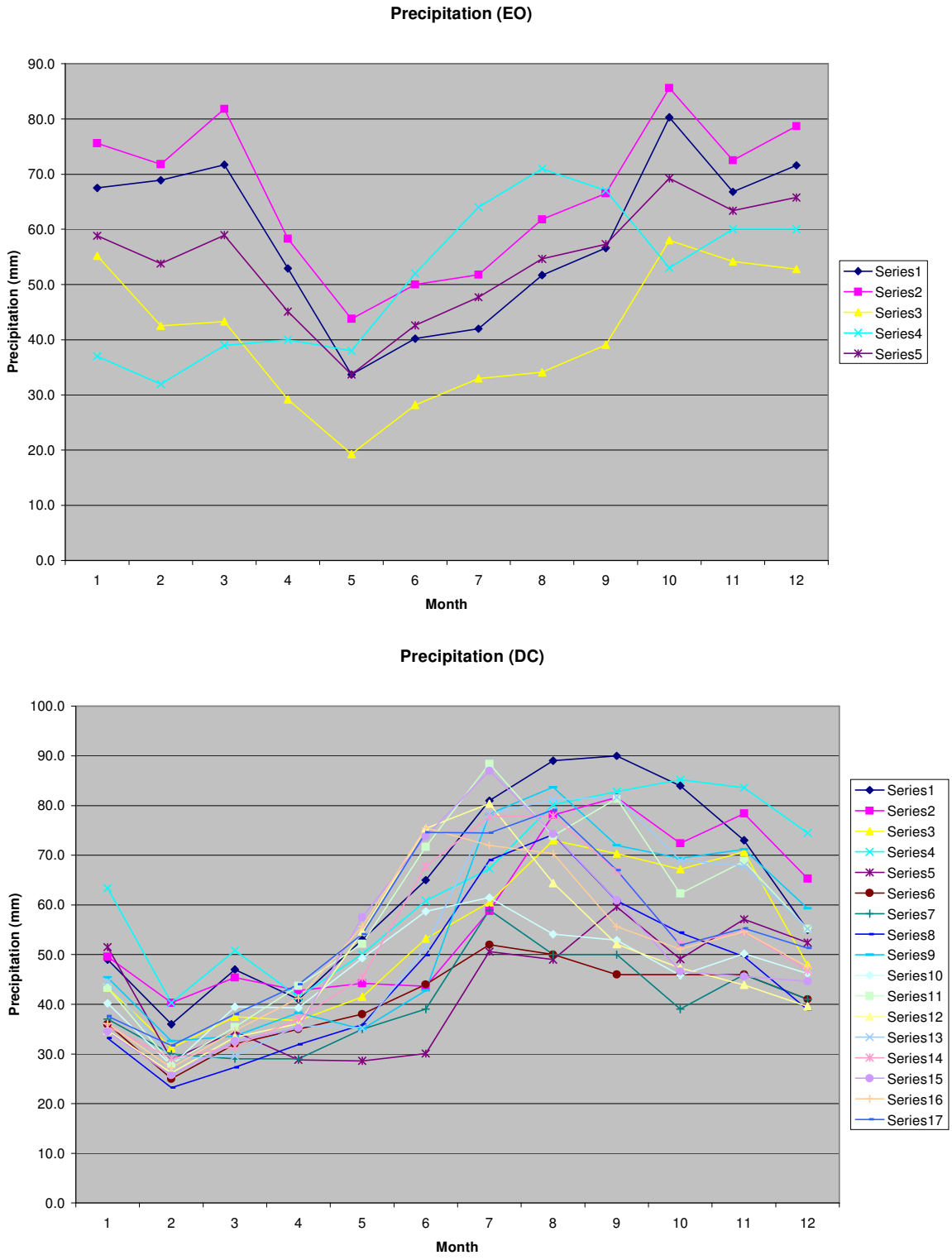

Figure ABA3.6: Precipitation Data for Analogue Stations for Central England (EO, DC)

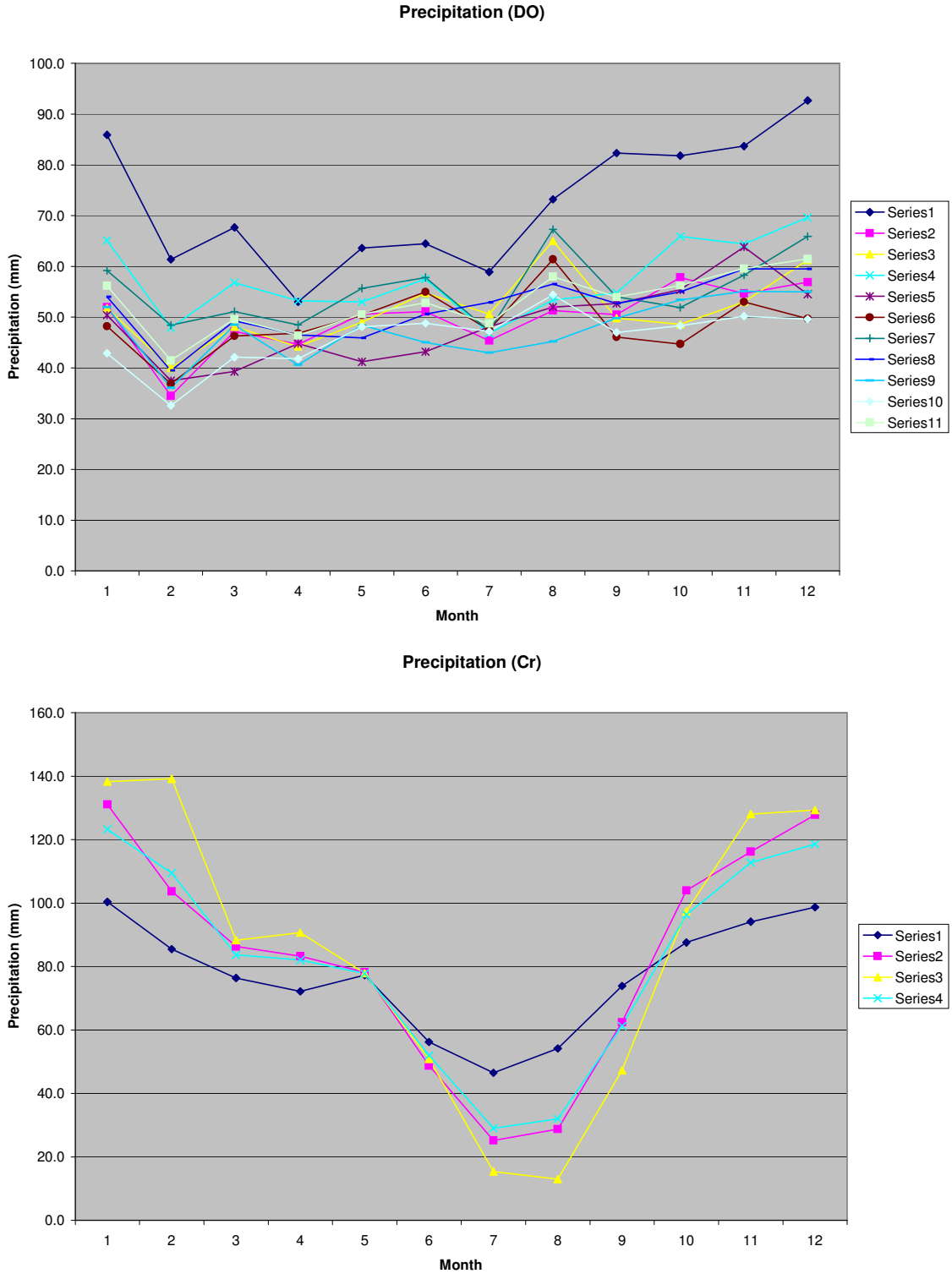

Figure ABA3.7: Precipitation Data for Analogue Stations for Central England (DO, Cr)

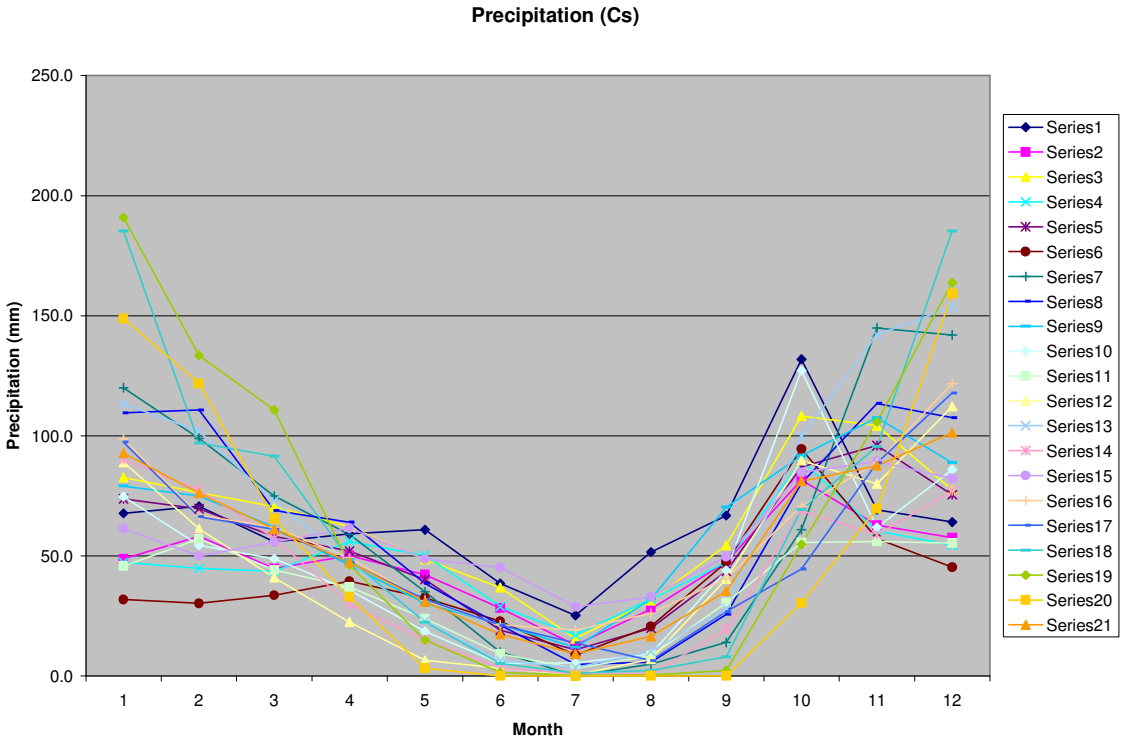

Figure ABA3.8: Precipitation Data for Analogue Stations for Central England (Cs)

The individual analogue station data are useful for supplementary calculations (e.g. the derivation of soil moisture deficit and irrigation requirements), but it is also convenient to present summary data averaged over stations for each climate class, as shown in Figure ABA3.9 and Figure ABA3.10 below for temperature and precipitation, respectively.

