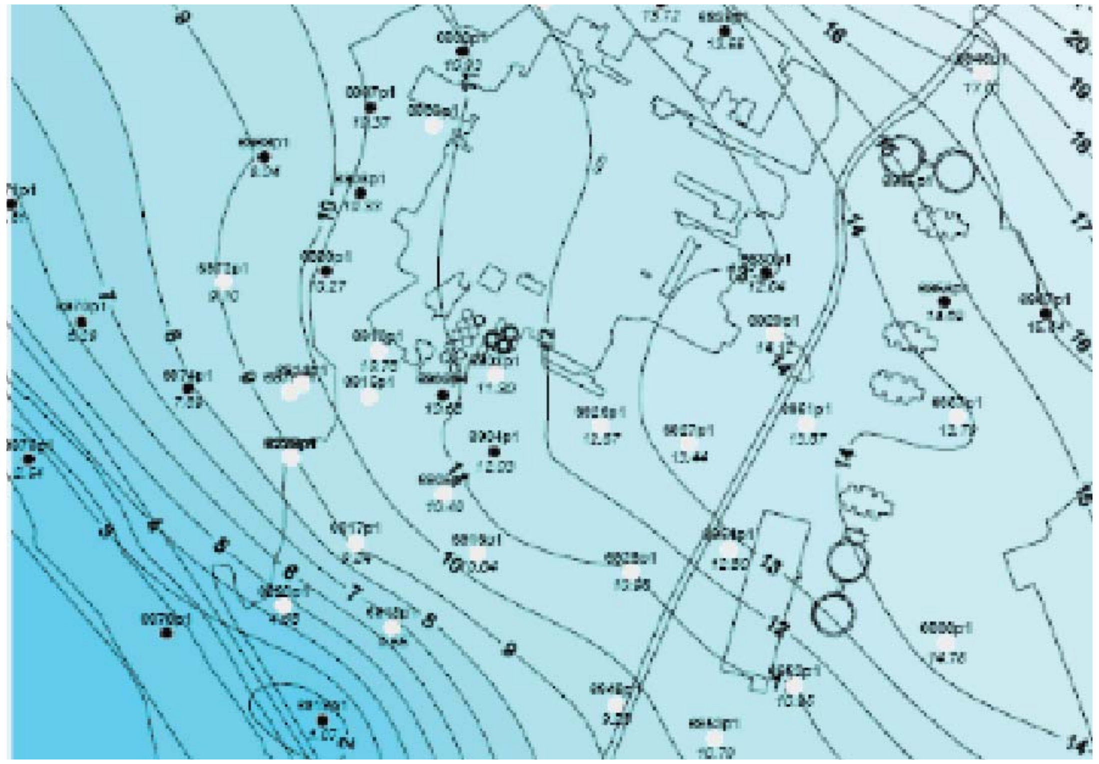
General Characteristics of the Principal Radioisotopes in Groundwater

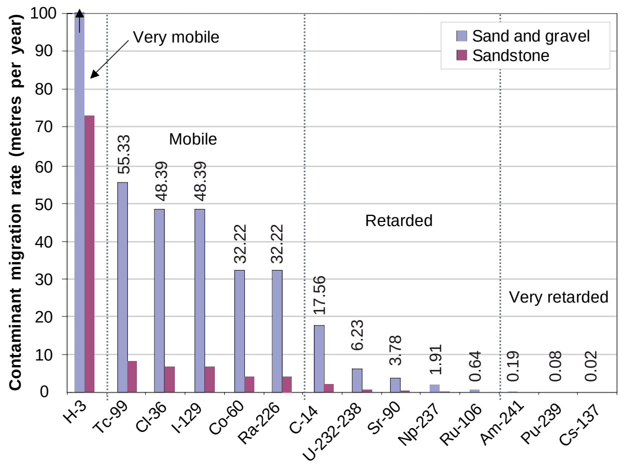


Boreholes drilled into the sediments below Sellafield typically encounter groundwater at 5 to 15 meters

The groundwater beneath the Sellafield site is monitored to detect for the presence of radionuclides. Each radionuclide has different properties, which will affect their movement and distribution in the groundwater environment. An understanding of these properties is therefore essential in the prediction of radionuclide migration. This paper briefly outlines the properties of the radionuclides analysed for in the Sellafield groundwater monitoring programme.

