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Study on the Effectiveness of Circulation Well for Remediation of Benzene and Toluene Contaminated Silt Sand Aquifer

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Abstract: In order to investigate the remediation effect of groundwater circulation well on benzene and toluene contaminated silt sand aquifer, a simulation remediation experiment was conducted in the laboratory using a two-dimensional simulation tank. The results showed that in the silt sand aquifer, the concentrations of benzene and toluene decreased from 179.210 mg/L and 327.520 mg/L to below the detection limit after 24 h of operation of the circulation well. The closer to the circulation well in the horizontal direction, the faster the removal efficiency of benzene and toluene. The study has shown that circulating wells have good remediation effects on both benzene- and toluene-contaminated chalk sand aquifers.

Key words: Groundwater circulation well, benzene, toluene.

1. Introduction

With the rapid development of social and economic development, groundwater is an important strategic water resource, and the development and use of groundwater is increasing. However, water pollution problems are serious. Benzene and toluene, as a kind of endocrine disruptor, have the characteristics of high volatility and high toxicity, which are extremely harmful to human health, and can cause cancer and teratogenicity in human body [1-3]. In recent years, the contamination of groundwater by benzene and toluene has been very prominent. However, due to the complexity and hidden characteristics of groundwater, it is difficult to control, and the cost of treatment is high, so it is difficult to promote the groundwater treatment project. GCW (Groundwater Circulation Well) is a kind of in-situ remediation technology, which integrates aeration, gas lifting, and blowing off into one, overcoming the shortcomings of long remediation cycle of groundwater pump and treat, expensive water treatment cost, limited radius of influence at the aeration, and low removal rate [4-6]. Currently, GCW is widely used in Europe and the United States, but it is still mainly in the experimental research stage in China, For example, Sun Ranran et al. [7] laboratory simulated the effect of GCW in treating MTBE (Methyl Tertiary-Butyl Ether) in soil and groundwater; Lu Liang et al. [8] investigated the remediation effect of aniline using thermally-enhanced GCW; Bai Jing et al. [9] experimentally simulated the

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effect of GCW on aquifers with NAPL (Non-Aqueous Phase Liquid) materials in aquifers; Zhao Suli et al. [10, 11] conducted bioremediation studies using GCW.

In this study, the migration pattern of benzene and toluene and the remediation effect of GCW in silt sand aquifers were investigated by conducting experiments in the laboratory using two-dimensional simulation tanks.

2. Materials and Methods

2.1 Materials

The experimental sand was purchased from a sand quarry in Langfang City, Hebei Province, China, and powdered sand was sieved after drying; the experimental clay was taken from a farmland in Langfang City, Hebei Province, China. Due to the limitation of purchasing qualification, 0# diesel oil purchased from Sinopec Baimiao gas station in Langfang City, Hebei Province, China was used as the source of benzene and toluene.

2.2 Equipment

The experimental setup is an organic glass tank, with specific dimensions shown in Fig. 1. The 110 cm long section in the middle of the device simulates the underground aquifer, and the groundwater circulation well is located in the middle of the simulation tank, with uniform sampling ports distributed on the side of the simulation tank. Ensure that all flower holes in the upper part of the circulation well are located below the groundwater level.

2.3 Methods

2.3.1 Benzene and Toluene Migration Pattern Test

The identical simulation tank was filled with 56 cm thick silt sand, which were loaded in layers and tamped continuously, and covered with a 1 cm thick clay layer above the sand layer to effectively inhibit the volatilization of volatile organic chemicals (VOCs). A leakage source

