STUDIES ON TRITIUM MONITORING AND GROUNDWATER DATING OF CRYSTALLINE ROCKS IN KOREA

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ABSTRACT

Environmental tritium samples were taken from precipitation, surface water, groundwater and sea water in Korea from 1961-1996. The tritium content of the precipitation, surface water, groundwater, and sea water in 1996 were found to be 10TU, 14TU, 15TU and 4TU, respectively. Our results indicate that the tritium content tends to increase with latitude and altitude. Moreover, the tritium content of surface water and groundwater near the heavy water-type nuclear power plant were measured at higher than natural levels. In addition, the tritium content of discharged water from the fracture zone of the horizontal tunnel in the Chungyang area was analyzed. Using the Piston Flow Model (PFM) and the Exponential Model (EM), the tritium content data were analyzed in order to date groundwater The results of the groundwater dating were approximately 14 to 20 years.

INTRODUCTION

Environmental tritium has been present in the hydrological water cycle and water velocity (IAEA, 1983, Larson 1982, Egbola 1983). However, in the 1960s, with the increase of activity related to atomic energy, the concentrations of tritium dramatically increased as measured by the International Atomic Energy Agency of Korea (IAEA). The IAEA measured tritium levels in precipitation between the years 1961 to 1976. From 1977 onwards, the tritium data were not collected and therefore raised some concerns. The regular measurement of tritium levels was restarted again in 1981 by the Korea Atomic Energy Research Institute in collaboration with Konkuk University. The purpose of this study is to investigate the concentrations of tritium in Korea from 1981-1996.

METHODOLOGY

Measurements of tritium were taken throughout Korea from 1981 to 1996. A monitoring station at Taejon was set up in order to measure the tritium levels in the precipitation. Samples from groundwater, surface water and sea water were gathered in the proximity of the nearby nuclear facility. In addition from 1990 to 1994, measurements were taken of the hydrological cycle and water velocity in groundwater in the Chongyang mine in ChoongNam Province. Input data of the hydrological cycle and the groundwater velocity prior to 1990 were collected from the IAEA. All the sample types including precipitation, sea water, groundwater and surface water were made into concentrated samples. The analysis of the contents was done by the Liquid Scintillation Counter method (Parkard 2550 model) (Calt, 1976).

RESULTS

Table 1 reports the results of our analysis of the tritium contents. From 1961 to 1976, the tritium content in the precipitation was collected from the IAEA samples from Pohang. In addition, from 1981 to 1986 the concentration results were from the data collected from the Taejon samples. However, due to the fact that no measurements of tritium samples were taken in Korea during the years 1978 to 1980, the analytical concentrations of the tritium samples from neighbouring countries were utilized. In addition, the results of the samples of surface water, groundwater, and sea water levels of tritium from the monitoring sites are indicated in Table 2.

Table 1 Tritium concentration of precipitation in Korea (Pohang : 1961-1976, Taejon : 1981-1996)

Year	Tritium (TU)	Year	Tritium (TU)	Year	Tritium (TU)
1961	39.0	1972	40.8	1987	14.9
1962	225.1	1973	31.0	1988	21.2
1963	1384.6	1974	33.6	1989	11.6
1964	720.3	1975	22.6	1990	8.3
1965	347.6	1976	18.4	1991	8.7
1966	238.9	1981	38.6	1992	9.6
1967	148.5	1982	32.8	1993	9.6
1968	98.2	1983	22.4	1994	9.3
1969	82.8	1984	18.8	1995	9.2
1970	63.5	1985	19.5	1996	7.1
1971	70.2	1986	26.4	-	-

Table 2 The distribution of the average yearly tritium concentrations of surface, groundwater and sea water in Korea (Unit: TU)

Site	Surface Water	Groundwater	Sea Water
Cheju	13	12	4
Yonggwang	10	13	5
Kori	13	14	5
Wolsong	12	14	4
Taejon	13	14	-
Ulchin	15	14	5
Yongweol	17	18	-
Seoul	19	18	-
Kimpo	19	18	-
Moonsan	18	16	-
Samchuk	14	16	-
Baekdu Mt.	43	19	-

DISCUSSION

Tritium Distribution in Korea

The tritium concentrations in precipitation prior to 1951 were estimated from 4 to 20TU, varying depending on the distance from the coastline and the local temperature. However, in 1953, large quantities of anthropogenic tritium entered the water cycle and pushed the concentration of tritium above natural levels. A large concentration of tritium was also evident in the precipitation at the Ottawa station in Canada in 1963. The tritium levels were estimated to be about 10,000TU (IAEA 1992). However, following the enactment of the atmospheric test ban treaty, the value of tritium rapidly decreased. At approximately the same time, the Pohang station in Korea experienced increased tritium concentrations of 1,384TU. However, the tritium concentrations have recently decreased to the pre-1953 levels of approximately 10TU.

