Groundwater flow system in Kherlen River basin revealed by environmental tritium

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I Introduction

Groundwater is very important in arid and semi arid region, where people use to support their life. As our study area, Kherlen River belongs to semi arid region, it is important to study groundwater flow system in the region. According to the previous groundwater study of the study area, Abe (2003) was described the difference of regional recharge rate, flow process, and the interaction between groundwater and river water depend on the stable hydrogen and oxygen isotopes and water chemistry. However, the residence time of groundwater flow system has not been studied yet. In this study, environmental tritium was used to reveal the residence time of groundwater flow.

II Study area and its hydrological characteristics

Kherlen River basin is located the northeast part of Mongolia, and is belonged to semi-arid climate region. According to the Onodera (1996) and Taniguchi (1996), groundwater flow process in arid and semi-arid region is mostly affected by precipitation amount and evapotranspiration. Therefore, we have to consider these factors to reveal the groundwater flow system in study area.

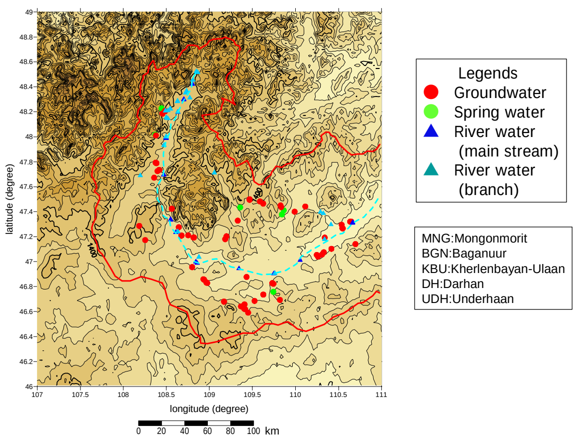

Fig. 1 Sampling points in Kherlen River basin.

III Methods

Hydrological investigation and sampling of groundwater, spring water, and river water were conducted in the study area from 25^{th} to 28^{th} of July, and from 3^{rd} to 12^{th} of October 2003. In total 117 water samples were collected and 51 samples were done for tritium analysis. The analytical precisions for the measurements of tritium concentration is around ±1.0 T.U.. Stable hydrogen and oxygen results by Abe (2003) has also been used for the consideration.

IV Results and discussions

1. Precipitation amount and isotopic property of groundwater and river water

Abe (2003) mentioned that precipitation was mainly occurred from May to September, and also mentioned that Mongonmorit area, the precipitation was relatively higher than that of the other part. And the stable isotope ratio in all sampled surface and subsurface water shows the isotopic characteristic of the summer precipitation. By this reason, Abe (2003) mentioned that the groundwater was originated from the local precipitation and the recharge process has occurred mainly in summer season; May to September.

2. Relationship between tritium concentration and local climate

Fig. 2 and Fig. 3 show distributions of total precipitation and vaporization during May to August in the study area. The distributions of those figure shows clear relationship to the topographical gradient. The precipitation amount shows to decrease toward the south, while the vaporization amount shows to increase, respectively. In the studied semi-arid area, it is expected that the groundwater flow process is affected both by precipitation amount and evapotranspiration.

Depend on this, we tried to obtain the relation among precipitation and vaporization amounts and tritium concentration of sampled water (Fig. 4, 5). The precipitation and vaporization amounts for each sampling point were estimated by the interpolation of Fig. 4, 5. This figure shows that variation range of tritium concentration is wide in relatively high altitude area. While, that of tritium concentration in relatively low altitude area ranges relatively narrow. Therefore, the altitudinal difference of tritium concentration range could be explained by precipitation or vaporization difference.