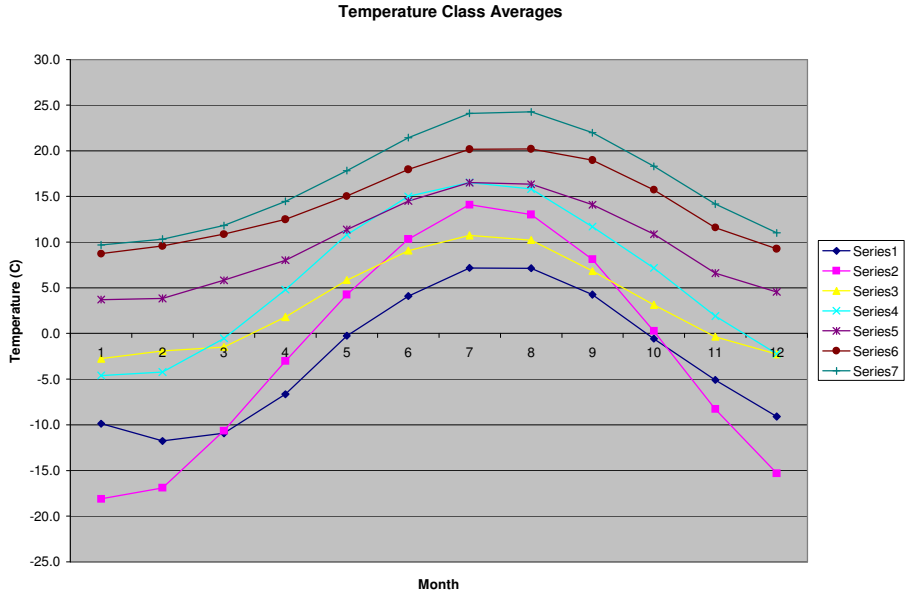

Figure ABA3.9: Temperature Class Averages for Analogue Stations representative of Central England

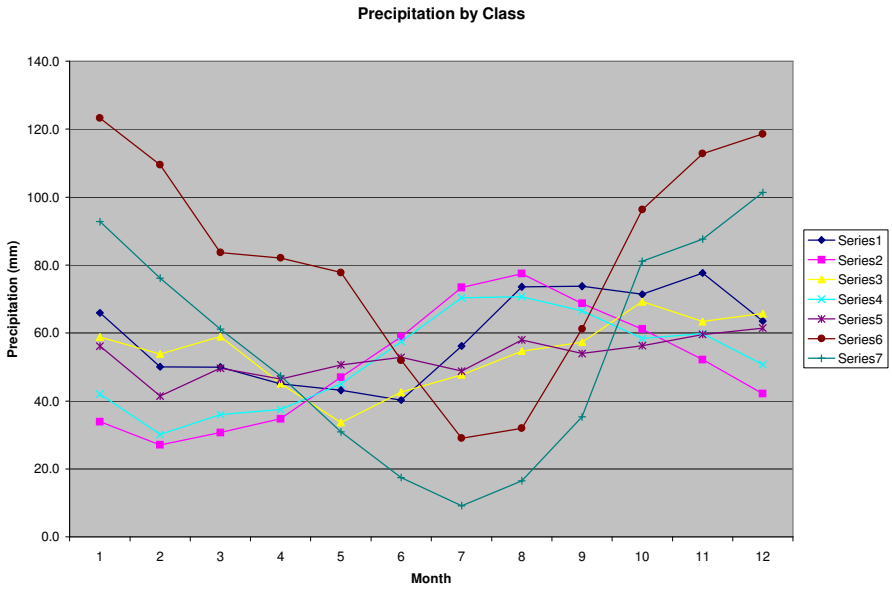

Figure ABA3.10: Precipitation Class Averages for Analogue Stations representative of Central England

In these two figures, Series 1 to 7 correspond to FT, EC, EO, DC, DO, Cr and Cs, in that sequence. An accentuated seasonal cycle of temperature in EC and DC conditions is clear in Figure ABA3.9. Figure ABA3.10 shows that there is no strong seasonal variation in precipitation, except for Cr and Cs conditions, in which a summer drought becomes progressively more marked.

C. FACTORS CONTRIBUTING TO LANDSCAPE DESCRIPTIONS FOR USE IN THE IDENTIFICATION OF LANDSCAPE ANALOGUES (AS USED IN BIOMASS 2003 AND BIOCLIM)

Based on the BIOMASS (2003) methodology, as described in BIOCLIM (2004), it is appropriate to describe the various climate states identified and landscape contributing factors that may be of interest to safety assessments, as shown in the following tables. The table numbering corresponds to that in the BIOMASS (2003) methodology specification.

Table CI. Climate Type Classification

Climate State	Köppen/Trewartha Class	Description
1	DO	Landscape and climate similar to that at the present day.
2	Cr or Cs	Landscape similar to that at the present day, but with a climate with an annual mean temperature between 3 and 6°C warmer.
3	EO	Landscape similar in form to that at the present day, but with EO climatic conditions and an agricultural system based on mainly on animal husbandry, with much less arable farming than at the present day.
4	FT	Landscape similar in form to that at the present day, but with a mean annual temperature of about -5°C, the existence of discontinuous permafrost and tundra vegetation persisting for a few thousand years.
5	EC	Landscape similar in form to that at the present day, but with EC climatic conditions, discontinuous permafrost and tundra-type vegetation

Table TI. Topographical categories

Stage 1	Geographical Context	Inland and Coastal
	Altitude	Lowland
	Landform	Plain to Subdued
	Localised Erosion	Fluvially incised
Stage 2	Geographical Context	Inland and Coastal
	Altitude	Lowland
	Landform	Plain to Subdued
	Localised Erosion	Fluvially incised
Stage 3	Geographical Context	Inland and Coastal
	Altitude	Lowland
	Landform	Plain to Subdued
	Localised Erosion	Fluvially incised
Stage 4	Geographical Context	Inland and Coastal
	Altitude	Lowland
	Landform	Plain to Subdued

	Localised Erosion	Fluvially incised
Stage 5	Geographical Context	Inland and Coastal
	Altitude	Lowland
	Landform	Plain to Subdued
	Localised Erosion	Fluvially incised

Table WI. Characteristics of Water Bodies compared with Present	
State	**Characteristics**
1	Mainly flowing rivers and streams. Substantial lakes and wetlands are uncommon, but do occur. Estuarine environments are present. Rivers and estuaries discharge to shallow coastal waters.
2	Stream and river flow reduced in summer, with some smaller streams becoming ephemeral. Increases in winter precipitation could result in increased channel sizes. Summer flows might not fill these channels from bank to bank. Groundwater resources would be less than at present. Regional water levels would be lower and spring lines would be shifted downslope. Global sea-level rise of a few metres or more would result in inundation of estuaries and low-lying farmland and wetland areas, e.g. the fens and Norfolk Broads. Increases in surface-water storage to ensure better capture of winter precipitation for subsequent use in the hotter, somewhat drier, summers.
3	Overall annual moisture excess. Groundwater levels higher than at the present day. Marshes are likely to be extensive in depressions and along water courses and requirements are likely to be for drainage rather than surface water storage. However, the main land use is likely to be for animal husbandry and resource utilization is likely to be reduced relative to the present day, so there will be a limited requirement to drain wetland areas. Sea-level is likely to be a few metres to tens of metres lower than at present, so surface drainage systems will extend across the current offshore continental shelf. Indeed, land bridges may develop between Britain, Ireland and the Continent. Lakes and wetlands could be a major feature of the current offshore areas, as these are likely to exhibit only limited topographic variability.
4	Tundra type environment. Extensive wetlands in lowland areas. Sea-level is likely to be some tens of metres lower than at present, so surface drainage systems will extend across the current offshore continental shelf. Indeed, land bridges may exist between Britain, Ireland and the Continent. Lakes and wetlands could be a major feature of the current offshore areas, as these are likely to exhibit only limited topographic variability. The main distinction from State 3 is due to the very cold winters. These would lead to extensive snowpack development and the freezing of rivers and streams. The spring melt would be associated with ice dams in the rivers and very high peak flows. Stream channel sizes would be adjusted to these high peak flows. Groundwater flow patterns would be affected by discontinuous permafrost and the seasonal freezing of soil water. Ice-sheet formation would be limited to the north-western upland areas, so Central England would not be glaciated.
5	Overall annual moisture excess. Groundwater levels higher than at the present day. Marshes are likely to be extensive in depressions and along water courses and requirements are likely to be for drainage rather than surface water storage. However, the main land use is likely to be for animal husbandry and resource utilization is likely to be reduced relative to the present day, so there will be a limited requirement to drain wetland areas. Sea-level is likely to be some tens

Table WI. Characteristics of Water Bodies compared with Present	
	of metres lower than at present, so surface drainage systems will extend across the current offshore continental shelf. Indeed, land bridges may exist between Britain, Ireland and the Continent. Lakes and wetlands could be a major feature of the current offshore areas, as these are likely to exhibit only limited topographic variability. The main distinction from State 3 is due to the very cold winters. These would lead to extensive snowpack development and the freezing of rivers and streams. The spring melt would be associated with ice dams in the rivers and very high peak flows. Stream channel sizes would be adjusted to these high peak flows. Groundwater flow patterns would be affected by discontinuous permafrost and the seasonal freezing of soil water. Ice-sheet development in Britain is not considered likely to occur.

