Theoretical model of geothermal tail water reinjection based on an equivalent flow channel model: A case study in Xianxian, North China Plain

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Introduction: The goal of this simulation is to propose a theoretical model framework based on tracer experiments and equivalent channel models for inversion of unknown parameters of geothermal reservoirs and prediction of thermal breakthroughs in production wells.

The problem to be solved is:

1. How to applied the solute transport theory to modify the analytical solution describing the change in solute concentration in the production well.
2. How to Inverse the Parameters of Thermal Reservoir Based on MMA Algorithms.
3. How to obtain an analytical solution of the temperature change in the production well.

Computing method: The tracer migration process in the seepage channel can be described by the convection-diffusion equation in classical porous media (Bodin et al, 2003):

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} - u\frac{\partial C}{\partial x}$$

Through MMA algorithm to establish a theoretical framework for back analysis of thermal storage parameters. The objective function or the original optimization problem P can be defined as:

$$\mathit{Minimize}: f_0(\mathbf{x}) = \frac{1}{2}\sum_{i=1}^{n}\left(h_i(\mathbf{x}) - \overline{h}_i\right)^2$$

$$\mathit{Subject\ to}: h_1(\mathbf{x}) \geq 0$$

$$x_j^{min} \leq x_j \leq x_j^{max},\ j = 1, \cdots, n$$

Assuming that the water-rock interface temperature is equal, the differential equation for convective heat transfer control in the seepage channel is:

$$(\rho c)_f b\frac{\partial T}{\partial t} + c_w\frac{q_e}{h}\frac{\partial T}{\partial x} - 2k_r\frac{\partial T}{\partial y}\Big|_{y=\frac{b}{2}} = 0$$

assumes that there are several dominant seepage channels between the geothermal wells, the seepage in the dominant flow channel may be approximately equivalent to a one-dimensional Darcy flow.