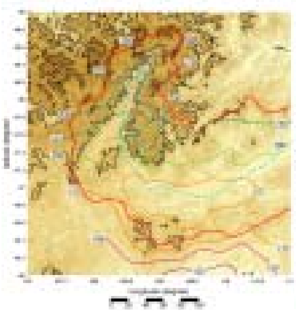

Fig. 2 Distribution of mean precipitation amount during May-Aug. (After ATLAS for Kherlen River)

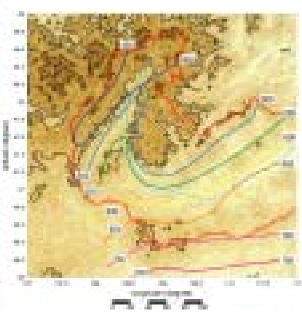

Fig. 3 Distribution of mean vaporization amount during May-Aug. (After ATLAS for Kherlen River)

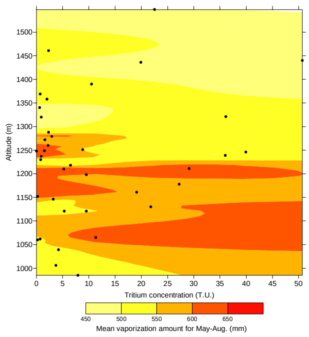

Fig. 4 Relationship among tritium concentration, altitude, vaporization.

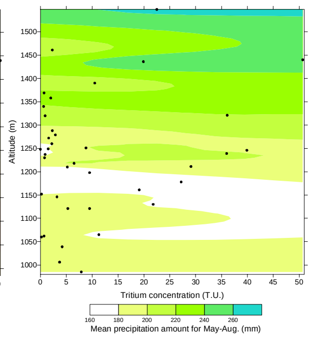

Fig. 5 Relationship among tritium concentration, altitude, precipitation.

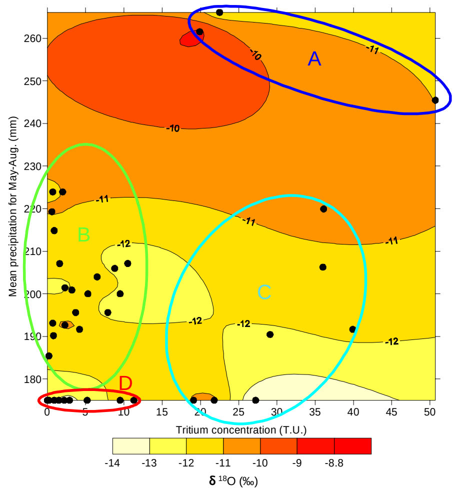

Fig. 6 Distribution of δ^{18}O ratio in groundwater on the relation figure of tritium concentration and precipitation.

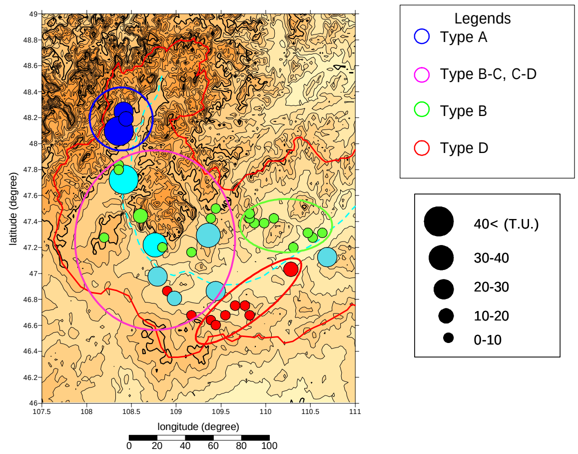

Fig. 7 Classification of groundwater type. Using tritium concentration, precipitation and δ^{18}O.

3. Classification of groundwater type

Fig. 6 shows the relation of tritium concentration, precipitation amount and δ^{18}O rate. Based on this figure, we tried to classify of the groundwater type in the study area into four types depend on their regional climatic and isotopic characteristics. Four typical groundwater types are as follows;

1) Type A: high tritium concentration with relatively high precipitation and low δ^{18}O ratio
2) Type B: low tritium concentration with middle precipitation and middle δ^{18}O ratio
3) Type C: high tritium concentration with middle precipitation and middle δ^{18}O ratio
4) Type D: low tritium concentration with relatively low precipitation and high δ^{18}O ratio

Fig. 7 shows distribution map of four types of groundwater. In this figure, Type A located in upstream area, while Type B and Type D distributed eastern or southern downstream area. The mixed area of Type B and Type C was located in the midstream area of the Kherlen River basin. According to this distribution pattern, it is possible to classify into four typical groundwater areas in the study basin (Fig. 7).