Table HI. Classification of Human Community Types based on Socio-economic and Environmental Considerations

State	Trading	Biosphere Control	Community Types and Activities
1	Large-scale	High	Commercial agriculture and horticulture. More limited silviculture (but some deciduous and coniferous woodland management on more marginal land, e.g. heathland). Large-scale mixed farming characteristic with extensive monoproduction of edible and some non-edible crops. Hamlets, villages, market towns and cities in a trading network. Fish farming not extensive. Some water plants (watercress) from streams. Glasshouse horticulture for specialist purposes only (e.g. early fruit, decorative plants for cut flowers and gardens). Range of small scale commercial agricultural practices in market towns, but only a small percentage of the population engaged directly or indirectly in agricultural activities. However, garden cultivation of fruit and vegetables common. Extensive use of groundwater and surface water resources for agricultural and domestic irrigation in some drier areas, e.g. East Anglia.
2	Large-scale	High	Agriculture as at the present day, but with a greater degree of irrigation of high value fruit and vegetable crops. Probably not sufficiently dry in summer to justify irrigation of pasture. Increased yields of most crops (particularly with irrigation) and possibly more than one harvest per year for some crop types. No substantial difference in human community characteristics and infrastructure relative to the present day.
3	Large scale or small scale	High	Largely treeless landscape. Agriculture dominated by animal husbandry, with land given over to summer grass for either summer grazing or hay production. Animals over-wintered indoors. Some arable cultivation of vegetables and barley in areas of least severe climate. Extensive areas of semi-natural vegetation comprising low-growing shrubs. Small scale trading would occur with widely dispersed small villages, hamlets and isolated homesteads. However, it would be possible to sustain a mix of urban and rural communities, as at the present day.
4	None	None	Natural vegetation of the tundra type. Land use primarily herding and hunting. Communities mainly located close to the coastline with a substantial reliance on marine organisms in their diet. However, the coastline would have retreated considerably due to eustatic sea-level fall.

5	Small scale	High	The natural vegetation would be low shrub and herb vegetation characteristic of tundra environments. However, agricultural systems and human communities could closely resemble those under State 3. The more extreme conditions would tend to favour small scale trading with few market or urban centres.

Table BI. Ecosystem Classification

NATURAL SYSTEMS		
Terrestrial Ecosystems		**Aquatic Ecosystems**
State	**Description**	**Description**
1	Very little extent of natural systems. Woodland and shrubland is the natural climax vegetation.	Mainly rivers and streams. Substantial fish stocks, but fishing mainly for sport not consumption. Some shallow lakes and wetlands. Estuaries and shallow offshore waters.
2	Very little extent of natural systems. Woodland and shrubland is the natural climax vegetation.	Mainly rivers and streams. Substantial fish stocks. Some shallow lakes and wetlands. Estuaries and shallow offshore waters.
3	Limited extent of natural systems. Where agriculture is not practiced, semi-natural systems are likely to dominate.	Mainly rivers and streams. Estuarine and coastal waters of less significance than at the present day. Wetlands more extensive than at the present day, possibly particularly in current offshore areas.
4	Primarily natural systems. Tundra.	Mainly rivers and streams. Extensive wetlands.
5	Possibly extensive tundra vegetation.	Mainly rivers and streams. Extensive wetlands.

SEMI-NATURAL SYSTEMS		
Terrestrial Ecosystems		**Aquatic Ecosystems**
State	**Description**	**Description**
1	Minor areas of neglected grassland, lowland grass heath and bracken.	Not applicable. Discussed under natural systems.
2	Minor areas of neglected grassland, lowland grass heath and bracken.	
3	Extensive areas of low growing shrubs, neglected grassland, lowland grass heath and bracken.	
4	Primarily natural vegetation, as agriculture is not practiced, so agricultural land in succession to natural vegetation is not present.	
5	As for State 3, but with the balance more toward natural (tundra) vegetation.	

MANAGED SYSTEMS	
State	**Description**
1	**Terrestrial Ecosystems**
	Mainly field crops. Some tree crops (e.g. fruit orchards). Limited greenhouses. Mainly improved, but some rough, grassland. Intensive dairying, beef-cattle production, sheep rearing (on downland), pig industry and poultry. Extensive urban and suburban areas (high population density) and transport routes.
	Aquatic Ecosystems
	Some ponds, but mainly covered under natural ecosystems.
2	**Terrestrial Ecosystems**
	Mainly field crops. Some tree crops (e.g. fruit orchards). Limited greenhouses. Mainly improved, but some rough, grassland. Intensive dairying, beef-cattle production, sheep rearing (on downland), pig industry and poultry. Extensive urban and suburban areas (high population density) and transport routes.
	Aquatic Ecosystems
	Some ponds, but mainly covered under natural ecosystems.

3	**Terrestrial Ecosystems**
	Mainly animal husbandry. Both intensive dairying and beef production are likely to be practiced. Sheep rearing, pig rearing and poultry. Some vegetable production. May be increased use of greenhouses to grow fruits and vegetables. Barley production likely to be used for animal feed. Reduced extent of urban and suburban areas and transport routes relative to the present day.
	Aquatic Ecosystems
	Some ponds, but mainly covered under natural ecosystems.
4	**Terrestrial Ecosystems**
	No practice of agriculture.
	Aquatic Ecosystems
	Covered under natural ecosystems.
5	**Terrestrial Ecosystems**
	Mainly animal husbandry. Both intensive dairying and beef production are likely to be practiced. Sheep rearing, pig rearing and poultry. Some vegetable production. May be increased use of greenhouses to grow fruits and vegetables. Conditions too severe for barley production. Reduced extent of urban and suburban areas and transport routes relative to the present day. Generally, reduced extent of agriculture, urban and suburban areas relative to State 3.
	Aquatic Ecosystems
	Some ponds, but mainly covered under natural ecosystems.

Table SI: Zonal soil types

State	Soil type	Description	Comments
1	Forest Brown Earths/Agricultural	Natural soils are often Brown Earths or Brown Forest podzols. However, these have been substantially modified by long-term agricultural activities. Well-drained, deep soils are characteristic, though some gleyed soils with near-surface impermeable layers also occur.	A detailed account of the soils of Central England, with emphasis on their hydrological characteristics is given in Institute of Hydrology (1995).
2	Forest Brown Earths/Agricultural	As for State 1.	
3	Forest Brown Earths/Agricultural	Increased extent of gleyed soils with raised groundwater levels. Development of more extensive range of organic soils in wetlands.	
4	Tundra humus soils	Extensive organic soils in wetlands. Substantial cryoturbation structures due to seasonal freezing and the development of permafrost.	
5	Tundra humus soils with some areas of agricultural soil.	Agricultural soils as for State 3, but declining in area and quality.	

D. ANALOGUE STUDY BASED ON: CHERNOBYL, UKRAINE

The Chernobyl accident in 1986 was the most serious radiological incident on record, a catastrophe that caused much human misery, vast economic disruption and had profound social and environmental consequences. It was also a disaster for the nuclear industry. However, as terrible a tragedy as it was, the accident has provided a unique opportunity for much to be learnt regarding the behaviour of radionuclides in the biosphere and the near surface environment. In particular, the widespread contamination of a large variety of different environments, natural, semi-natural and human-dominated, under different climatic conditions has provided opportunities to test many of the assumptions that have been employed in the construction and application of models designed to simulate the behaviour of radionuclides in the biosphere. In some senses the Chernobyl accident may be regarded as an unplanned experiment carried out on a huge scale and affecting a wide diversity of environmental situations where the radionuclides deposited at a known date act as markers and tracers of the processes relevant to the forecasting of anthropogenic contaminant migration patterns. These opportunities for study have not been wasted and since the Chernobyl accident, many studies have been published on, for example, geochemistry, radioecology and health and environmental impacts. A number of the studies that have been carried out deal with landscape settings, soil and hydrogeochemical processes that are pertinent to the assessment of the potential future impacts of the geological disposal of radioactive wastes.

This data sheet deals with radionuclide migration into surface media and the hydrogeological environment after the Chernobyl accident. In order to facilitate the use of Chernobyl information for different aspects of near-surface studies and for ease of analysis, it is divided into three sections: (1) Observations of, and mechanisms for, the contamination of groundwaters; (2) Speciation and mobility and (3) the testing of models using Chernobyl data.

Observations of groundwater contamination

Shestopalov et al. (2003) state that sixteen years after the Chernobyl accident, the predominant part of the radionuclide activity is to be found in the upper 10cm layer of natural soils or within the plough layer of agroecosystems. It has frequently been asserted that particle-reactive radionuclides deposited in fallout such as 137Cs are rapidly and strongly ‘fixed’ within surface soils, that soil cores may be analysed to determine the local inventory of deposition and that the subsequent redistribution of activity occurs in association with soil or sediment particles (e.g. Walling and He, 1997). These assertions may have general validity, but observations within the areas most affected by the Chernobyl accident reveal that 90Sr and 137Cs have penetrated to considerable depths below ground and have contaminated major aquifers over a wide area (Shestopalov et al. 2003). The appearance of 134Cs, which has a half-life of 2 years, in groundwater soon after the accident was taken to confirm the Chernobyl origin of the contamination. According to Shestopalov et al. (2003) the annual vertical transfer from soil to the vadose zone exceeds by between 5-25 times the amount removed by the Prypyat river within the Chernobyl exclusion zone.

