Groundwater flow systems in eastern half of Fukushima prefecture and its surrounding
~calculation of mean residence time based on CFCs and SF_6~

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Introduction

The tsunami occurring at the time of Tohoku Pacific Ocean earthquake on March 11, 2011, caused Fukushima Nuclear Power Plant accident happen to emit radioactive nuclei in the atmosphere. In Fukushima, groundwater has been used as not only agriculture but daily purposes. Since the radioactive nuclei move slowly in the groundwater system, it is necessary to continue observing groundwater for a long term to understand movement process and residence time. For that reason, it is important to understand groundwater flow system. The purpose of this study is to document the groundwater flow systems of the eastern half of Fukushima prefecture and its surrounding i.e. south of Miyagi and north of Tochigi prefectures. Here, the residence time of groundwaters collected in November, 2016 in July and October, 2015 and discussed based on the result of CFCs and SF_6 analyses.

Results

The study area was divided into three areas; area A (Hamadori and eastern slope of Abukuma mountains), area B (between the ridges of Abukuma and Echigo mountains included Nakadori), and area C (the southernmost part of Sendai plain).

The groundwaters from area A contained CFC-12 60-5000ppt, CFC-11 10-8000ppt and CFC-113 5-300ppt. The concentrations were lower in the groundwaters from the plains along the seashore than those from mountain area Those from area B contained CFC-12 100-10000ppt, CFC-11 10-10000ppt and CFC-113 8-500ppt. The concentrations were lower in those from the northern plain than the others. Although the concentrations of SF_6 were obtained only for the samples collected only from the central to southern part of the plain of this area, most of these waters contained excess SF_6 over the atmospheric one. The groundwaters from area C contained CFC-12 190-1000ppt, CFC-11 50-2000ppt and CFC-113 10-60ppt. Although the ranges of those value were overlapped with those of area A, only a few samples had the high concentrations.

Combination of the obtained concentrations suggest the four different models of groundwater flow i.e. Piston flow(PFM), Exponential mixing(EMM), the intermediate of PFM and EMM(PFM/EMM), Binary mixing(BMM). Some data could not be explained by these models. Most groundwaters can be explained EMM, BMM or PFM/EMM. Therefore, most of the studied groundwaters, especially from the plains, have more than two origins. However, the groundwaters from the mountain area had a single origin. Calculated mean residence times were 6-82 years and about 70% these were 15-40 years old. Groundwaters having short residence time within 15 years were concentrated from the slope to the foot of mountains over areas A and C. Many groundwater were 15-30 years old in the area B, while those older than 31 years were concentrated on foot of the mountains and in the plains. The residence time of areas A and C was generally longer than area B.

Discussion

Samples dissolving excess SF_6 were concentrated on the plain of area B probably because factories near the sampling sites discharged it in the 1990s, which was calculated recharge ages. According to Fukushima prefecture prevention of global warming promotion center, the amount of SF_6 discharge in Fukushima would reach the peak to cause the dissolution of the excess SF_6.
In the plains between Abukuma Mountains and Echigo Mountains (Nakadori), precipitations recharged on these mountains and the plain part were mixed in the aquifer. It must be the reason why many groundwaters can be applied to mixing model. The mixing model can explain the groundwater flows especially at the foot of mountains because there is meeting of groundwates originated from the dofferent recharge areas.
The shorter residence time of groundwater from the areas A and C than those from B would be due to the elevations of recharge areas. Groundwaters in areas A and C were mainly recharged on the lower Abukuma mountains and those in area B did mainly on the higher Echigo mountains; i.e., paths to the sampling sites at the lower altitudes are comparatively short from the Abukuma mountains than Echigo mountains.

