Environmental Geology (1995) 25: 211–213

M. M. Soliman · M. Nour El-Din · N. A. Hassan

Recharging of contaminated aquifer with reclaimed sewage water

Received: 1 August 1994 / Accepted: 20 October 1994

Abstract About 40% of the water supply of Cairo, Egypt, is drawn from a groundwater reservoir located southeast of the Nile Delta. Several thousand shallow wells supply drinking water to the farmers from the same groundwater reservoir, which is recharged by seepage from Ismailia canal, the irrigation canal network, and other wastewater lagoons in the same areas. Sewage water lagoons were located at the high ground of the area, recharging contaminated water into the aquifer. Since the groundwater in this area is used for drinking purposes, it was decided to treat the sewage water recharging the aquifer for health reasons. In this paper a solution to the problem is presented using an injection well recharging good quality water into the aquifer. A pumping well located at a distance downstream is used to pump the contaminated water out of the aquifer. A three-dimensional solute transport model was developed to study the concentration distribution with remediation time in the contaminated zone.

Key words Recharge · Contamination · Aquifer · Sewage · Water · Treatment · Quality · Model

Introduction

A water supply station was constructed in an area east of Ismailia canal and northeast of Cairo to supply drinking water to cities and villages located in this area (Fig. 1). The drinking water is pumped from the groundwater aquifer located in the zone. The results of the chemical analysis of the groundwater indicated contamination with iron and $CaCO_3$ and contaminants of sewage origin (nitrate, sodium chloride, and traces of bacteria). The major source of contaminants is the sewage effluent that was used for irrigation. The sewage water was primarily treated by siltation ponds. The farm that used the sewage water is located on higher ground east of the area (Fig. 2). The contaminated irrigation water seeped through the ground, recharging the groundwater aquifer and causing its contamination. Because the groundwater level below the farm forms a groundwater mound, the groundwater flow is moving westward. Figure 2 shows the piezometric hydraulic gradient, which is below the ground surface, dipping westward.

The subsurface soils consist of alluvial deposits. The main aquifer is composed of sandy soil overlain by a silty clay cap with variable thickness. The lower boundary of the aquifer is located on a limestone bed as shown in Fig. 2.

To solve the problem of contamination, a treatment plant was recently constructed to treat the sewage water on a tertiary basis before its use. It was found, however, that the groundwater aquifer would require a long period of time for remediation, if it relied only on the slow infiltration rate from irrigation by the reclaimed sewage water.

In this paper, a solution for this problem is discussed using an injection well recharging the aquifer with a good quality treated sewage water. A pumping well is located at a distance downstream. The remediation time and concentration distribution in the aquifer were determined using a three-dimensional solute transport model.

Model development and its result

A three-dimensional finite element model (Soliman and others 1993) was used based on the groundwater flow equation and the solute transport equation, respectively (Soliman and others 1991, 1993; Soliman and Hassan 1993).

$$\nabla \cdot (K \cdot \nabla h) \pm Q = S \frac{\partial h}{\partial t} \tag{1}$$

M. M. Soliman (✉) · M. Nour El-Din · N. A. Hassan
Faculty of Engineering, Ain Shams University, Cairo, 24 Mohamed Mahmoud Kassim, Heliopolis, Cairo, Egypt