Figure 1 shows the distribution of 137Cs in Quaternary and Eocene formations to a depth of 80m south of Chernobyl. This distribution is qualitatively similar to that for 137Cs deposition after the accident (De Cort et al. 1998). Figures 2 and 3 show the distribution of 90Sr in Quaternary and Eocene aquifers respectively in 1996. The maximum contamination of groundwater in the Eocene aquifer is observed within the cone of depression created by the Kiev water-supply system which suggests a linkage which was established through a special investigation. However,

Shestopalov et al. (2003) did not believe that 'technogenic' (i.e. man-made) pathways such as wells were responsible for the observed distributions. They also dismissed the likelihood of lateral migration over long distances due to watershed characteristics, although the exchange of aquifer and Dnieper River waters, both naturally and technogenically-induced is suggested by the pattern of contamination. They suggested instead that groundwater contamination results from the water percolating through the unsaturated zone from the land surface. In support of this, Shestopalov et al. (2003) reported measured values of 137Cs in marl rock along a 1km transect of the Kiev metro system at 80m depth. The values ranged from 0.3 – 1.1 Bq/kg.

A complex pattern of radionuclide contamination resulted from the Chernobyl accident because the release was extended over 10 days and involved both gaseous and particulate forms. The initial large release was due to the mechanical fragmentation of fuel, whilst the second large release between day 7 and 10 was associated with the high temperatures reached in the core melt (NEA, 2002). During the period of release there were frequent changes in meteorological conditions and patterns of deposition were dependent on wind direction and dispersion parameters, particle size and the occurrence of rainfall. Subsequent to deposition, Shestopalov et al. (2003) found that the vertical distribution of radionuclides within the soil, and hence by implication, of groundwater contamination, was influenced by the form of deposition, landscape situation, land use, soil type and soil hydrological and chemical parameters. The transfer of radionuclides from fuel particles to soil solution was found to be directly preconditioned by the dissolution of the particle matrix. This depended on the oxidation state and chemical stability of the particles and on soil acidity. In acid soils the rate of dissolution is significantly greater than in neutral soils where the maximum soil solution concentration may not arise until 10-20 years after the accident.

The distribution of landforms, soils and vegetation is significant in terms of the vulnerability of groundwaters to contamination. The highest rate of 90Sr vertical migration was found on immature sandy soils with a low humic content associated with river floodplains. High rates of migration were also observed on arable lands with low levels of organic matter in the Ap horizon. At the scale of a soil profile, Figure 4 shows the vertical distribution of 90Sr within a sandy soil with an intrinsically low moisture retaining capability, a low organic matter content and no vegetation cover. The higher rates of vertical radionuclide migration were attributed to non-equilibrium soil conditions and convectional flow in zone of high local radioactivity (Shestopalov et al. 2003). Figure 5 illustrates the very heterogeneous distribution of contaminant that may arise within a soil profile under these conditions. At the time of sampling there was no correlation between radionuclide concentration and soil moisture content.

Rogachevskaya and Zektser (2003) presented the results of an investigation of shallow groundwater vulnerability within the Dnieper artesian basin, which was one of the areas most polluted by the Chernobyl accident. This study took into consideration the depth of the vadose zone, the hydraulic properties of the soils and the migration behaviour of contaminants, all of which determine the travel time to the water table. The vadose zone mainly comprises Quaternary sediments which are widely used as a decentralised water supply by small settlements. The sediments are very variable in composition but sandy types predominant. The soils and well developed surface water network are closely connected and favour the recharge and discharge of the aquifer. The predominant mode of recharge is local infiltration. Since the Chernobyl accident, Rogachevskaya and Zektser (2003) reported that 137Cs and 90Sr have migrated from the surface to both shallow unconfined and

deep confined aquifers. Caesium migration velocities were reported to double below the top soil layer with effective retardation factors significantly lower than those reported in literature sources. Similar findings were reported by Holgye and Maly (2000) who studied the vertical movement of Chernobyl radionuclides in undisturbed grassland soils at three sites in Bohemia. They found that the convection transport rate of the plutonium and caesium increased with depth. Rogachevskaya and Zektser (2003) calculated a dispersion coefficient of 10 cm2/yr from the vertical concentration distribution relative to the concentration mass-centre and concluded that the soil was not an absolute barrier to radionuclide migration through the vadose zone. The migration rate was observed to vary between types of regional landscape and soil compositional class. Areas subject to human intervention were considered to be particularly vulnerable as were sandy soils.

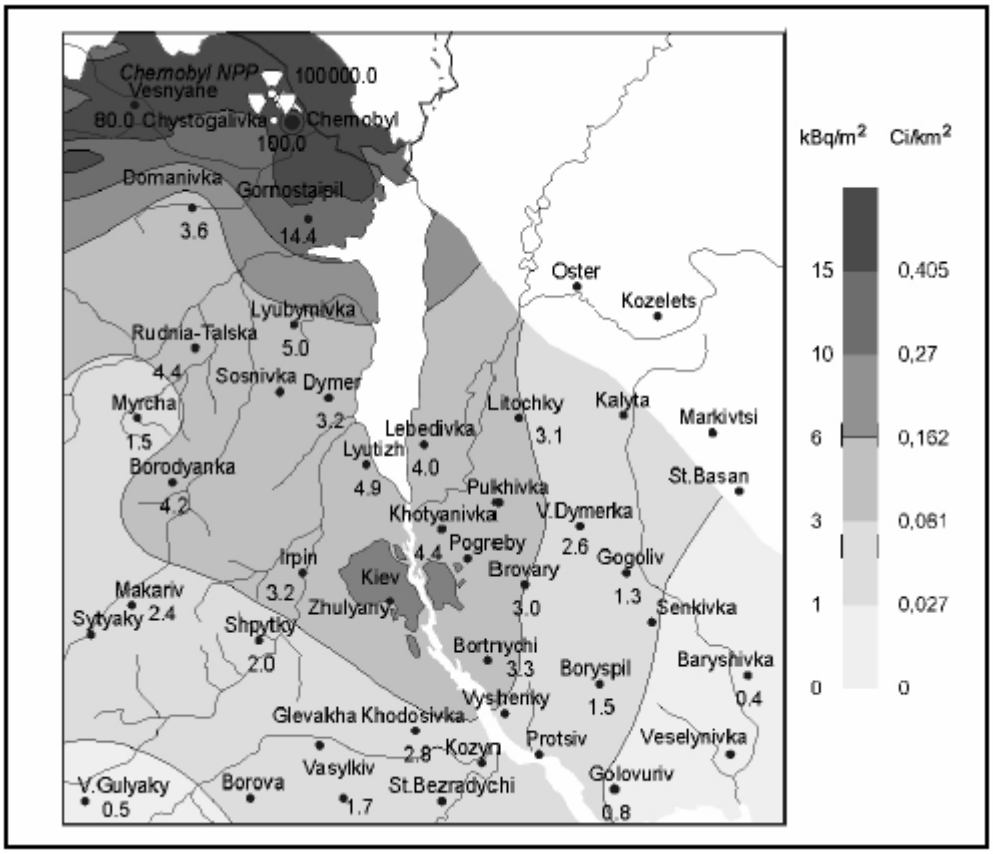

Figure 1. Total 137Cs accumulation in Quaternary and Eocene formations (depth to 80m) within the Kiev region (Shestopalov et al. 2003).

In common with Shestopalov et al. (2003), Sobotovich et al. (2003) noted the penetration of radionuclides below the ground surface following the Chernobyl accident and suggested that as the potential for surface runoff was limited, the main process (other than radioactive decay) for natural attenuation of contamination was through vertical migration. They also noted the dependence of this process on landscape (relief and geographical feature, soil texture and vegetation cover), geochemical conditions (e.g. soil acidity) and on factors influencing the initial mobilization of radionuclides from fuel particles. Sobotovich et al. (2003) analysed observations of contaminant mobility in terms of kinetic-rate constants for radionuclide speciation with particular reference to rates of immobilization and remobilization.

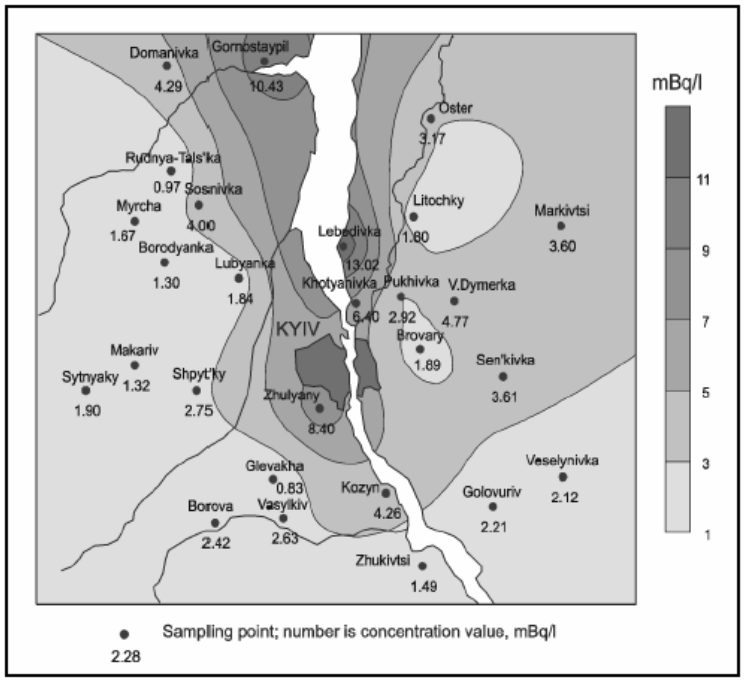

Figure 2. Distribution of 90Sr in a Quaternary water-bearing complex (7-20m) in 1996.

