Budget analysis on groundwater and river water interaction in Kherlen River Basin, eastern Mongolia

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Hypothesis

Interaction between GW and River

GW to River

Permafrost

River to GW

No permafrost

Baganuur

Monganmorit

Kherlenbayan-Ulaan

Interaction between GW and River
But...
The groundwater wells seem to situate in a topographic hollow?
Objectives

- To quantify the interaction process between groundwater and river water
- To investigate water budget of the groundwater well
**Methods**

- **Interaction between groundwater and river water**
  - River discharge measurement of the mainstream and the tributaries

- **Water budget of the well**
  - Measurement of area of topographical watershed of the well
Spatial distribution of discharge rate observed from June 8 to 12, 2004.
Oxygen-18 and d-excess variation along the main stream

\[ d\text{-}\text{excess} = \delta D - 8 \cdot \delta^{18}O \]

Horizontal distance along Kherlen River (km)

\[ \delta^{18}O \text{ (‰)} \]

\[ \text{d-excess (‰)} \]

UDH

BGN

MNG

Oxygen 18

d-excess
Water and isotope budget of the stream

\[
Q_{in} - E + G_{in} + q_{in} = Q_{out}
\]

\[
Q_{in} \delta_{in} - E \delta_v + G_{in} \delta_g + q_{in} \delta_{qin} = Q_{out} \delta_{out}
\]

\(\delta_{in}\): isotope ratio of inflow; \(\delta_v\): isotope ratio of evaporated vapor;
\(\delta_g\): isotope ratio of groundwater; \(\delta_{out}\): isotope ratio of outflow;
\(\delta_{qin}\): isotope ratio of tributary
Isotopic fluctuation during evaporation

Craig and Gordon (1964)

\[
\frac{R_v}{R_l} - 1 = \frac{h_A(\delta_L - \delta_A)}{(1 + \delta_L) - \varepsilon^*} \frac{(a - h_A)(\frac{a \alpha_{v-l} e_{i,L}}{e}) + e_i}{e}
\]

- \( R_l \): isotopic ratio of liquid water
- \( R_v \): isotopic ratio of water vapor
- \( a \): activity at water surface
- \( \alpha_{v-l} \): fractionation factor
- \( e \): resistance against atmospheric vapor diffusion
- \( e_i, e_{i,L} \): resistance against isotope molecular diffusion in vapor and liquid water
- \( h_A \): relative humidity
- \( \varepsilon^* \): \( a (1 - \alpha_{v-l}) + \Delta \varepsilon \)
- \( \Delta \varepsilon \): \( (a - h_A)(e_i / e - 1) \)
Summary of budget analysis at the intervals along the stream

- **Mongonmorit→Baganuur**
  - Elevation: 1390 to 1290 m
  - Horizontal distance: 58 km
  - $Q_{in}$: 10.8 m$^3$/s
  - $Q_{out}$: 12.1 m$^3$/s
  - $\delta_{in}$: -16.0 ‰
  - $\delta_{out}$: -15.0 ‰
  - $\delta_g$: -11.2 ‰
  - $\delta_v$: -29.0 ‰
  - $\delta_{qin}$: -11.4, -10.2, -9.3 ‰
  - $q_{in}$: 0.003, 0.04, 0.02 m$^3$/s
  - $E$: 0.1 m$^3$/s (4 mm/d)
  - $G_{in}$: 1.0 m$^3$/s (1.7 x 10$^{-2}$ m$^3$/s/km)

- **Baganuur→Underhaan**
  - Elevation: 1290 to 1020 m
  - Horizontal distance: 247 km
  - $Q_{in}$: 12.1 m$^3$/s
  - $Q_{out}$: 12.6 m$^3$/s
  - $\delta_{in}$: -15.0 ‰
  - $\delta_{out}$: -12.6 ‰
  - $\delta_g$: -12.9 ‰
  - $\delta_v$: -24.6 ‰
  - $\delta_{qin}$: -11.5 ‰
  - $q_{in}$: 0.4 m$^3$/s
  - $E$: 2.4 m$^3$/s (16 mm/d)
  - $G_{in}$: 2.6 m$^3$/s (1.1 x 10$^{-2}$ m$^3$/s/km)
Water budget estimation of a well

\[ P - E - G_{out} - U = \Delta S \]

- \( P \): precipitation
- \( E \): evapotranspiration
- \( U \): pumping rate
- \( G_{out} \): groundwater discharge rate
- \( \Delta S \): change of storage volume
Water budget estimation for a well near Dergehaan

\[ P - E - G_{out} - U = \Delta S \]

Catchment area: 1,111,758 km²
\[ P: 226 \text{ mm/(Apr – Sep 2004)} \]
\[ E: 97 \text{ mm/(Apr – Sep 2004)} \]

\( G_{out} \):
- Saturated conductivity: \( K = 10^{-4} \text{ m/s} \) (Asano, 2004)
- Hydraulic gradient: \( 10^{-3} \)
- Depth of aquifer: 20 m (Groundwater data base, IMH, Mongolia)
- Width of groundwater discharge zone: 600 m
\( G_{out} = 38,400 \text{ m}^3/\text{yr} \)

For sustainable use of groundwater, \( \Delta S \) should be 0 mm,
\( U = 187 \text{ m}^3/\text{day} \)
Summary

• Groundwater should discharge into the Kherlen River from MNG to UDH.
  – Groundwater inflow rate in upper stream region might be more than that in lower stream region.

• Available volume of groundwater well at DGH seems to be enough, but not huge.
  – If you have a just half input of annual average precipitation for several years, the well might be dried out.

• More detailed quantitative estimation should be necessary for groundwater inflow and well budget.