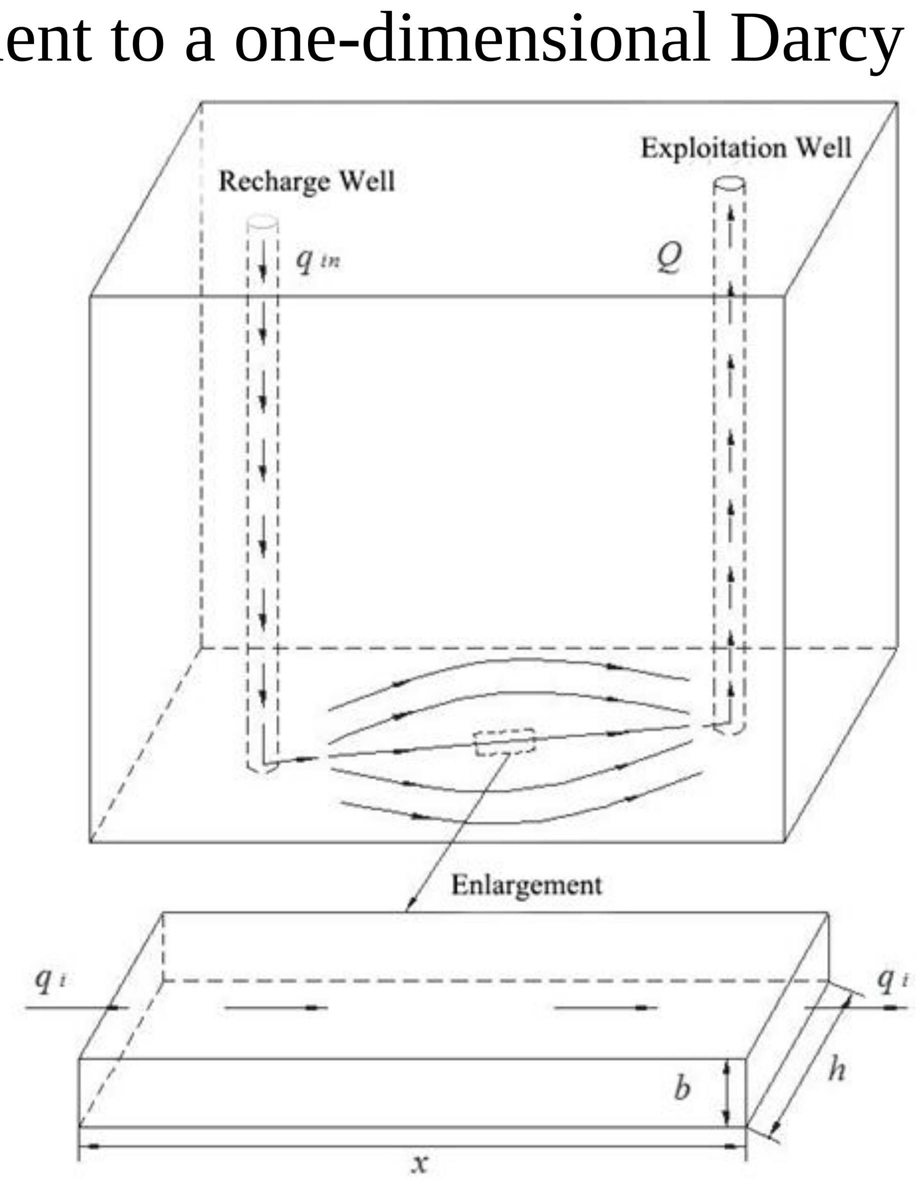

Figure 1. Sketch of the deep thermal reservoir seepage channel model

Result: **1.** The water sample was sent to the testing centre to test the concentration of the tracer, and a scatter diagram of the tracer concentration in the geothermal water with time was obtained, as shown in Figure. 2.

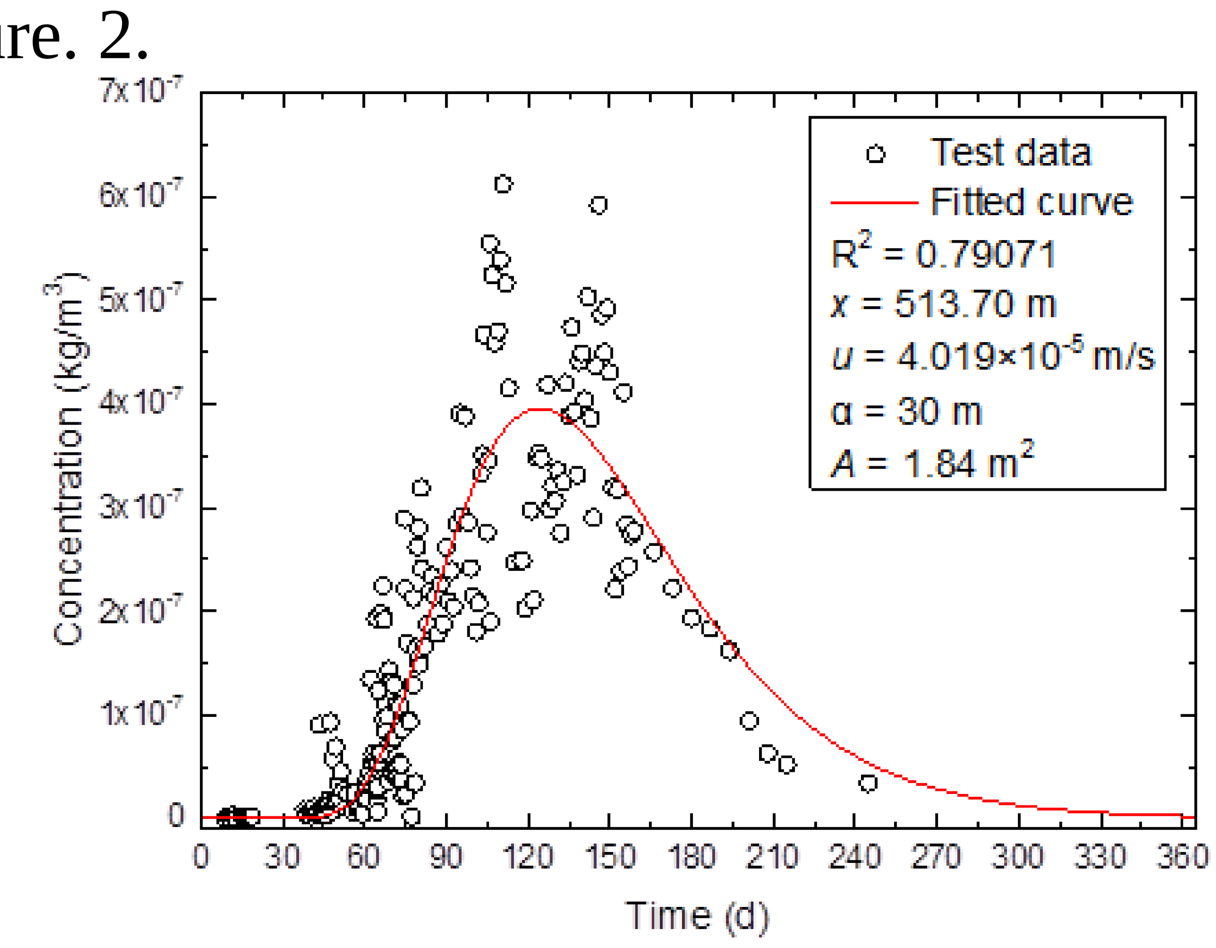

Figure 2. Tracer test data and the fitted curve

2. The fitting analysis of the tracer test data was conducted based on equation and the MMA inversion algorithm, and the parameter values in the inversion are shown in Table 1.

