CHEMICAL ENGINEERING TRANSACTIONS

VOL. 59, 2017

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Zhuo Yang, Junjie Ba, Jing Pan

ISBN 978-88-95608- 49-5; **ISSN** 2283-9216

DOI: 10.3303/CET1759154

Simulation of Water and Salt Migration and Enrichment Processes in Typical Section

Qichen Hao

Chinese academy of geological sciences hydrogeological environment geology institute, Shijiazhuang 050006, China
haoqishen@hostmail.com

In order to study the influencing factors of water and salt enrichment, this paper mainly analyzed the moving rules of water and salt and water chemical variation characteristics under the control of groundwater flow. Combined with the ancient climate fluctuations, it reproduces the evolution process of water and salt migration in geologic history. The results show that there only develop the local water flow system and regional water flow system in the present condition, and the proportion of local water system circulation reaches 82.25%. They also indicate that the water and salt migration and enrichment process are obviously affected by the flow system. Besides, water-soluble fractions tend to concentrate continuously. The simulation results also show that the coupling relationship between water and salt transport and groundwater flow is mainly reflected in the change of fluid density. When the concentration of water-soluble components is largely different, the effect of fluid density on water flow cannot be neglected.

1. Introduction

The inland basins in China, with scare precipitation and intensive evaporation, have long suffered from water shortages, particularly from a scarcity of clean water (Bing, et al., 2015). The conversion between surface water and groundwater is frequently (Guo, et al., 2015; Gomez-Pastora et al., 2016; Papini et al., 2016; Mendoza et al., 2017). The temporal and spatial distribution of water resources is very uneven. Consequently, a clear understanding of groundwater flow system is critical for solving these problems (Li, et al., 2013).
Based on the paleoclimatic evolution history since the last interstadial period, a coupled simulation model of water flow and water - salt migration in Qaidam was established. The water source and groundwater age were chosen as the fitting criteria to correct the model. Based on the interpretation of the simulation results, the water and salt migration and enrichment processes of the basin were analyzed from the hydrodynamic point of view, and finally worked out the model of water and salt enrichment pattern. In addition, the rule of water chemistry variation under the present conditions was analyzed from the horizontal and vertical directions. Based on the above analysis, it finally studied the controlling factors of water and salt enrichment.

2. Experiment

2.1 Established water flow and water and salt migration model

The simulation ranges from the surface to the quaternary basement. The bottom boundary of the model is treated as a water-segregated boundary, neglecting the exchange capacity between the Quaternary aquifer and bedrock fissure water. The upper boundary is treated as a flow boundary or a three-class boundary. The river infiltration in front of the mountain is a given flow boundary and is the only replenishment source in the simulation area. Infiltration volume and infiltration location are given according to the infiltration distribution of the river, which is close to 75 ka B. P. of last glacial period. Therefore, the simulation period is determined as the beginning of the last glacial period to the present of 70 ka. By referring to the literature we know that the Ge'ermu river basin precipitation then is 3.2 times of the average, the river runoff is 2.1 times of the average.
The model is divided into 3,150 computational units, and the pressure distribution of the flow model under steady conditions is taken as the initial pressure condition of the salt-water migration. The 14C dating results are used to validate the model. Based on the simulated velocity vector field, the underground age distribution

Please cite this article as: Qichen Hao, 2017, Simulation of water and salt migration and enrichment processes in typical section, Chemical Engineering Transactions, 59, 919-924 DOI:10.3303/CET1759154

is calculated by the mass tracing principle. The results of isotope dating are in good agreement with the numerical simulation. The results of age fitting show that the numerical simulation can reproduce the seepage process. The accuracy of the model is reliable. Table 1 shows the simulation results of Paleohydrological characteristic restoration since the Late Pleistocene in the Qaidam Basin

Table 1: Results of paleohydrological characteristic restoration since the Late Pleistocene in the Qaidam Basin

Age	Ice Ages and Interglacials	Temperature (°C)	Precipitation	Runoff	Evaporation
15~ Now	Late glacial and post-glacial period	4	100%	100%	100%
25~15ka B.P.	The pleniglacial of the last interstadial period	1~2	30%	58%	125%
45~25ka B.P.	The first interstadial period	7~8	179%	147%	65%
70~45ka B.P.	The first period of ice age	4	100%	100%	100%

2.2 Simulating analysis of water and salt migration and enrichment processes

The simulation results show that a special water and water-salt interaction process is also showed in different times. The central region of the typical section since 70 ka has been in the enrichment stage. Figure1 to figure 7 show the distribution of water and salt from 70 ka B.P. to the present.

