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Groundwater travel time distributions of a drinking water well field characterized by ^{85}Kr, ^{3}H/^{3}He and ^{39}Ar

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The travel time distribution of a drinking water well field largely determines the future evolution of water quality. The goal of this study was to assess the value of groundwater age tracers (^{85}Kr, ^{3}H/^{3}He and ^{39}Ar) to characterize the travel time distributions of the production wells and the surrounding monitoring network for future water quality prognosis and well vulnerability assessment.

The Holten well field produces drinking water from sandy ice-pushed ridges and peri-glacial aeolian deposits in the east of the Netherlands. Seven production wells were sampled for ^{85}Kr, ^{3}H/^{3}He and ^{39}Ar. Four wells are screened at 15-45 m below surface ("shallow wells"), three at 45-70 m below surface ("deep wells"). The stable noble gas samples were collected in copper tubes. The ^{85}Kr and ^{39}Ar samples were collected by degassing 2-4m^3 of well water at the site. A particle tracking study using a numerical groundwater flow model provided initial estimates of the travel time distributions and expected tracer concentrations for each of the wells.

The travel time distributions were characterized by fitting various black box models (exponential, dispersion) to the measured tracer concentrations. Because these mathematical models can be too stringent, a discrete travel time distribution model (DTTDM) was developed. The DTTDM consists of five discreet bins of travel times: four 15-year wide bins (0-15, 15-30, 30-45, 45-60) and one for the "old" groundwater component. The distribution of travel times within each bin is assumed to be uniform. The contribution of each bin was varied by 5% increments, resulting in 10626 possible travel time distributions. These travel time distributions are "shape free": the shape is not constrained by a mathematical function. The measured tracer concentrations were compared to the 10626 predicted tracer concentrations and the best fit was selected and accepted if the Chi-squared probability exceeded 5%.

The tracer concentrations predicted by the numerical model matched qualitatively with the measured concentrations. The presence and age of old groundwater in the deep production wells was indicated by the ^{39}Ar measurements. Radiogenic helium was detected in two of the three deep wells. The detection of ^{85}Kr revealed a very young groundwater component in one of the three deep wells that was not predicted by the numerical model. This indicates a vulnerability to recent contaminations in the capture area of this production well.

While ^{85}Kr and ^{39}Ar represent either the young and old component of groundwater ages, ^{3}H/^{3}He is sensitive to water components that recharged in the 1960s when the ^{3}H concentrations in precipitation were highest. The combination of ^{85}Kr, ^{3}H/^{3}He and ^{39}Ar provides crucial information to determine accurate travel time distributions in the age range up to 1000 years. The discrete travel time distributions calculated for these wells have been used to assess the vulnerability to anthropogenic contamination and provide future water quality prognoses.

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