MOBILIZATION OF CESIUM IN ORGANIC RICH SOILS:  
CORRELATION WITH PRODUCTION OF DISSOLVED ORGANIC  
CARBON

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Abstract. A study of the downward movement of $^{137}$Cs in an undisturbed forest soil is presented. Seasonal variations and depth profiles of $^{137}$Cs activities were measured in seepage water, which is the transport medium for the downward movement of anthropogenic substances in soils. Furthermore the correlation of $^{137}$Cs mobilization and production of dissolved organic carbon (DOC) was investigated. Seasonal variations of both $^{137}$Cs and DOC fluxes in the seepage water in a depth of 5 cm depth were observed, where the maximum fluxes in the summer months were about one order of magnitude higher than the minimum fluxes in the winter months. $^{137}$Cs fluxes are found to be correlated with DOC fluxes with a correlation coefficient of $r = 0.63$, and both are highly correlated with soil temperature. This indicates that cesium is bound to soil organic material. The production of DOC is controlled by microbial decomposition of soil organic matter and we assume that this holds true for the $^{137}$Cs release as well. The actual transport velocity (0.2 ± 0.14 mm/a) of $^{137}$Cs (calculated by the weighed mean of $^{137}$Cs concentration in the seepage water and the total $^{137}$Cs content of the soil) is about one order of magnitude less than the mean transport velocity (1.2 ± 0.3 mm/a) over the past 25 years (calculated from the $^{137}$Cs depth profile). It is possible that the transport velocity of $^{137}$Cs in undisturbed soils decreases with time as it binds to aged organic material which is less easily decomposable than fresh organic material.

1. Introduction

During the last decades radioisotopes were anthropogenically released into the atmosphere and deposited on the soil surface. In the soil the transport of anthropogenic substances from the surface to the root zone and groundwater is regulated by their chemical properties and by the displacement of their carrier substance. Risk assessments of plant uptake and groundwater infiltration, and therefore the uptake of pollutants via the human food chain, are based on parameterizations of these transport processes. In the top soil layer clay particles and soil organic matter act as carrier for many anthropogenic trace elements. In this paper a new approach towards a better understanding of the transport component which is dependent on the carrier is presented and discussed.

To investigate the effects of soil organic matter turnover on the mobility of trace elements in a natural system the study was carried out in a forest ecosystem. We investigated the behavior of $^{137}$Cs, one of the relevant artificial radioisotopes in the environment which may also be used as a tracer for the behavior of other
anthropogenic trace elements. $^{137}$Cs has no natural background and is easy to detect by $\gamma$-spectrometry.

$^{137}$Cs ($t_{1/2} = 30.1$ years) is widely distributed in soils of the northern hemisphere. One main source of $^{137}$Cs has been the atmospheric nuclear weapon testings in the sixties with maximum deposition rates in 1963 and 1964. In Europe a second main source of $^{137}$Cs was the Chernobyl reactor accident in 1986. The $^{137}$Cs inventories in Central European soils range from $10^3$ to $10^4$ Bq/m$^2$. The entire $^{137}$Cs inventory in undisturbed forest soils is contained in the upper 20 cm.

From a survey of the depth distribution of bomb produced $^{137}$Cs in forest soils Dörr and Münnich [1991] concluded that cesium transport is mainly controlled by soil organic matter displacement and turnover. Laboratory experiments [Tegen et al., 1991] also indicated the influence of organic matter turnover on the mobility of cesium.

The present study continues the investigation of the mobility of cesium in undisturbed soils. In the top layer of an organic rich forest soil parallel measurements of $^{137}$Cs, DOC, seepage water fluxes, and other relevant parameters to describe the soil organic carbon reservoir were carried out over a period of 18 month.

2. Materials and Methods

The sampling site is located in the upper Rhine valley about 15 km south of Heidelberg (Sandhausen). The humus layer below the beech/spruce forest is about 15 cm deep. The clay fraction in the sandy soil is negligible. The hydrology and hydrochemistry of this area has been described by Cordt [1990], Dörr and Münnich [1987a], Jacob et al. [1992], Regenberg [1987], and Weyand and Schweisfurth [1988].

Seepage water was sampled using stainless steel lysimeter plates. Plates were installed at one site in depths of 5, 10, 30 and 50 cm. In a depth of 5 cm a second lysimeter plate was installed in a distance of about 3 m. The seepage water was collected in plastic bottles which were emptied once a week. The efficiency of the lysimeters was tested by Br$^-$ tracer experiments [Tegen, 1992].

To measure the DOC concentration in the seepage water 1 ml of the sample was first filtered through a 0.4 $\mu$m filter. Afterwards the DOC was completely oxidized to CO$_2$ by ultraviolet radiation. The produced CO$_2$ was measured quantitatively with a CO$_2$ Coulometer (UIC Coulometrics INC., No. 5011). This method is described in detail in Tegen [1992]. The reproducibility of the DOC concentration measurement is 2% while the natural variability (derived from parallel measurements of samples from the two plates in 5 cm depth) is 10%.

$^{137}$Cs was measured by low level $\gamma$ spectrometry (n-type HPGE detector, Canberra Packard, Frankfurt). The sample volume was 11 of seepage water for each measurement. As we were interested in the “dissolved” fraction of $^{137}$Cs the water samples were first filtered through a 0.4 $\mu$m filter. The measurement time was up