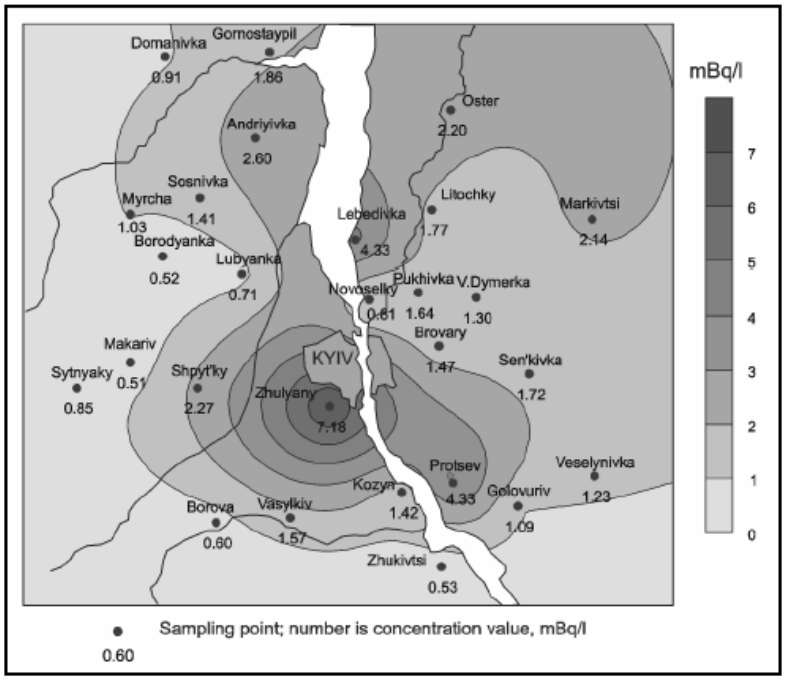

Figure 3. Distribution of 90Sr in the Eocene water-bearing complex (30-60m) in 1996

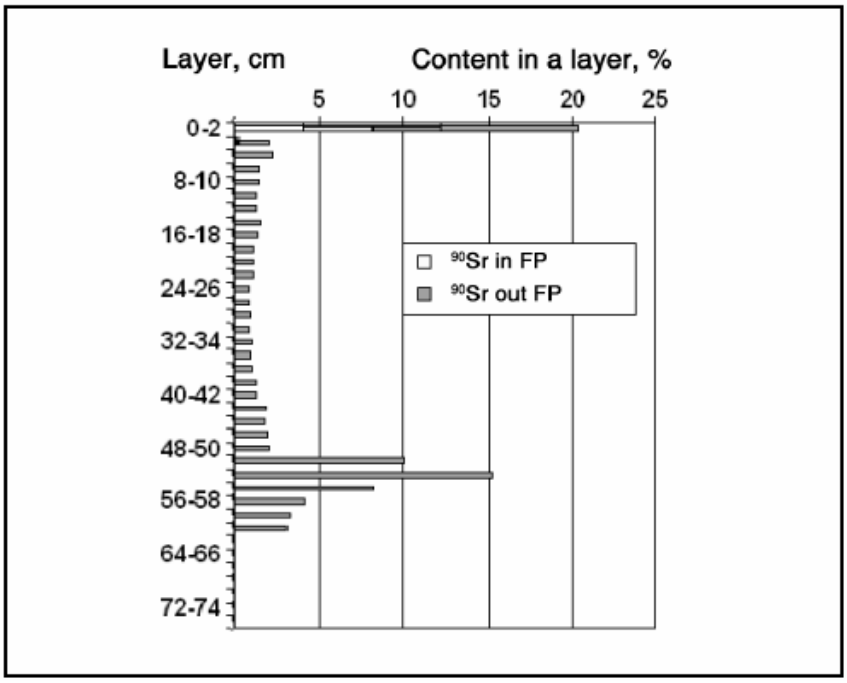

Figure 4. Vertical distribution of 90Sr within a sandy soil in 1996.

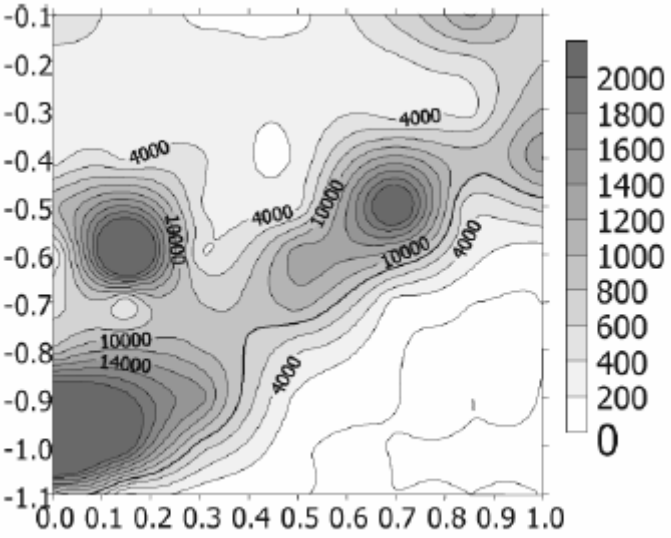

Figure 5. Two-dimensional distribution of 90Sr (Bq/kg) in a pit face excavated into a sandy soil with a low organic matter content (Shestopalov et al. 2003).

Preferential flow is the rapid movement of water and solutes through soils that bypasses a large portion of the soil matrix. As a consequence, the residence time of solutes is shorter than expected based on the assumption of convective-dispersive flow. Field studies have shown that surface applied herbicides, fertilizers, heavy metals, radionuclides and microorganisms are transported faster and to greater depths than predicted, leading to the risk of groundwater contamination (Bevan and Germann, 1982). Hagedorn and Bundt (2002) used a dye tracer to identify preferential pathways in a fine-loamy Dystic Cambisol in a spruce-beech forest in

Switzerland. Subsequent analysis showed that within preferential flow pathways, the activities of 137Cs, 210Pb and 239,240Pu and concentrations of soil organic matter were substantially enriched relative to those of the soil matrix to depth 50cm, beyond which the differences were not statistically significant. The caesium originated mainly from the Chernobyl accident and most of the local inventory was deposited during a single rainstorm. In contrast, the lead derives from continuous natural atmospheric deposition and the plutonium from nuclear weapons fallout primarily during the 1950s and 1960s. This strongly suggests that the preferential flow paths in the soil studied are persistent for decades.

Speciation and mobility

The concept of the equilibrium distribution coefficient or Kd is almost universally employed in models of radionuclide transport in soils and rocks because it is convenient and because it can be shown to adequately describe the migration behaviour of contaminants under idealized equilibrium conditions. However, whilst a single value of retardation may be retrospectively obtained that adequately describes a known distribution for the bulk of a contaminant in geological media, Kd is often a poor predictor of radionuclide transport within natural or poorly characterized near-surface media. There are many reasons for this, but non-equilibrium conditions, especially within the soil and vadose zones, and speciation offer the most promising explanations. These factors may be particularly significant in accounting for the relative high mobility of small fractions of contaminant or heterogeneous patterns of transport. The potential significance of preferential pathways has been referred to above and clearly heterogeneity and anisotropy in soils physical properties, both intrinsic (e.g. hydraulic conductivity) and environmental (degree of saturation) may produce complex patterns of transport. However, the Chernobyl data suggest that paying more attention to speciation is likely to improve the success of predictive modeling.

Most long-lived radionuclides deposited on the soil from the atmosphere are sorbed rather efficiently by the various soil components (organic matter, clay minerals, sesquioxides). As a consequence, the concentrations of these radionuclides in the solution phase are usually quite low. Nevertheless, this quantity is of fundamental interest for a given radionuclide and for a given soil, because it is this fraction which is most readily available for ecological processes, such as plant uptake or for vertical migration in the soil. The soil solution, however, contains not only dissolved inorganic ions but also (depending on a variety of factors) various amounts of dissolved organic matter (e.g. fulvic or humic acids). The low capacity of many of the soil types characteristic of semi-natural ecosystems to immobilize radiocaesium whilst retaining it in the upper horizons of soil has proved to be the main reason for the continuing high activity concentrations in plants and animals in the UK. The retention within such soils is due to the high, but reversible, sorbing capacity of organic matter and to the low content of clay minerals (Howard, 1998). Desorbing caesium is available for plant uptake and for infiltration within the soil. Caesium associated with organic matter is generally likely to be less available for fixation and hence more available for transport. Burrough et al. (1999) reviewed evidence from research in the Pripyat catchment and found that radiocaesium is highly mobile in both river water and in poorly drained organic soils due to the ecological conditions prevalent in the area.

Speciation determines the potential mobility of radionuclides, but transport may occur in both dissolved and particulate forms and hence is influenced by physical and environmental factors. Radionuclides in dissolved and colloidal form are available for transport to rivers and via groundwaters. Radionuclides that are

particle-associated and that reside at the ground surface are susceptible to erosion and overland transport. The coexistence of multiple species of radionuclides in soil solution has attracted considerable interest in explaining the different behaviours of radionuclides in natural systems. Chernobyl has provided valuable data in this regard because it highlighted several aspects of radionuclide behaviour: In particular, the rapid penetration of radionuclides within soil profiles at early times especially under conditions of wet deposition, and the difficulty of modelling the behaviour in soils of radionucides associated with discrete particles of low initial solubility (SCOPE, 1993).

Amano et al. (1999) studied the availability for transport of Chernobyl radionuclides in undisturbed surface pine forest soils (sandy with surface organic layers) along the River Sahan within the exclusion zone. The speciation (by chemical extraction) of radionuclides (Cs, Sr, Pu and Am) in bulk surface soils was compared with the speciation (determine using ultrafiltration) in the water soluble fraction.