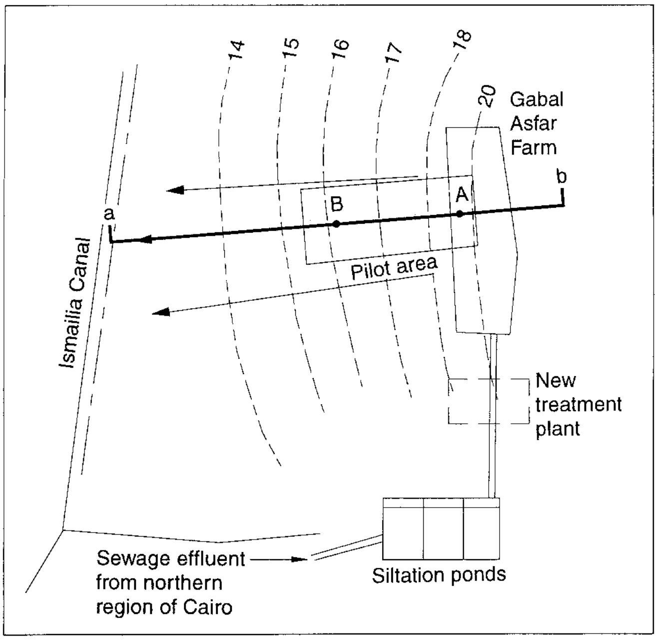

Fig. 1 Location map

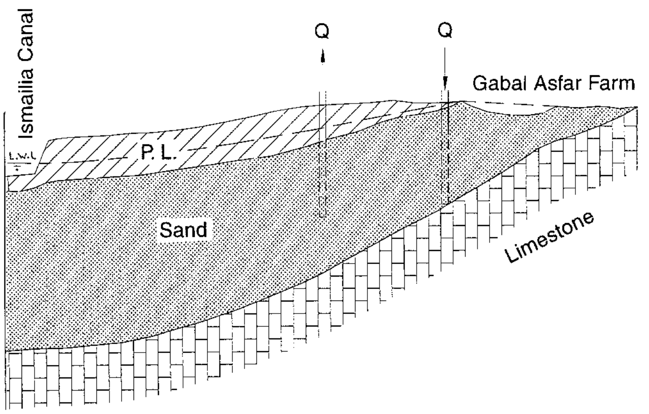

Fig. 2 Geological section

where K is the hydraulic conductivity L(Length) T^{-1}(Transmissivity), h is the potential head L, $\pm Q$ is the source (+) or sink (−) strength $L\ T^{-1}$, and S is the storativity

$$\nabla\cdot(D\cdot\nabla C) \pm C' = R\frac{\partial c}{\partial t} - V\cdot\nabla C \tag{2}$$

where D is the hydrodynamic dispersion coefficient L^2 T^{-1}, C is the groundwater flow concentration mg l^{-1}, C' is the source (+) or sink (−) concentration (mg l^{-1}) of the strength (1 T^{-1}), V is the pore water velocity ($L\ T^{-1}$), R is the retardation factor (equals 1, for insignificant reactive effect of the solute discussed in this paper).

The pilot area shown in Fig. 1 is adopted because there are sufficient chemical analysis data. The side boundaries of the pilot area were selected to coincide with two flow lines, as shown by the groundwater flow net. The upstream and downstream boundaries were two equipotential lines.

