RADIONUCLIDE LEVELS AT TWO SITES IN A WATER EXTRACTION AREA IN THE NETHERLANDS AFTER CHERNOBYL

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Abstract. The coastal dune aquifer, providing drinking water for a large part of the population of the western Netherlands, is recharged by rainfall and artificial infiltration of Rhine water. Chernobyl fall-out has been detected in both water sources. At the Castricum lysimeter station the rainfall-derived water, draining from 2.25 m of unsaturated sandy soil, shows levels of Cs-137 around the detection limit of 20 to 40 mBq kg⁻¹. At this site, the soil itself retained some Chernobyl-derived Cs-137 in the top 10 cm, where a similar quantity of old Cs-137 has also been retained. Penetration of old Cs-137 is deeper (up to 70 cm) under oak vegetation than in the bare soil. In the infiltration channels, fed by Rhine water, the bottom mud contains only Chernobyl-derived Cs nuclides. Radioactivity from Cs-137 is about one tenth of that from natural radioactivity due to K-40. Cesium levels are apparently unrelated to adsorptive properties.

1. Introduction

For over a century the coastal dunes along the Dutch North Sea coast have provided water for the densely populated and highly industrialized western part of the Netherlands. Since natural groundwater recharge has become insufficient to compensate for the withdrawal, water is taken from the Rhine, pre-purified, transported by pipeline and infiltrated into the aquifer. In effect, the aquifer acts as a subsurface reservoir.

During the fallout episode following the Chernobyl reactor accident on the 26th of April 1986, the total amount of Cs-137 deposited from the atmosphere in this area varied between 500 and 3000 Bq m⁻², while beta-activity of Rhine water reached a peak of 13 600 Bq m⁻³ (not counting the contribution from K-40) on the 7th of May and remained high for several days (CCRX, 1986).

Understandably, this fallout caused some concern to the water supply companies. In the first place, no direct evidence was available as to how the radionuclides would behave in these particular soils, with very low organic matter and very low exchange capacity. And secondly, it was to be expected that radioactive materials would accumulate in certain materials during the water treatment process.

From the literature on the behavior in the natural environment of radionuclides generated by nuclear technology it appears that the persistent Cs-137 is generally adsorbed to a great extent in soils and sediments (e.g. Nishita et al., 1956; Bachhuber et al., 1981). However, some transport in the soil may occur (Shagalova, 1982), and as Watson (1963), and Kawase and Yokoyama (1973) have pointed out, some
anomalies do seem to occur. The amounts adsorbed do not necessarily correlate with the cation exchange capacity and soil-water relationships are suspected to somehow influence the distribution process. In addition, as long as diffusion of micro-quantities of electrolytes under field conditions and transport by non-Darcy flow in the soil remain little known phenomena, it has been considered worthwhile to check on the actual distribution of Chernobyl-derived Cs-137 in the water extraction area discussed here.

2. Materials and methods

The water extraction concession area of the Provincial Water Supply Company of North-Holland (PWN), 25 km NW of Amsterdam, is a suitable place for hydrological investigations because of the presence of the lysimeter station near Castricum next to the channels where Rhine water is infiltrated into the aquifer. For the location see Figure 1.

The terrain where the lysimeter site and the infiltration site are situated lies behind the Younger Coastal Dunes, in the rather flat Old Coastal Dune area, at approx. 3.75 m above mean sea-level. Average groundwater levels are about 1.50 m above sea-level. Therefore, the depth of soil above the groundwater level is generally around 2.25 m.

The four lysimeters, built in 1939–1940 and still functional, each consist of a concrete box 25 by 25 m and with a depth of 2.50 m, open at the top and encased in the soil in such a manner that the upper edges of the walls are flush with the soil surface. At the bottom of the box drainage pipes collect the percolating water after its passage through a depth of 2.25 m of unsaturated sandy dune soil. The time of passage of water from the sand surface to the drainwater collecting reservoir varies somewhat due to the finite distance (about 5 m) between the drain pipes at the bottom of the lysimeter. So any input pulse at the top of the lysimeter would result in a signal at the collecting vessel that would be somewhat more averaged out in time than would be the case in the natural soil. Despite this, quantity and composition of the water collected from the drainage pipes are expected to be very similar to quantity and composition of water recharging the groundwater body in the area. Details of the construction of the lysimeters may be found in Mulder (1985), and Stuyfzand (1984). Water balance and mean residence times of water in the lysimeters have been determined by Stuyfzand (1984) and are summarized in Table I. In view of the fact that lysimeter 1, which is devoid of vegetation, shows the shortest residence times, this lysimeter has been selected for monitoring the radionuclide content of drainwater. Accordingly, soil samples have been taken from non-vegetated soil nearby. To investigate the influence of vegetation cover on radionuclide distribution in the soil, the soil of lysimeter 3, with an oak forest cover, has been also sampled.

The infiltration system to the SE of the lysimeter station consists of interconnected channels, about 25 m wide and 0.5 m deep, with the length totalling about 4.5