The levels of tritium in surface water tend to increase northward in Korea. At the most southern point of Korea, Cheju Island, the levels of tritium were measured at 13TU whereas at the most northern part, Baekdo Mountain, higher levels of tritium concentrations were measured at 43TU. Thus, the tritium distribution in Korea reveals the effect of latitude. In groundwater, the tritium contents vary from 10 to 19TU which is similar to the pre-thermonuclear period. However the contents in the oceanic and coastal sampling sites show considerably lower concentrations than from the continental sites. The tritium content of sea water in 1996 was approximately 4TU as shown in Table 2. The decrease in the concentration may be due to the water vapor exchange between the atmosphere and the sea surface.

Table 3 shows the results of the tritium monitoring effects in the water samples near the Korean nuclear facilities in 1995. Water samples taken from the heavy-water type (CANDU) nuclear power plant at the Wolsong site revealed tritium contents of 240TU and 373TU in the surface water and groundwater, respectively. (Table 3) These values are not a serious health hazard. The International Commission in Radiological Protection (ICRP) recommends that levels of tritium not exceed the annual limits of ($3x10^9$ Bq) for oral ingestion. However, with the construction of new nuclear power plants and the inevitable release of tritium, the levels of tritium are expected to increase in the next few decades. Therefore, the continued monitoring of tritium is recommended.

Table 3 The tritium monitoring of nuclear facilities in Korea. (Unit: TU)

Year	**Kori** [1)]		**Wolsong**[2)]	
	Surface Water	Groundwater	Surface Water	Groundwater
1981	27	25	28	26
1982	26	21	25	24
1983	23	24	45	101
1984	22	23	76	307
1985	18	15	99	203
1986	21	20	255	197
1987	23	22	345	240
1988	29	27	480	265
1989	23	25	351	219
1990	16	21	505	212
1991	21	20	581	251
1992	22	25	664	295
1993	15	10	530	356
1994	18	19	581	391
1995	14	15	240	373

1) Light water reactor, operated from 1978
2) Heavy water reactor, operated from 1983

Dating of Groundwater

Dating the exact age of groundwater with tritium is difficult due the variable input of tritium since the advent of thermonuclear testing in 1952. However, the presence of tritium in the groundwater can be used as a guide to determine the age of groundwater through radioactive decay. Through the rate of decay, the levels of tritium in the precipitation in 1952 of between 4TU and 20TU decayed to approximately 1TU to 4TU in the 1990s. However, in dating groundwater, any mixing, including tritium free water, may reveal higher concentrations of tritium due to the significant increase in the tritium levels in the 1960s. Therefore, for the recent samples, care should be taken when qualitatively interpreting the tritium data without an accurate estimation of the recharged local tritium content.

Since the direct age of groundwater may not be derived from the tritium data, several alternative methods have been proposed to compare the tritium sample at the discharge or sampling point with that of the recharge at the inlet of a groundwater system. Each respective contribution would be corrected for radioactive decay (at 5.5% per year) at the time of sampling. Thus, the distribution of residence times at each contribution area can be estimated. Note that this method assumes that the precipitation reaches the groundwater immediately.

There are two models for dating based on the behavior of groundwater flow: the piston flow model and the exponential model. The piston flow model (PFM) assumes that there are no different flow lines and that the tracer of both the hydrodynamical dispersion and the molecular diffusion are negligible. Thus the tracer moves from the recharge area with the mean velocity of water with the concentration at the discharge is $C_D = C_R e^{-\lambda t}$, where t is the turnover time or transit time. In the exponential model (EM), a tracer concentration C_R is mixed completely and instantaneously within the continuous flow of the discharged groundwater. The homogenized outflow of the tritium is discharged with a tracer concentration corresponding to that of the reservoir flow.

Table 4. Tritium contents of discharged water in the horizontal tunnel in Chungyang area. (Unit: TU) Sampling points:

Sampling Date	A	B	C	D	E
Jun. 1990	8.8	10.2	19.6	-	10.1
May. 1991	13.5	11.9	21.1	-	13.6
Jul. 1991	13.0	11.4	19.3	-	15.1
Apr. 1992	11.2	12.4	19.1	-	17.6
Jul. 1992	12.8	10.6	17.1	7.9	12.4
Aug. 1992	11.3	-	19.2	10.8	13.8
Jul. 1994	7.5	8.3	15.1	9.3	-
Sep. 1994	7.7	8.7	14.5	9.4	10.2
Oct. 1994	8.7	8.8	14.1	8.4	7.9

At the hydrogeochemical study site for radioactive waste disposal, the tritium contents of the discharged water from the fracture zone of the horizontal tunnel in the Chungyang area are reported in Table 4. The groundwater from the tritium contents of the discharged water was dated using the PFM and the EM. The data of tritium content in precipitation were used as an input function for groundwater dating. The results of groundwater dating estimated by the PFM were from 14 to 16.9 years. The EM results indicated that the groundwater was 11.3 to 14 years. These estimated values were checked by comparing the increase of the input level and output level of tritium data occurring in precipitation.

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KEY WORDS

Korea, Tritium, Groundwater, Surface water, Precipitation.