70~45 ka B. P. Climate conditions are similar to those of today. During the subsequent 30 ka, the water-soluble fraction concentrated continuously. To 45 ka B. P. The majority of groundwater in the middle of the basin has evolved into saline water. There forms a distribution of higher saline concentration in the upper layer than in the under layer in the overflow zone. 45 ~ 25ka B. P. is the first interstadial period, which is the relatively warm era in the last interstadial period. A sudden decrease in recharge resulted in enhanced regional water flow, with the water and salt enrichment center returning to the middle of the basin. Due to the difference between the shallow water and the deep water, the groundwater in the middle part of the basin has free convection, and the groundwater with lower concentration moves upwards under the action of buoyancy, while the groundwater with higher concentration moves downward. At present, most of the groundwater in the center part of the basin is 10 ~ 20 g/L of salt water. Under the condition that the climatic and terrain conditions do not change greatly, the water-soluble fractions of groundwater will continue to concentrate.

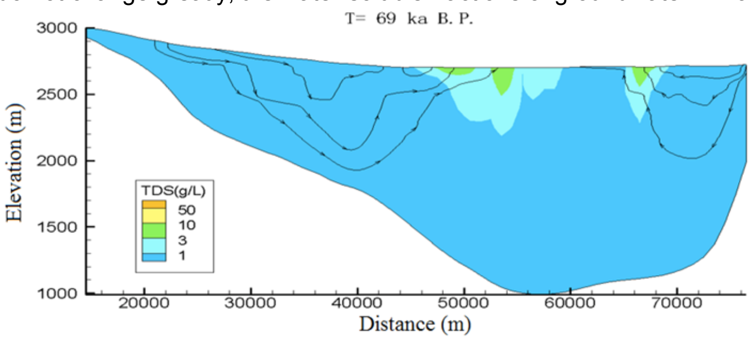

Figure 1: The distribution of water and salt around 70 ka B.P.

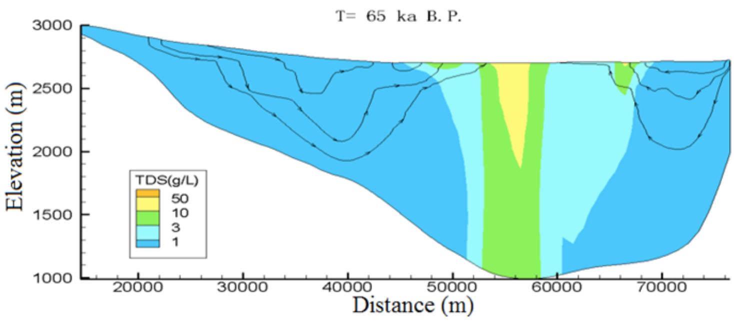

Figure 2: The distribution of water and salt around 65 ka B.P.

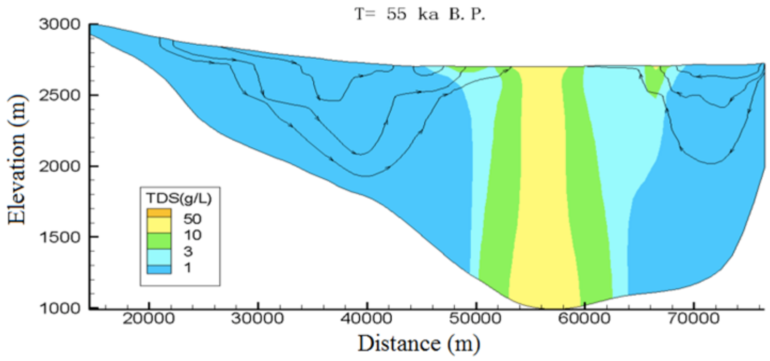

Figure 3: The distribution of water and salt around 55 ka B.P.

