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Journal of Environmental Radioactivity 92 (2007) 16–29
JOURNAL OF ENVIRONMENTAL RADIOACTIVITY
www.elsevier.com/locate/jenvrad

Systematics of radon at the Wairakei geothermal region, New Zealand

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Received 13 January 2006; received in revised form 18 July 2006; accepted 8 September 2006
Available online 23 October 2006

Abstract

^{222}Rn and ^{220}Rn in geothermal steam at Wairakei, NZ, range from 11 to 19 500 Bq kg^{-1}, and 25 to 16 700 Bq kg^{-1}, respectively, but do not cause toxic concentrations in air. The wide ranges are mainly due to differences in different physical conditions underground (e.g. thin silica diffusion barriers), not geochemical differences. Groundwater Rn from outside the area probably plays only a minor role. ^{210}Po was found present in non-toxic levels in the steam. Historical records showed little change in Rn concentration over several decades, therefore potentially hazardous concentrations might be predicted from early exploration. ^{220}Rn concentrations at Wairakei should decrease as the field becomes steam-dominated. Rock surfaces were variably leached or enriched with U, Th, Ra and ^{210}Pb, providing a possible model for deposition in cooler regions near the field. Estimates of ^{222}Rn permeability ranged from 2 to 77% of the maximum possible, with a median of 13%.

Keywords: Wairakei; Rn-222; Rn-220; Po-210; Ra-226; Uranium; Thorium; Diffusion; Groundwater; Steam

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0265-931X/$ - see front matter
doi:10.1016/j.jenvrad.2006.09.003

1. Introduction

Radon, a natural radioactive gas and daughter of radium, exists in the environment mainly as ^{222}Rn (half-life 3.8 days, daughter of ^{226}Ra) and ^{220}Rn (half-life 56 s, daughter of ^{224}Ra). Both occur in geothermal field steam and our study area was a New Zealand geothermal field, Wairakei, previously surveyed for ^{222}Rn only (Whitehead, 1980). We describe Rn distribution, variability and the factors affecting it and for the first time we show that the radiological hazard from ^{220}Rn is negligible. We suggest the hazard from ^{210}Po is minor.

1.1. Physical conditions within the Wairakei geothermal field

In the Wairakei geothermal field, the underground feed to the wells has historically been pressurised hot water, and boiling occurred in the wells as the fluid ascended. With exploitation and the resulting reservoir drawdown, the depth at which boiling occurred deepened; this led to formation of steam caps within the upper rocks. Some wells that used to be liquid feed are now steam or mixed feed. In this paper ‘‘steam-dominated’’ indicates close to 100% of the feed to the well is steam, and ‘‘liquid-dominated’’ indicates wells in which the initial feed is liquid but some boiling occurs in the well. Those wells supplied by both a liquid and steam source are described as ‘‘mixed’’. These varying conditions somewhat affect the surface concentration of radon, because of gas partition properties, as we show later.

1.2. ^{222}Rn in geothermal steam

This radionuclide has been frequently analysed in geothermal steam, partly from radiological concern and partly because it should give information about conditions deep underground. Concentrations of ^{222}Rn are positively related to the enthalpy (Balcazar et al., 1991). Various other authors have suggested one should be able to derive an estimate of deep rock fracturing, porosity, the area of the heat transfer surface, and even the mean fracture width (Stoker and Kruger, 1975; Andrews et al., 1986; Andrews and Hussain, 1989). For a review see Ku et al. (1992). Significant radiological hazards have not been found.

1.3. ^{220}Rn in geothermal steam

From typical known ratios and activities of parent radionuclides in typical volcanic rocks it may be calculated that concentrations for ^{220}Rn (half-life 56 s) at equilibrium would be about 25% higher than for ^{222}Rn. However, some authors have found concentrations in geothermal steam as much as 1000 times higher (Horiuchi et al., 1979; Kamada, 1961a,b), which suggests routine pre-exploitation analysis for ^{220}Rn would be prudent. The present paper gives results for Wairakei, after several decades of exploitation, using a new analysis method with improved sensitivity, and also attempts to apply the suggestion of D’Amore and Sabroux (1976–1977), that it should be possible to use ^{222}Rn and ^{220}Rn contents to calculate measures of diffusion near the foot of geothermal wells.

1.4. Geochemical alteration

The rock for many metres around the deep fractures underground is highly altered (Steiner, 1977). During alteration, the macroscopic structure of the original rock is not removed but