4. Estimation of residence time

In order to estimate the residence time of four groundwater type areas, the time-series variation of tritium concentration in precipitation measured by IAEA was used. In Mongolia, the precipitation data at Ulaanbaatar was measured from 1990 to 2000. In addition, the data from 1970 to 1983 is extracted from precipitation at Habarovsk in Russia, where is close in latitude as Mongolia. The lack of data from 1950 to 1970 was recovered by the estimation from the data at Ottawa in Canada (IAEA, 1953-2002). The data before 1950, the mean value between 4-25T.U. is used (natural level of tritium concentration in precipitation by GAT, 1980). The residence time estimation uses piston flow model. In addition, two cross sections along the representative slope were shown to understand the isotopic changes including tritium concentration. The residence time of each groundwater type are shown as follows:

1) Type A

Groundwater in this area showed the similar value as recent precipitation (Fig. 8). Estimated concentration range of this type groundwater almost covers the tritium variation in precipitation. Thus, residence time of this groundwater estimated to be relatively short after infiltration. As well, groundwater flow system was thought to be active because of less low tritium concentration groundwater.

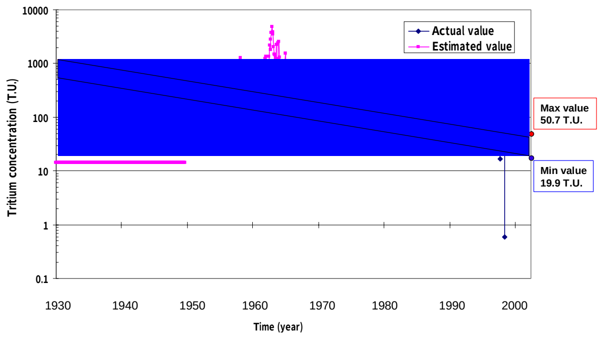

Fig. 8 Residence time of Groundwater in Type A area estimated from time series variation of tritium concentration in precipitation.

2) Type B-C, Type C-D

In the cross section of this area, d-excess and tritium range widely along the slope section. In detail, the d-excess decrease against tritium concentration increase. Thus, both groundwater with long residence time from the mountain and the recently recharged groundwater are existed in the same plain.

Fig. 9 shows the residence time of these groundwater types estimated from time series variation of tritium concentration in precipitation. Min value shows completely different from precipitation, while max value shows the similar concentration to the precipitation trend. Estimated recharge year from the min value is in the 1930's, while max value is quite recent. Thus, it is thought that groundwater in this area has wide range of the residence time.

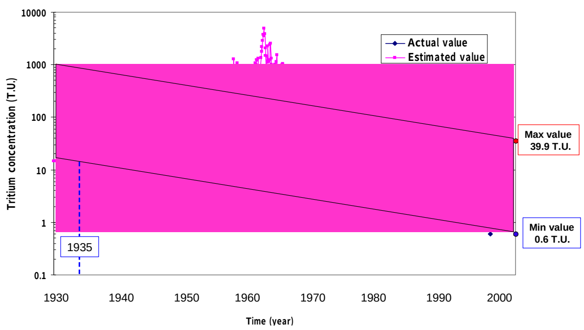

Fig. 9 Residence time of Groundwater in Type B-C and C-D areas estimated from time series variation of tritium concentration in precipitation.

3) Type B, Type D

Here, Type D is shown as an example because of similarity between Type B and Type D.

In the cross section of type D area, d-excess and tritium range narrow along the slope section. In detail, the d-excess shows relatively steady and tritium concentrations were also steady with very low values. By this reason, locally recharged groundwater with long residence time is existed locally. This means the recharge process in this area thought to be less active.

Fig. 10 shows the residence time of Type D groundwater estimated from time series variation of tritium concentration in precipitation. This groundwater shows completely different from the precipitation. Max and min values indicate the estimated recharge year in the 1950's and over. Thus, the residence time of this groundwater type is very long around 50 years at least, and the recharge rate is thought to be very few.