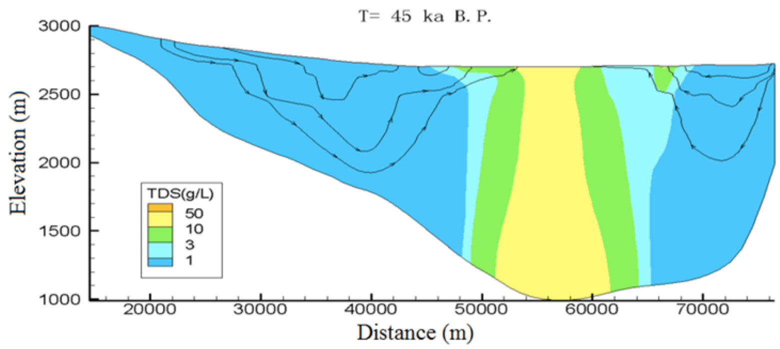

Figure 4: The distribution of water and salt around 45 ka B.P.

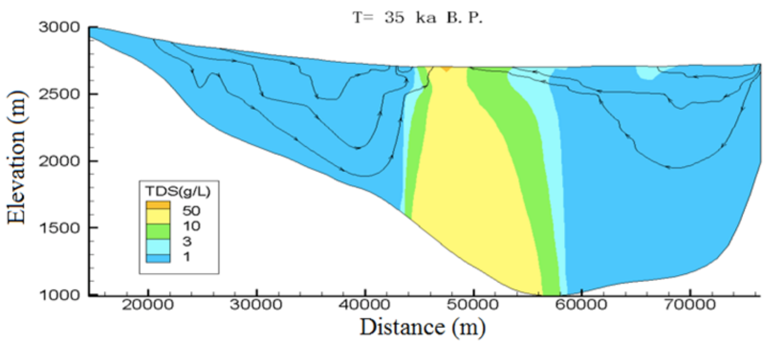

Figure 5: The distribution of water and salt around 35 ka B.P.

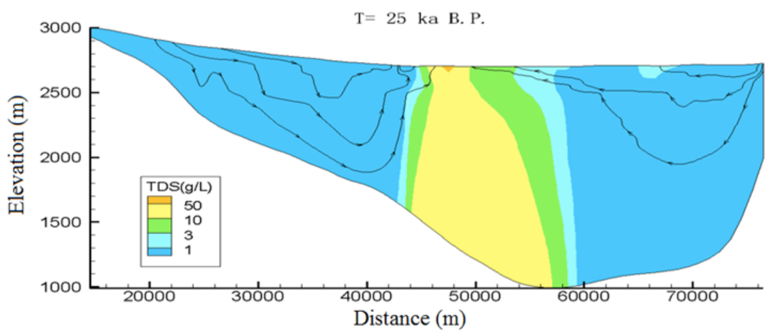

Figure 6: The distribution of water and salt around 25 ka B.P.

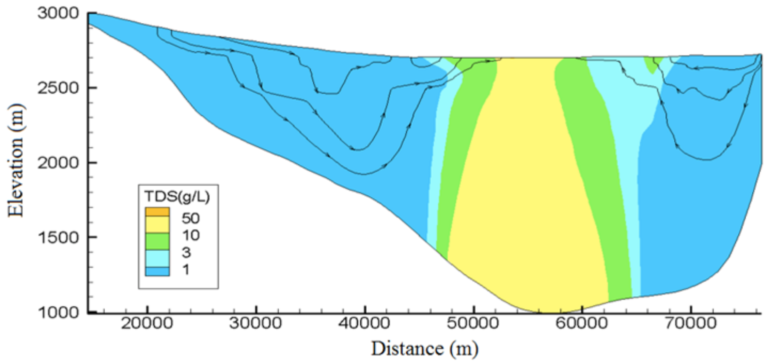

Figure 7: The distribution of water and salt now

3. Results and discussions

3.1 Variation characteristics of water soluble fraction

Figure 8 and 9 show the variation of the chemical composition of the groundwater in a 100-m depth on runoff direction. The main reason for the decrease of the concentration of water-soluble components is the mixing effect of groundwater with high concentration of local water flow system and fresh water in middle flow system or regional flow system. From the larger spatial scale, the change of brackish water in groundwater runoff path has a certain mutation. The above analysis shows that not only the boundaries of salt water and fresh water in the coastal zone are obvious, but might also in the groundwater of the inland basin. The research on boundary line of salt water and fresh water in the inland basin is helpful for a clearer understanding of water and salt distribution characteristics, and also has a reference function for studying the distribution of wedge-shaped freshwater bodies.