A list of radionuclides likely to be present in groundwater beneath the Sellafield site with estimates of travel velocities and distances are shown in Table 1. It should be recognised that these travel distances and velocities are only indicative as the calculations, which include a number of assumptions, are simplifications of far more complex transport processes.

However, it can be seen that tritium in particular appears to be capable of migrating significant distances (3.5 times as far as the next most mobile radionuclide, technetium-99). Tritium is not subject to any sorption onto the ground it passes through and it is widely accepted that it moves at the same velocity as groundwater.



Tritium

The radio-isotope tritium (^3H) was specifically manufactured at Sellafield from 1955 to 1962. It was produced by irradiation of lithium-magnesium cartridges which were subsequently heated in furnaces to drive off ¬^3H gas. The spent furnace linings, still impregnated with residual quantities of tritium, were disposed of in trenches, in a dry silo and in concrete mortuaries. Tritium is also generated in nuclear fuel by ternary fission during routine commercial operation of reactors and will be present in the spent fuel reprocessing circuits, albeit in very much smaller quantities compared to the deliberate manufacturing phase. Potential sources of tritium leaked to ground from spent fuel processing include active evaporator overheads as well as effluent treatment facilities, ponds and sludge storage tanks.

Tritium is present in very low concentrations in the natural environment due to the effects of cosmic radiation in the atmosphere, but the following discussion relates only to the artificially produced isotope. The behaviour of tritiated water is indistinguishable from unaffected groundwater and therefore this isotope is the most mobile of the group of radioactive contaminants. However, it has a relatively short decay half-life (12.3 years) and it is also readily dispersed. Tritium may have first entered the groundwater in the mid-1950's, presumably as a consequence of rainwater leaching spent furnace liner waste posited in trenches within Separation Area. The presence of tritium in springs and boreholes was first observed in the mid-1970's and monitoring since that time has shown a steady decrease in activity concentrations.

From the available data, the three-dimensional spatial distribution of tritium activity is very variable and is not easily represented by a simple contour map of activity values. The maximum activity levels of approximately 10,000 Bq/l (1.0 E+07 Bq/m^3) are observed in monitor wells closest to Separation Area and generally decrease down-hydraulic gradient towards the river Ehen until the isotope becomes undetectable at the laboratory detection limit of ~ 100 Bq/l (1.0 E+05 Bq/m^3). For comparison, the World Health Organisation (WHO) gives a guideline drinking water standard for tritium of 10,000 Bq/l and the UK Drinking Water Inspectorate (DWI) has an indicator value of 100 Bq/l above which further analysis of the radioactive isotopes in the water should be carried out.

Technetium-99

This isotope, which is a long-lived fission waste product (half life of 212,000 years), is less mobile than tritium, but it is still soluble and is capable of continuous migration in groundwater. It has been observed in monitor well samples and is apparently derived from more than one source inside Separation Area.

Analytical determination of technetium-99 is not as straightforward as for tritium and routine monitoring for this isotope did not begin until 2000. As a consequence, knowledge of the existence and extent of the technetium-99 plume is relatively recent and improved during the SCLS programme. The maximum activity concentration of technetium-99 observed during SCLS Phase 1 is 230 Bq/l (2.3 E+05 Bq/m^3), in monitor wells near to the site main gate. For comparison, the World Health Organisation (WHO) gives a guideline drinking water standard for technetium-99 of 100 Bq/l.

Strontium-90

This isotope has limited solubility in groundwater and readily binds to the glacial sediment.

Nevertheless, beta activity from strontium-90 is detectable in groundwater samples from a number of monitor wells inside Separation Area, where most of the contamination is contained, and also in some monitor wells outside of Separation Area where it forms a co-contaminant with other isotopes. Unlike tritium and technetium-99, strontium-90 has not migrated as far as the railway line and appears to be contained, for the most part, within the site boundaries.

Small areas of beta activity in groundwater, which are probably caused by strontium-90, have been observed during the SCLS programme in other isolated wells near to the Management Centre and between Separation Area and the Calder River. A longer period of monitoring and data collection is required before the significance of these anomalies, if any, can be ascertained.

Other radio-isotopes

The only other radio-isotope discovered in new monitor wells during the SCLS programme is caesium-137. Like strontium-90, this also binds to sediment and is only present in very low activity concentrations. It appears to be only detectable in filtered solids rather than as a dissolved component of the groundwater.

No evidence for migrating alpha emitters (uranium and trans-uranic isotopes) in groundwater was discovered during the SCLS programme.

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