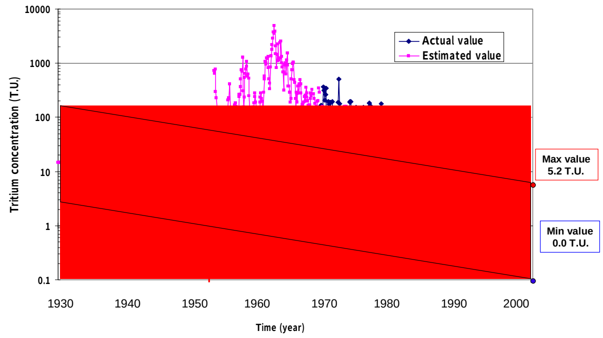

Fig. 10 Residence time of Groundwater in Type D area estimated from time series variation of tritium concentration in precipitation.

5. Hydrological property of river water

Fig. 12, 13 show the variation of river discharge and tritium concentration along the Kherlen River. In the upstream area, there are many branches that flow into the

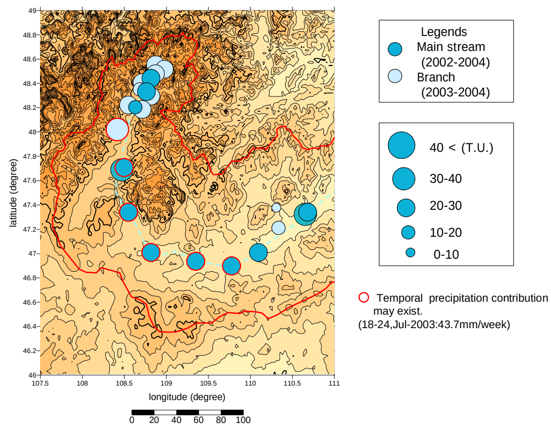

Fig. 11 Distribution of tritium concentration in river water.

main stream, and discharge in the main stream increased toward stream. On the other hand, below 1,400 m altitude there are a few branches and change of discharge rate is not much significant. Tritium concentration of branch river water in the upstream area is relatively higher than that in down stream and little concentration change is shown along the main stream water. Thus, it is thought that the contribution from branch to main stream is mainly occurred in upstream area, and not much in the downstream area.

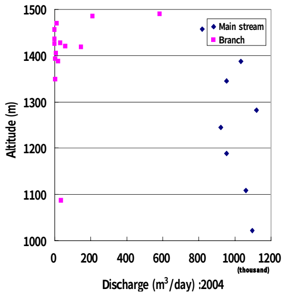

Fig.12 Variation of river discharge along the Kherlen River.

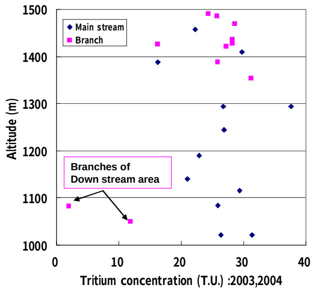

Fig.13 Variation of river tritium concentration along the Kherlen River.

V Conclusions

1) There exist clear concentration differences of Tritium concentration in the shallow groundwater in the study area; the relatively high concentration in the upper basin area with recent precipitation level (20-40 T.U.), downstream area with low concentration (less than 10 T.U.), and midstream area with both high and low tritium concentration mixing area.
2) Major reason to create this regional concentration differences is the difference of recharge process of the area which is mostly affected by the local precipitation amount.
3) The tritium concentration in the groundwater along the estimated flow line by the topographical valley cross section does not show the clear ageing trend calculated by radioactive decay of tritium. This trend is almost similar as that by HCO_3 content or EC content in the groundwater along the same line.
4) The difference between the short groundwater residence time in the upper basin area characterized by their relatively high precipitation amount and the long residence time in the dry downstream area could be firstly explained by the difference of local recharge rate. However, the existence of the permafrost layer within the groundwater aquifer may create the difference of groundwater flow scale and affect their residence time. To evaluate this permafrost effect, the groundwater flow simulation of the catchment's scale will be planned to conduct.
5) The tritium concentration in the Kherlen River water shows relatively high content in the upstream area and keeps this content to their mid and downstream. This means that the main stream water of the Kherlen River is mostly recharged by the upper basin area. This recharge character agrees quite well with that estimated from the change of the river discharge rate or stable isotopic ratio in the river water along the Kherlen River.

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