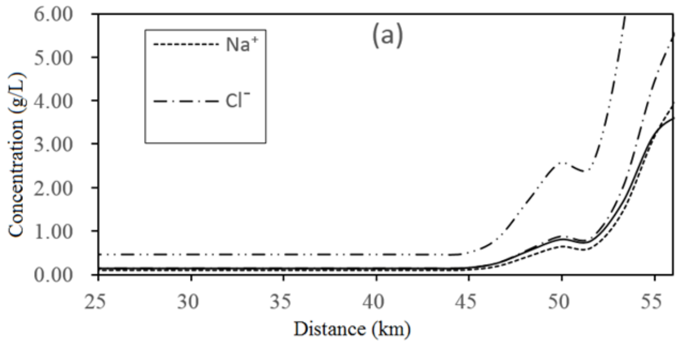

Figure 8: The variation of the chemical compositions of the groundwater on runoff direction

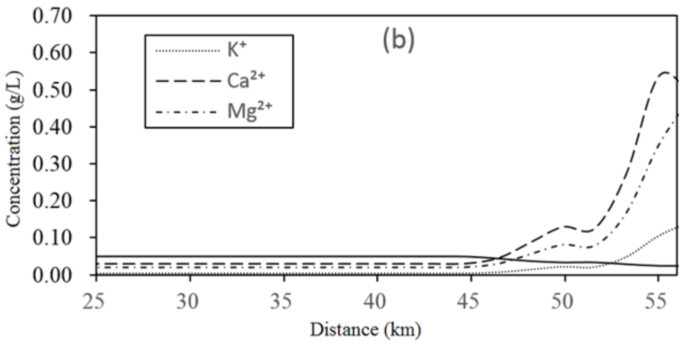

Figure 9: The variation of the chemical compositions of the groundwater on runoff direction

3.2 Variation characteristics in vertical direction

The variation of water soluble fraction in vertical direction has typical zonation (Zhi-feng, et al., 2013). In the middle part of the basin, which is the final rich area of salt, the water-soluble fraction has little variation in the vertical direction if without other effects. However, due to the influence of formation litho logy, depositional rule and geological action, the variation of chemical compositions of water is more complicated in vertical direction. In addition, the exploration depth of CK8 hole is limited. Therefore, the lack of understanding of deep geological conditions is also one of the reasons causing the deviation of simulation results.

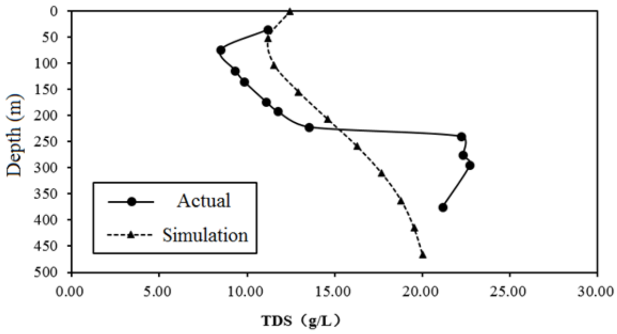

Figure 10: The variation of TDS in the groundwater of CK8 hole in different depths

There are many factors which can influence salt migration and enrichment (Du, et al., 2016). The main factors include the shape of the basin, geological effects, recharge and discharge pattern, and climatic conditions and so on. Water and salt enrichment is the result of comprehensive control of many factors. According to the results of previous numerical simulation, some opinions on the main controlling factors of water and salt enrichment are formed (Zeinijahromi, et al., 2015).

Basin shape is the basis of water and salt enrichment. Only in the catchment basin, can surface water and groundwater continue to carry water-soluble components to the central basin. Therefore, the completely enclosed catchment basin is the decisive factor controlling salt enrichment.

The fluctuation of the climate directly influences the recharge and discharge of the basin, such as river runoff and evaporation. The amount of runoff determines the number of water-soluble components in the basin, and the amount of evaporation determines the enrichment rate of water-soluble components. According to the previous numerical simulation results, there appears a desalination phenomenon for superficial groundwater in relatively warm and humid climate, while superficial groundwater enrichment will intensify in relatively dry climate. The dry and cold environment can increase the salt concentration, even salt formation, but cannot bring more water-soluble components (Peel, 2014). Water and salt enrichment will be in a relatively slow stage, and salt formation may eventually stagnate. In short, the intense climate change is more conducive to water and salt enrichment.