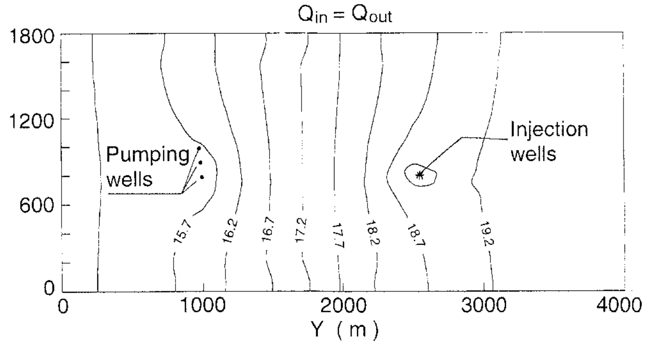

Fig. 3 Head pressure distribution

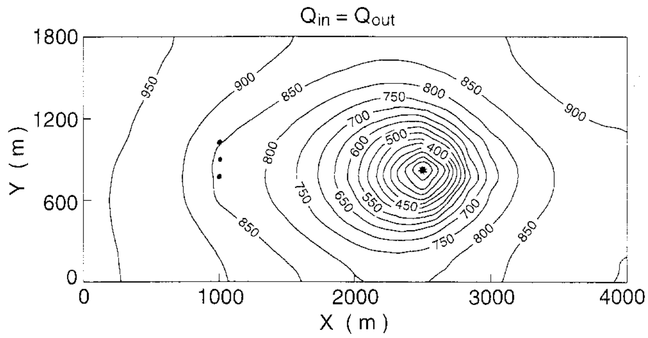

Fig. 4 Concentration distribution after 150 days

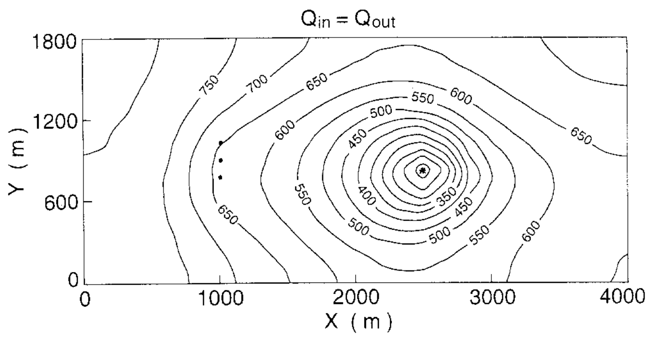

Fig. 5 Concentration distribution after 450 days

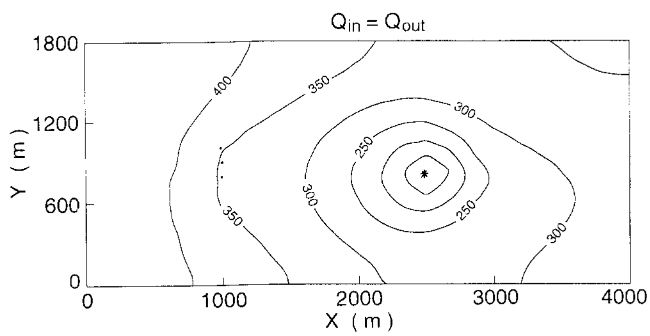

Fig. 6 Concentration distribution after 1350 days

The injected flow inside the pilot area at site A is the same as the pumped outflow at site B.

The model was first calibrated before injecting any discharge. The recharge value of 300 $m^3\ h^{-1}$ and the same value of discharge per well were introduced. For this condition the boundaries of the pilot area have insignificant changes as shown in Fig. 3.

The solute transport model was then run several times with a maximum time of 1350 days. The concentration ratio C'/C_0 at the injection site A was taken to be 0.1, i.e., 100 per thousand where C' is the concentration of the injected water and C_0 is the initial concentration of the contaminated groundwater. The concentration distribution for three selected times is shown in Figs. 4–6. Fully reclaimed water from the treatment plant was used for injection.

Figure 6 shows that after 1350 days of injection, the concentration ratio of the pollutant approached 40% near the downstream boundary of the pilot area, which was considered the safe limit as recommended by WHO.

Conclusion

Part of the sewage water used for irrigation seeps through the soil recharging the groundwater reservoir with contaminated water. In order to remediate the contaminated aquifer, an injection well was used to inject fully reclaimed sewage water to the aquifer. A three-dimensional finite element model was set up to study the effect of this solution and its time period.

References

Soliman MM and Hassan AA (1993) Adjustment of groundwater quality models. In: Proceedings, international symposium on engineering hydrology, San Francisco, CA. American Society of Civil Engineers, 25–30 July 1993, pp 814–819

Soliman MM, Maniack V, El-Mongy A, Talaat M, and Hassan AA (1991) Groundwater quality model with applications to various aquifers. Environ Geol Water Sci 17(3):201–208

Soliman MM, Nour MM, and Hassan NA (1993) Three dimensional solute transport model. Unpublished report submitted to Ain Shams University, Cairo, Egypt, pp 200–250