Chernobyl $^{137}$Cs in lichens: Use of specific activity showing differences in transport routes of Cs and $^{137}$Cs

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Lichens, sampled around Chernobyl in 1990 and in Slovenia in 1992, were analyzed for radionuclides and elements, including Cs. Data were processed by Monte Carlo aided Target Transformation Factor (MCTTFA). The resulting factors indicate environmental accumulation routes. $^{40}$K:K and $^{210}$Pb:Pb ratios tested the procedure, showing fully mixed $^{40}$K and K, while for $^{210}$Pb and Pb the expected variability in specific radioactivity was confirmed. $^{137}$Cs showed a large factor-specific variability in $^{137}$Cs:Cs ratios. For the 1990 data, MCTTFA singled-out $^{137}$Cs in a separate factor, suggesting that the overall behavior of $^{137}$Cs cannot be derived from that of Cs: source (route)-related specific radioactivity makes that all individual transport-components should be taken into account.

Introduction

The approach to the study of transport, concentration and effect of radionuclides in the environment does not differ significantly from those applied to other contaminants.1 A common feature of many recommendations for soils, plants and aquatic systems is that they do not include any time-dependent parameters. As a result, these models are not closely related to physical, chemical and biological processes occurring in the systems they describe. Ideally, dynamic models should be developed and used for all aspects of the transport of radionuclides in the environment. Possibly, the difference between the two approaches can be expressed by the principal difference between the concepts of Bioconcentration Factor and Transfer Rate, used in static and dynamic expressions of radionuclide behavior, respectively.2 As a consequence, judging radionuclide distribution from data on the overall distribution of the stable isotopes of the related element implicitly assumes similar overall end-point behavior, which in turn implies similar specific radioactivities in all environmental transport and accumulation routes.

The present paper addresses the behavior of environmental $^{137}$Cs relative to that of Cs, in a time frame of 6 years. In the context of the 1986 Chernobyl accident, from which $^{137}$Cs was released into the environment, two biomonitoring surveys were carried out. In 1990 a survey was performed in various regions around Chernobyl,3 and in 1992 a survey throughout Slovenia,4,5 both using lichens as the biomonitoring organisms. Throughout these 4–6 years, the lichen $^{137}$Cs inventory has been changing continuously (see Reference 6 for $^{137}$Cs and Reference 7 for cesium), following the environmental changes in $^{137}$Cs (concentration, half-life). The interpretation of the multi-element data obtained was performed by Monte Carlo aided Target Transformation Factor Analysis (MCTTFA).8,9 The objective was to visualize the factor contents of both $^{137}$Cs and Cs, which may indicate source-dependent behavior and distribution of $^{137}$Cs and Cs. The MCTTFA performance was calibrated by processing data on K and $^{40}$K, and on $^{210}$Pb and Pb.

Experimental

Surveys

In summer 1990, an IAEA co-ordinated biomonitoring survey was carried out, concerning the aftermath of the 1986 Chernobyl accident in the USSR. The lichen Parmelia sulcata was sampled in the Novozybkov, Bragin and Ovruc regions around Chernobyl (Fig. 1). The total survey comprised 128 samples, taken at 64 sites. Details on survey areas, sampling and sample preparation routines are presented by VAN DE BERG et al.3 In Slovenia, a national survey was performed in 1992, using the epiphytic lichen Hypogymnia physodes (L.) Nyl (Fig. 1). Here, 133 samples were taken and processed from 86 sampling sites following procedures described by JERAN et al.4

Analyses

For the USSR survey, $\gamma$-spectrometric determinations of $^{137}$Cs were performed as reported by VAN DE BERG et al.3 Multi-element determinations were carried out by routine instrumental neutron activation analysis (INAA) at the IRI Institute, following procedures described by BLAUAUW10 and BODE.11 The analytical performance was monitored by the regular analysis of the reference material NBS-1572 (Citrus Leaves).

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Fig. 1. Sampling sites, and $^{137}$Cs (Bq/g) and Cs concentrations (mg/kg) in the USSR survey (left column) and Slovenian survey (right column). Lichen species used were Parmelia sulcata (USSR) and Hypogymnia physodes (Slovenia). Interpolation routines in mapping used $1/r^2$ weighing of distance ($r$), grid cells were obtained by drawing $50 \times 50$ lines in a square fitting the survey area.