The change of groundwater recharge and discharge may also affect the change of groundwater flow system, and indirectly affect the migration of salt, especially the salt migration in salt accumulation zone. In a word, the hydrological cycle controls the migration and distribution of salt, while the distribution of salt also affects the water cycle; the two are mutually affected. There are many factors that affect the enrichment of water and salt, but ultimately, water and salt enrichment will be controlled by the water flow.

4. Conclusion

The simulation results show that the central region of the typical section since 70 ka has been in the enrichment stage, and the variation of groundwater flow under the influence of climatic conditions has obvious control effect on water and salt migration. At present, most of the groundwater in the central basin is 10 ~ 20 g/L of salt water and the water-soluble fractions of groundwater will continue to concentrate. The changes of chemical compositions of water in the horizontal direction have both consistency and specificity. In general, the concentration of water chemical components increased along with the runoff. Influenced by the wedge-shaped freshwater bodies and mineral saturation precipitation, the concentration of water chemical components may decrease in some parts. The variation of water soluble fraction in vertical direction has typical zonation and the variation regularity of different zonation is not consistent. In the middle of the basin, there is the possibility that the salt and water migration direction is opposite to that of the water flow. Water and salt migration process is affected both by climate and groundwater flow.

Reference

Bing H., He P., Zhang Y. (2015). Cyclic freeze–thaw as a mechanism for water and salt migration in soil. Environmental Earth Sciences, 74(1), 675-681.
Bing H., He P., Zhang, Y., 2015., Cyclic freeze–thaw as a mechanism for water and salt migration in soil. Environmental Earth Sciences, 74(1), 675-681.
Crevacore E., Boccardo G., Marchisio D., Sethi R., 2016, Microscale colloidal transport simulations for groundwater remediation, Chemical Engineering Transactions, 47, 271-276, DOI: 10.3303/CET1647046
Du L., Zheng Z., Li, T. (2016). Effect of irrigation frequency on migration regularity of greenhouse soil salt during different growth stages of pepper. Transactions of the Chinese Society of Agricultural Engineering, 32(20), 114-121.
Gomez-Pastora J., Bringas E., Ortiz I., 2016, Design of novel adsorption processes for the removal of arsenic from polluted groundwater employing functionalized magnetic nanoparticles, Chemical Engineering Transactions, 47, 241-246, DOI: 10.3303/CET1647041
Guo X., Liu J., Qin H., Liu,Y., Tian Q., Li D. (2015). Recovery of metal values from waste printed circuit boards using an alkali fusion–leaching–separation process. Hydrometallurgy, 156, 199-205.
Jin Z.F., Hudan T., Mou H.C., Mahhe M., Li W.J., 2013, Soil Water and Salt Migration in Cotton Field under Soil Freezing-Thawing Temperature [J]. Arid Zone Research, 4, 009.
Li X., Chang S.X., Salifu K.F. (2013). Soil texture and layering effects on water and salt dynamics in the presence of a water table: a review. Environmental Reviews, 22(1), 41-50.
Mendoza M.B., Ngilangil L.E., Vilar D.A., 2017, Groundwater and leachate quality assessment in balaoan sanitary landfill in la union, northern philippines, Chemical Engineering Transactions, 56, 247-252, DOI: 10.3303/CET1756042
Papini Petrangeli M., Majone M., Arjmand F., Silvestri D. , Sagliaschi M., Sucato S., Alesi E., 2016, First pilot test on integration of gcw (groundwater circulation well) with ena (enhanced natural attenuation) for chlorinated solvents source remediation, Chemical Engineering Transactions, 49, 91-96, DOI: 10.3303/CET1649016
Peel F.J. (2014). How do salt withdrawal minibasins form? Insights from forward modelling, and implications for hydrocarbon migration. Tectonophysics, 630, 222-235.
Zeinijahromi A., Farajzadeh R., Bruining J.H., Bedrikovetsky P. (2016). Effect of fines migration on oil–water relative permeability during two-phase flow in porous media. Fuel, 176, 222-236.