For bulk topsoil, about 90% of 90Sr was found to be in the water soluble and the exchangeable fraction. Very little of the 90Sr and 137Cs were found in the free fulvic and humic acid fractions. Of these radionuclides, 90Sr was mostly found in the water soluble and exchangeable fractions. The majority of 137Cs, Pu isotopes and 241Am in the surface soil were found to be in the humic plus insoluble fraction, but water soluble and exchangeable fractions of 137Cs, Pu isotopes and 241Am were also found. Pu isotopes and Am-241 were mostly present in comparable amounts in the free humic and free fulvic acid fractions, which can dissolve in water.

Within the soil solution phase, most of the Pu (79%) and Am (68%) exist in the molecular weight fractions beyond 10,000 Da (Daltons), in spite of the fact that most of the dissolved organic carbon fraction (69%) exist in the molecular weight below 10,000 Da. This means that transuranic elements, such as Pu and Am, are associated with high molecular weight materials containing carbon such as humic substances in water leachates. On the contrary, most of Cs (85%) and Sr (63%) exist in the molecular weight fraction of below 10,000 Da, reflecting the fact that they mostly exist in lower molecular weight forms or ionic forms associated with low molecular materials. However, some of Cs and Sr exist in the molecular weight band beyond 10,000 Da suggesting that some parts of Cs and Sr is associated with higher molecular materials.

Agapkina et al. (1995) investigated by means of gell filtration the association of radionuclides with soil organic matter in soil solution from forest topsoils from a location 6km from Chernobyl. The litter, humus and mineral layers within the top 5cm of the soil were distinguished and differences in speciation noted for the different layers. Plutonium and americium are generally associated with the poorly soluble humic fraction of topsoils which explains their generally low mobility, but they are also found to be mostly associated in solution with the high molecular weight fraction. Whilst americium was found to some extent in lower molecular weight fractions this was not the case for plutonium. Strontium was found to be mostly associated (86%) with low molecular weight organics within the litter layer but was essentially present in inorganic form in the other layers. Caesium in the litter layer was associated mostly (90%) with medium weight organics but in the deepest (mineral) layer was almost uniformly distributed between the 5 fractions distinguished in the analysis. It was concluded that caesium is most sensitive to the nature of the organic matter and plutonium was the least sensitive. Agapkina et al. (1995) felt that as Kd was probably an insufficient measure of mobility and that more attention could be paid to speciation within the solution phase. A further

difficulty in employing the concept Kd simplistically is the tendency of radionuclides to become progressively fixed within the mineral phase and thus rendered less mobile over time (SCOPE, 1993).

Organic matter clearly plays a major role in radionuclide behaviour. For example, Epik and Yaprak (2003) suggested that fungal mycelium may play a role in retaining caesium within the upper humic-rich layers of forest soils and may be responsible for a significant fraction of the overall inventory. Kudelsky et al. (1996) looked at the behaviour of Chernobyl-derived caesium in a hydrologically isolated bog system in the catchment of the Pripyat River, Belarus. They found that the runoff coefficients for radiocaesium from peat bogs 8 years after the accident were about one order of magnitude greater than those from unsaturated soils of higher mineral content.

Sobotovich et al. (2003) provide kinetic-rate constants for 5 landscape categories and 4 soil types based on 15 years of observations of radionuclide speciation within the Chernobyl exclusion zone. They noted time-dependence in the rates and inferred changes in the descending and ascending radionuclide fluxes. Because of the nature of the Chernobyl accident, Sobotovich et al. (2003) and other workers devoted much study to the mobilization of radionuclides into soil solution from deposited fuel particles relative to the behaviour of condensed evaporation products. The 'species' involved were those identified through chemical extraction so that distinctions were made between water-soluble forms, exchangeable cations, organic-bound forms and 'fixed' forms. In this respect it is worth noting that these distinctions do not determine speciation as such. but merely extractability and some workers such as Davydov et al. (2002) do not consider this to be scientifically valid or to provide quantification of 'species'. Thus the kinetic-rate constants provided by Sobotovich et al. (2003) may also be 'apparent' rates in much the same way as Kd describes an apparent, net, retardation. Davydov et al. (2002) used an ultrafiltration method and concluded that caesium exists in soil in ionic (molecular) species.

Gri et al. (2000) also consider that the explanation to 137Cs mobility lies in speciation and in the reactivity state of exchange 'pools'. They were unable to correlate caesium behaviour with soil parameters such as cation exchange capacity and noted mechanisms by which sorption by clays may be inhibited by organic matter complexes. They concluded that caesium may remain available for cation exchange and hence continue to be available for downward migration in soils. In this respect it is pertinent to note that Hilton et al. (1992) found that, compared with global fallout, the 137Cs from Chernobyl (in far distant locations) was much more mobile in the first four years after the accident. They found that the water-soluble fractions of Chernobyl and global fallout were about 70% and 8% respectively. Later on, ageing processes were said to lead to similar mobility values for caesium from both sources.

Amano and Onuma (2003) employed speciation as determined by sequential extraction to analyse depth profiles of Chernobyl radionuclides in a range of undisturbed soils some 10 years after the accident. They discussed the relative mobility of caesium, strontium, americium and plutonium isotopes under varying soil conditions and found that penetrating fractions of caesium and the actinide elements were generally present. The authors' identified acidic conditions and organic complexing as factors promoting mobility, but it is not clear whether they were also invoking colloidal phase transport.

Redistribution within the landscape

The initial pattern of radionuclide deposition was determined by proximity to the Chernobyl site, wind conditions during and immediately after the accident and the incidence of local rainstorms. While these initial conditions determined the regional patterns of concentrations, subsequent work has demonstrated the local mobility of radiocaesium through erosion and deposition within polluted areas, within river systems and also within the food chain. Once adsorbed onto clay minerals, 137Cs is strongly held and further transport in the landscape with mineral matter depends on the processes of erosion and sedimentation.

There have been a number of studies using global (weapons) fallout radionuclides (Cs and Pu) and Chernobyl deposition to determine areas of net erosion and deposition within the landscape (e.g. Panin et al. 2001). The methods used employ reference inventories, depth profiles of tracers and calibration models and generally seem to be more successful at indicating areas of net deposition than areas of net erosion. There will be situations where, for example, particle size fractionation and varying associations with organic matter cause caesium and plutonium to behaviour differently or to be lost from the system under study (e.g. Schimmack et al. 2001).

Radiocaesium deposited on organic soils may remain mobile (Howard, 1998) and may be lost through leaching to the river system. From there it may be redistributed in solution and in associated with suspended sediment (e.g Walling et al. 1998). Seasonal flooding has been used historically to fertilise riparian areas of the landscape and this process may lead to the accumulation of contaminants (e.g. Walling and He, 1997a,b).

Burrough et al. (1999) investigated the hypothesis that there is a relationship between flood events and the distribution of radiocaesium within the Pripyat catchment of which organic peat soils occupy about 47% of the land area. They also set out to investigate the reasons why some areas within the catchment have seen marked increases in 137Cs levels in milk since the initial deposition. For this purpose they prepared maps of the floodplain and of soil and land cover using a GIS system. They found that sites nearest to rivers generally had larger amounts of radiocaesium than sites further away and that in some areas concentrations in 1993 and 1994 exceed those measured in 1988. This was attributed to a major summer flood in 1993 which submerged a large area for 2-3 weeks. The land classed as rough pasture which occurs almost exclusively within the annually flooded zone seems particularly susceptible to the flood enhancement of 137Cs. Burrough et al. (1999) were not able to establish the role of soil erosion and leaching via groundwater in supplying 137Cs to the river during flood events, but did point to the large areas of organic soils as the source of caesium that was subsequently locally redeposited within the catchment.

Between the major flood in 1993 and 1994 there was a huge apparent loss of 137Cs from the topsoils in the annually flooded zones. This was attributed to leaching from organic soils. However, the decline in 137Cs concentrations in milk was greater than could be explained by leaching alone and progressive fixation by illite was implicated with the clay being derived by overbank sedimentation following flooding. The summer flood caused a brief, but substantial, increase in the 137Cs content of milk. This phenomena was not observed for spring floods that occur prior to the growing / grazing season. Burrough et al. (1999) suggest that during the 1993 summer flood, submerged plants took up the dissolved 137Cs directly from the river water by root uptake. Another possibility is that cows directly ingested the 137Cs by

either drinking the floodwater or by eating contaminated silt which covered the vegetation immediately after the flood.

In temperate climatic regions, erosion by wind and running water is limited by vegetation cover. On arable lands, cultivation may increase the susceptibility to erosion, but it also mixes surface and subsoils and to some extent buries surface deposited contamination. In other areas, earthworms and trampling by cattle may have much the same effect. In forest ecosystems, the Chernobyl experience is of efficient interception of air-borne contaminant and the strong retention and recycling of radionuclides with little opportunity for redistribution by erosion (SCOPE, 1993). In arid areas where the vegetation cover is sparse, much soil can be moved by erosion. In arid areas, much surface-derived contamination or contamination due to discharges to ephemeral streams will be retained within soils and sediments. These areas are frequently associated with high-intensity rainfall resulting in flash-flooding which is an efficient means of transporting sediment-associated contaminants. In contrast in upland ecosystems much surface-derived contamination may be retained in organic matter from which losses (other than by radioactive decay) may be primarily by leaching. Under cold climates, surface erosion during snowmelt may be effective in transporting contaminants (SCOPE, 1993).

Testing of Models using Chernobyl Data

Chernobyl derived data have been used in three modelling studies that are considered here: the Chernobyl Pilot Site Project; the BIOMOVS II 'Wash-off' scenario and the BIOMASS Iput Catchment study.