Table 1. Parameter values and inversion results

Parameter	Parameter Value	Inversion Result	Unit
x	275~1000	513.7	m
u	10^{-10}~10^{-1}	4.019×10^{-5}	m/s
α	1~500	30	m
A	0.1~100	1.84	m^2

3. The change in the production water temperature within 100 years is shown in Figure. 3.

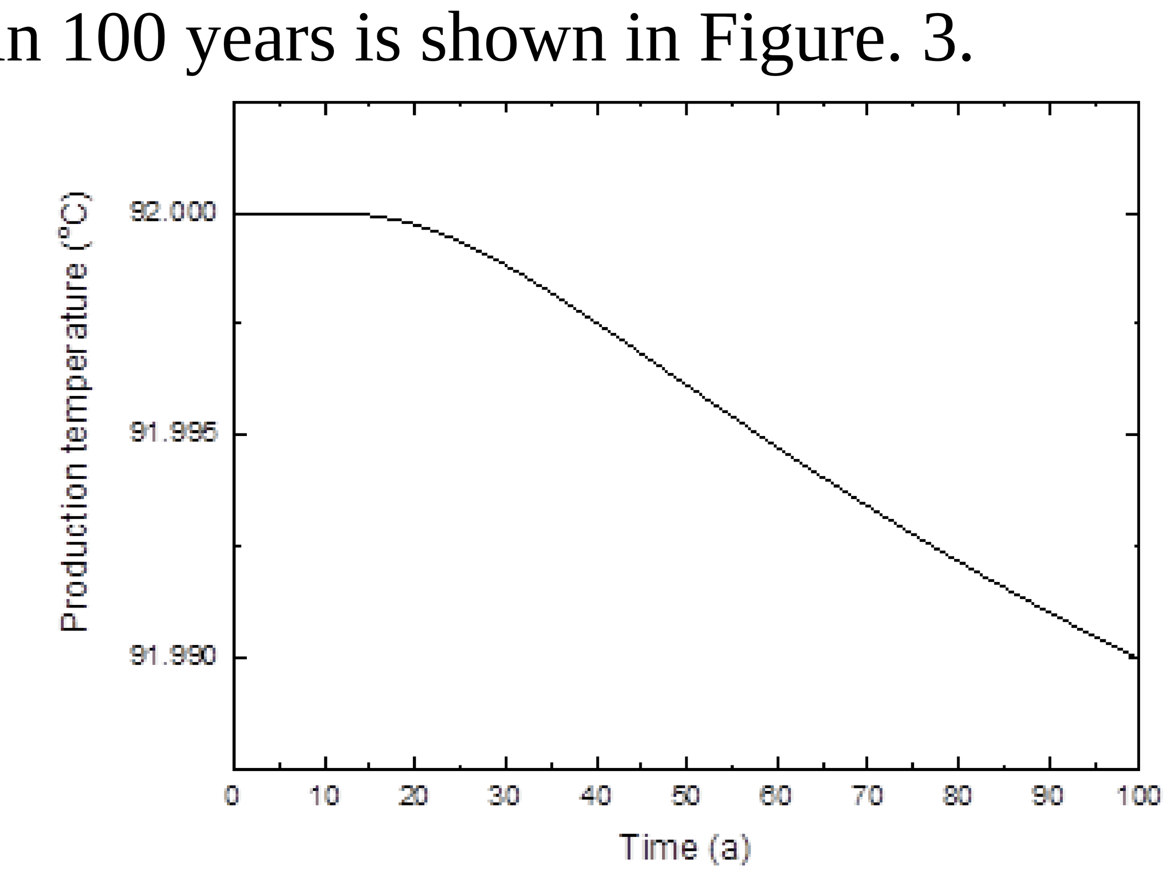

Figure 3. Variation curve of the production water temperature

Conclusion: 1. the tracer test data were used to carry out the parameter back analysis and the fit was good.

2. The values of the thermal reservoir parameters of the tracer test's back analysis were used to predict the thermal breakthrough for the geothermal well system. The results indicated that During the 100-year service life of a geothermal well system, no thermal breakthrough will occur.

References:

1. Bodin J, Delay F, Marsily G,Solute transport in a single fracture with negligible matrix permeability: 2. mathematical formalism,Hydrogeology Journal,11(4), 434-454, (2003).
2. Zhao Zhihong, Liu Guihong, Tan Xianfeng, et al, Theoretical model of geothermal tail water reinjection based on the equivalent seepage channel model, Hydrogeology＆Engineering Geology, 44(3), 158-164, (2017).