Chernobyl Pilot Site Project

The Project involved a shallow disposal site located 2.5 km from Chernobyl (Bugai et al., 2002). The trench is about 70m long, 8-10m wide and 2-2.5m deep. It is unlined. The 'waste' comprises heavily contaminated topsoil and pine tree trunks from the "red forest". Groundwater flow below the trench was approximately normal to the long axis of the trench. The Chernobyl Pilot Site Project had two main objectives. One objective was to study the dissolution mechanisms within the near-field of fall-out fuel particles and geochemical interactions within the trench between the soil and dissolved radionuclides. The second objective was to study the hydrodynamics of water and radionuclide transport within the unsaturated zone and in the aquifer underlying the burial trench. The geological situation is comparatively simple, comprising horizontally bedded eolian (permeable) and alluvial (less permeable) sands of Quaternary age that form an unconfined sandy aquifer overlying, at 30m, a low permeability Eocene marl layer. For 15 years radionuclides have been leached from the trench by rainwater (550-650 mm/y) and have penetrated through the unsaturated soil (2-3 m vertical distance) into the aquifer within which horizontal transport occurs. Annual recharge amounts to about 40% of precipitation. The inflow into the aquifer is event-based, with most of the recharge occurring during winter thaws and spring snowmelt and occasionally by large rainstorms during the summer-autumn period. The Project focused on the behaviour of 90Sr.

Figure 6 shows the development of the 90Sr plume as at June 2001. At the beginning of the project, it was believed that the site was suitable for a model validation exercise because it was considered to be 'simple' both hydrogeologically and in terms of waste characteristics. However, in both regards, the situation was revealed over time to be more complex than initially envisaged. For example, the

aquifer flow was found to be transient and 3-dimensional. As the project progressed and more was learnt about the factors influencing release and transport in the particular situation of the trench and aquifer, the modelling became more successful. The authors were of the view that the experience would be useful in dealing with future accidents. It was clear that a model based on initial assumptions about the wastes and the hydrogeology and using standard literature data values would not have provided a satisfactory projection. Significant factors influencing the outcome were transient effects on sorption interactions within the unsaturated zone and the geochemical evolution of the organic-rich source term.

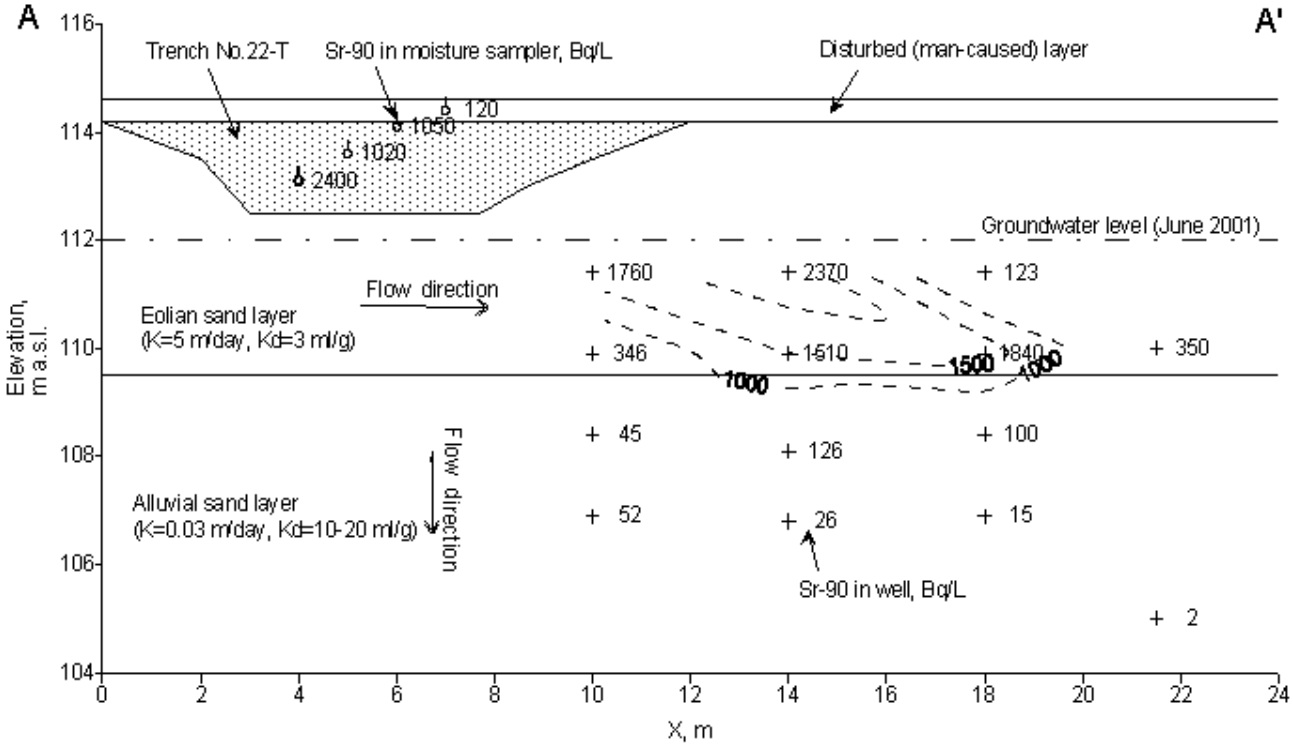

Figure 6. 90Sr distribution in cross-section through the disposal trench and aquifer in June 2001. http://www.eurosafe-forum.org/down2001/semb3_10.doc

BIOMOVS II: 'Wash-off' scenario

Konoplev et al. (1999) reported on the results of a validation exercise using data from two experimental plots close to Chernobyl. The experiments were developed within the framework of the BIOMOVS II international study (BIOMOVS II, 1996, Konoplev et al., 1996). One plot was subjected to simulated heavy rain, whilst the other plot used snowmelt. Participants in the exercise were requested to estimate the vertical distribution of total 137Cs and 90Sr and their specific forms in the soil prior to the experiments, concentrations of each radionuclide in surface runooff (separately for particulate and dissolved forms) and the total amount of each radionuclide lost from one of the plots during the experiment.

The experiments provided an opportunity for (1) evaluation of the movement of contaminants from soil to water; (2) calculation of the alteration and migration of contaminants in soil over different time scales; (3) increased understanding of contaminant transport at a process level; and (4) development and use of methods for the estimation of key parameters. A specific objective was to take into account chemical speciation and its effect on the transfer of contamination from soil to

water, as well as the geochemical and geophysical processes that affect such transfers.

The results showed considerable variation between the models and discrepancies with field observations (Figure 7). In general the predictions about speciation chemistry were unrealistic and it was found to be necessary to determine rates constants for the fixation and remobilisation transfers and not to assume the extent to which a radionuclide was present in an exchangeable form. The model that had most success (MOVE) used a method for estimating site-specific the values of the vertical migration parameters and also included convective transport of the dissolved radionuclide fraction. It was concluded that the use of expert judgement based on literature data in the absence of test data reduced the accuracy of predictions and brought additional uncertainty. It was recommended that risk assessment models should include submodels for estimating key model parameters, taking account of local environmental characteristics and those of the radionuclides involved.

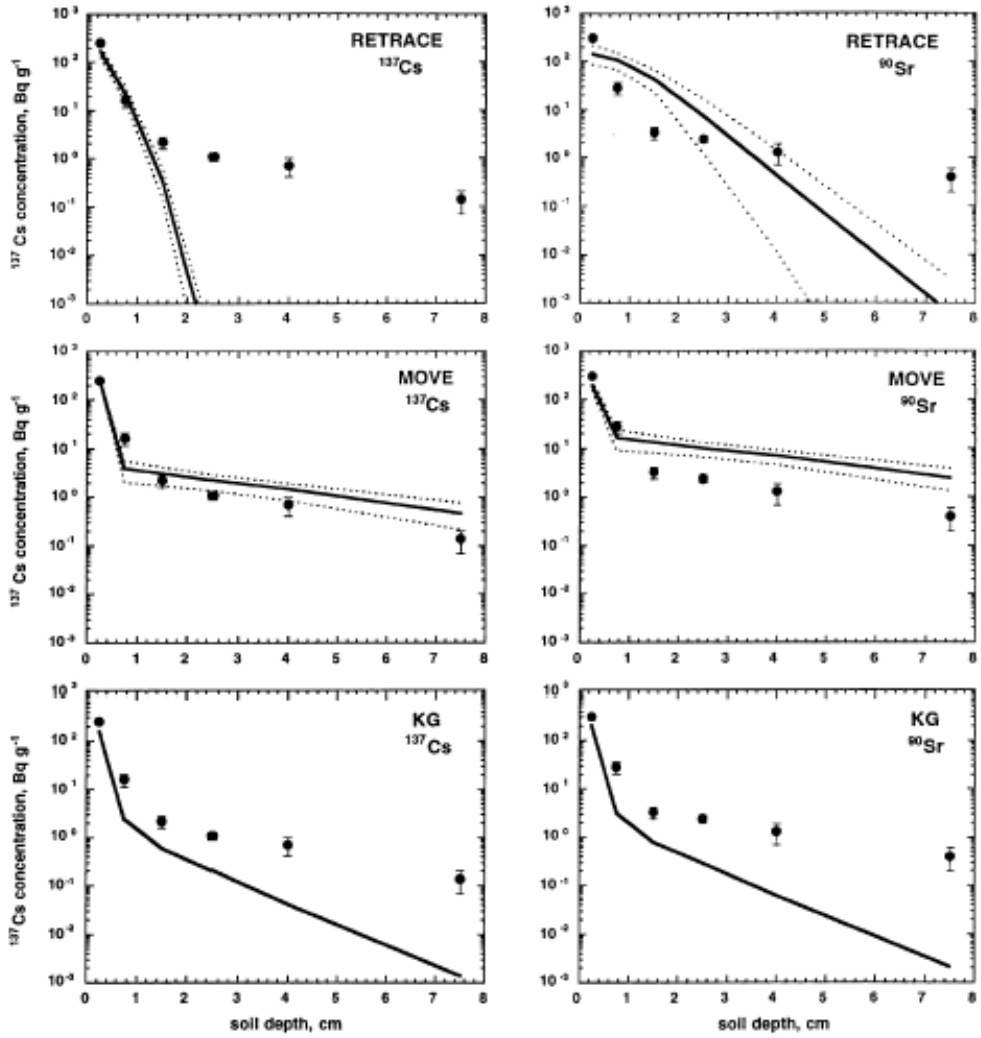

Figure 7. Comparison of predictions using the models RETRACE, MOVE and KG (solid lines) with observations (solid circles) for the vertical distribution of 137Cs and 90Sr in soil. Dashed lines represent 95% subjective confidence intervals on the predictions, vertical bars represent 95% confidence intervals on the observations.

BIOMASS: Iput Catchment

The main aim of the Iput river catchment modeling exercise was the reconstruction of the radioecology and assessment of doses within an area that was highly contaminated as a result of the Chernobyl accident (IAEA, 2003). The exercise was focused on concentrations in foods and doses to humans rather than on radionuclide behaviour in soils. However, an adequate description of the behaviour of radionuclides in soils is essential for correctly estimating concentrations in food stuffs.

The models employed for the representation of radionuclide migration in soils varied from the simple empirical to the detailed dynamic. The models differed from each other in the number of physico-chemical processes considered, as well as in the number of model parameters used in the calculations. In the simple models, one or two empirical parameters were used; numerical values of these parameters were taken from the literature or estimated from available data on the vertical distribution of radionuclides in soil.

The predicted dynamics of 137Cs concentrations in soil, presented in Figure 8, clearly demonstrate the great variability of predictions obtained with different assumptions about the values of key parameters. The lack of data on site specific values of key parameters representing 137Cs behavior in soils may be considered as the main source of misprediction in calculations of 137Cs activity in the root zone of plants, which, in turn, results in misprediction of concentrations in agricultural plant. In common with the findings from the BIOMOVS study reported above (Konoplev et al. (1999), radionuclide speciation and the kinetics of transfers between species was indicated to be the most significant consideration in the modelling of radionuclide mobility and plant availability.

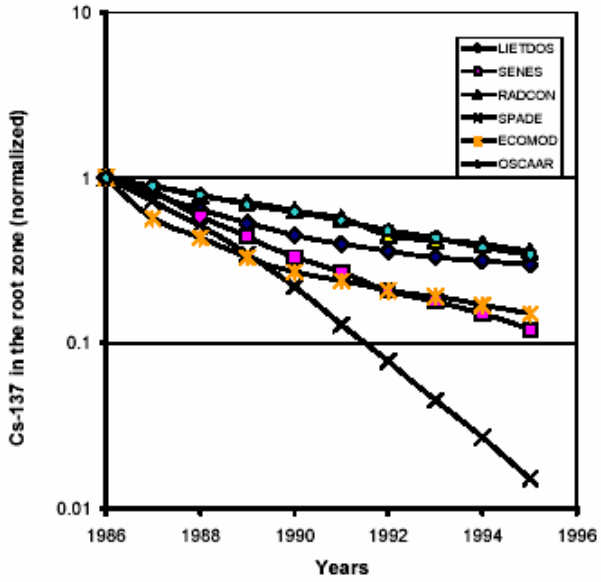

Figure 8. Predicted dynamics of a decrease of bioavailable 137Cs in the Iput test area (arable soils, root zone). Data have been normalized to the predicted values of the initial contamination.

Relevance

The Chernobyl accident has provided many opportunities to study the behaviour of radionuclides under a very wide range of conditions. Because of the intensity of contamination and also because of the amount of research interest generated by the accident, much has been learn about radionuclide behaviour that is potentially relevant to the management of radioactive waste. Information on transport under non-equilibrium situations is particularly helpful as is information on transport within natural (i.e. heterogeneous) media. Although much of the information relates to 90Sr and 137Cs in the surface environment, it is capable of being generalized and has value in relation to other contaminants under different situations.

Research carried out since the Chernobyl accident has reinforced the commonly held view that river floodplains are the landscape setting that should be the focus of attention in near-surface and biosphere models developed for the purpose of assessing the groundwater pathway derived risks that might arise from the disposal of radioactive wastes underground. River floodplains are the areas in which groundwaters are likely to emerge and interact strongly with surface waters. They are the areas most likely to act as sinks for radionuclides. They are readily accessible to humans and are commonly used for pasture for grazing. They are areas where fine grained sediments tend to accumulate by overbank and downslope deposition and hence are favoured locations for the accumulation of strongly sorbed contaminants. Floodplains may be associated with organic soils and hence may retain or accumulate contaminants that tend to readily form organic complexes. The Chernobyl experience has emphasized the need to account for speciation in radionuclide transport models and to be able to predict speciation under different landscape, soil and environmental conditions. The ability to predict speciation under widely varying surface and near-surface conditions should lead to an improved ability to predict the behaviour of contaminants in groundwaters.

Chernobyl has provided new information on radionuclide behaviour in upland, forest and natural ecosystems and as a result, a large dataset exists. It is also the case that radioecological models are available for a wider range of environments than was previously available and they can be employed with greater confidence. Although 90Sr and 137Cs are of limited interest in themselves, they have acted as tracers for transport mechanisms of potential interest to such deep geological disposal concepts. The Chernobyl experience is mainly relevant to an understanding of radionuclide behaviour under unsaturated conditions and within shallow unconfined aquifers. This hydrogeological setting would be suitable for evaluating the conduct of contaminant migration models.

Limitations

Much of the data relating to the Chernobyl accident concerns the behaviour of 90Sr and 137Cs. These radionuclides are of limited interest in terms of the risks associated with geological disposal of solid radioactive waste, but they have acted as tracers for transport mechanisms of potential interest to such disposals. The Chernobyl accident involved deposition of radionulcides to surface soils in the form of particles. This mode of contamination has limited relevance to assessments of the potential risks that may arise in the biosphere as a result of the geological disposal of radioactive wastes, but it provides some insight into near-field processes in shallow disposal facilties. Subsequent dissolution of components within the contaminant particles and their migration through soils has more relevance. The environmental research following the Chernobyl accident was unfocused in terms of

the situations relevant to deep disposal, although it does include floodplain and aquatic environments and stream-aquifer interactions.

Although the Chernobyl dataset is extensive and is available for evaluating the predictive power of models, they can generally be made to replicate field data through an iterative process of trial and error during which 'effective' values of parameters are determined and retrospectively justified. This does not necessarily increase the preparedness of models and modellers to deal with future situations.

Quantitative information

Data are generally available on radionuclide concentrations and depth profiles in a variety of soils, as a function of both depth and time.. These data are available for testing hypotheses about radionuclide behaviour. The data on radionuclide sorption, speciation and kinetics are probably the most valuable in this regard. The data on soil characteristics are variable as are the data on contaminant speciation with different quantities being reported using different methods.

The model testing and intercomparison exercises provide sources of data that may be helpful in the development of models designed to predict radionuclide speciation under a variety of conditions.

Uncertainties

The Chernobyl accident was, in effect, an uncontrolled experiment with regard to radioecological research. Natural systems are complex and their interpretation is associated with uncertainty. In the case of Chernobyl this uncertainty is increased by lack of information on the form, composition and spatial variation in contaminant deposition. Natural systems are anyway complex and their interpretation tends to be ambiguous. The data on 'speciation' acquired by means of chemical extraction procedures does not provide unambiguous information of chemical species.

Time-scale

The time-scale is that since the Chernobyl accident in 1986 and has provided valuable insights into short and medium term radionuclide mobility.

PA/safety case applications

Experience from the Chernobyl accident has improved knowledge of the ways in which soils influence rates of transfer of contaminants between solid and solution phases and influence the mobility and bioavailability of contaminants. The Chernobyl accident has also shed light on the processes that cause radionuclides to be redistributed within the biosphere. Experience from the Chernobyl accident continues to improve the models and data available for safety assessments.

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Added value comments

Each case study of radionuclide behaviour under different circumstances adds to the ability to respond to or anticipate radionuclide behaviour under future situations. The Chernobyl data clearly demonstrate that pathways exist for the rapid and widespread vertical transfer of radionuclides from soils to groundwaters via the vadose zone. This includes those radionuclides commonly considered to be strongly particle-reactive and hence with a strong tendency to be immobilised in geological media, The transport mechanisms of interest include convective flow under non-

equilibrium conditions, the presence of preferential pathways and the existence of mobile species or of the conditions necessary to maintain mobility.

Potential follow-up work

Further consideration of the potential for developing assessment models that can more readily accommodate the complexity of natural systems in respect of both physical and chemical transport processes. The determination of specific radionuclide species in geological media to replace apportionment based on selective chemical extraction. Replacement of Kd-based models by models that employ kinetic speciation data and can take account of soil compositional and environmental information. There is a need to explore methods of determining radionuclide speciation in as close to an in-situ condition as is possible. The most commonly reported methods employ extractants that change the system being investigated. The early phase, high mobility of Chernobyl radionuclides has not been adequately explained.

The model tests that have been conducted using Chernobyl data indicate the need to improve the capability to predict radionuclide mobility under non-equilbrium conditions. There is a requirement to have available models for the prediction of radionuclide speciation under different and varying environmental conditions.

Keywords

Chernobyl, preferential flow paths, speciation, groundwater, soil, redistribution, model testing

Reviewers and dates

Paul Degnan (UK Nirex) & Paul Kane (Kanvil Earth Sciences), October 2004