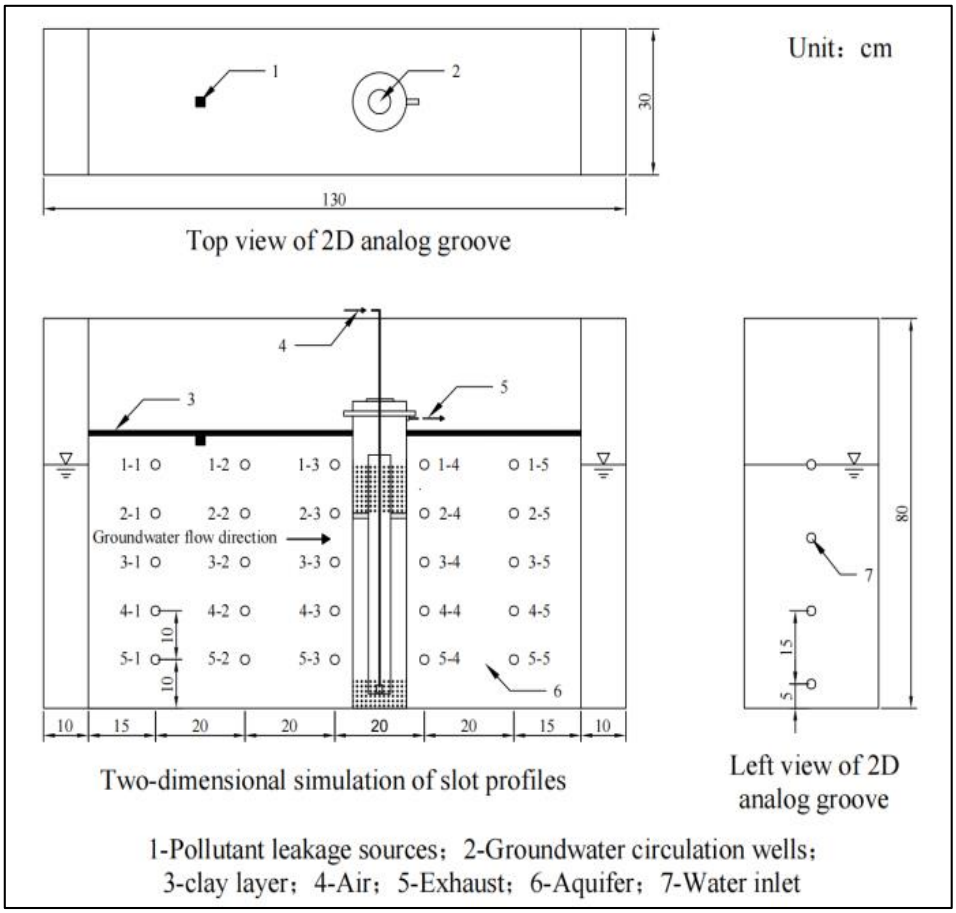

Fig. 1 Simulation tank structure.

tank was set up in the middle of the sampling ports of the 1st and 2nd columns of the simulation tank. The left water distribution area was slowly fed with a peristaltic pump, and the flow rate of the peristaltic pump was set to 0.05 m/d according to the results of the groundwater flow rate survey of the contaminated site. The entire simulation tank was saturated with water after 30 d. The simulation tank was then filled with water. After the simulation tank was full of water, 100 mL of 0# diesel fuel was injected into the location of the leakage source. Samples were taken from all sampling ports on the front of the simulation tank every 10 d and tested until the contaminants were distributed throughout the simulation tank.

2.3.2 GCW Restoration Effect Test

The remediation effect test of the simulation tank was carried out using the concentration of pollutant distribution after the whole simulation tank as the initial concentration, with an aeration rate of 25 L/min, and the simulation tank was sampled and tested after 1 h, 3 h, 5 h, 8 h, 12 h, and 24 h of reaction, respectively.

Benzene and toluene were determined by HJ 639-2012 Determination of Volatile Organic Compounds in Water Blow Trap/GC-MS (Gas Chromatography-Mass Spectrometry).

3. Data Analysis

3.1 Analysis of Contaminant Migration Data in Powdered Sand Simulation Tanks

The migration of benzene and toluene in the silt sand simulation tank is shown in Figs. 2 and 3. In the silt sand simulation tank, benzene and toluene were only detected in the first sampling port directly below the leakage source on the tenth day of the pollutant leakage,

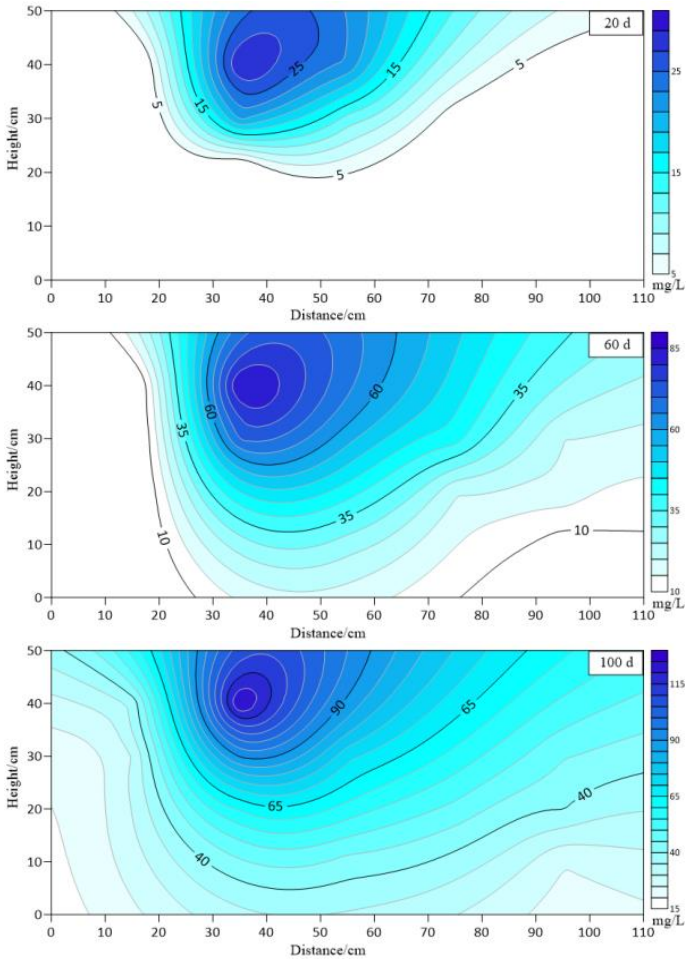

Fig. 2 Distribution of benzene concentration at different leakage times in the silt sand simulation tank.

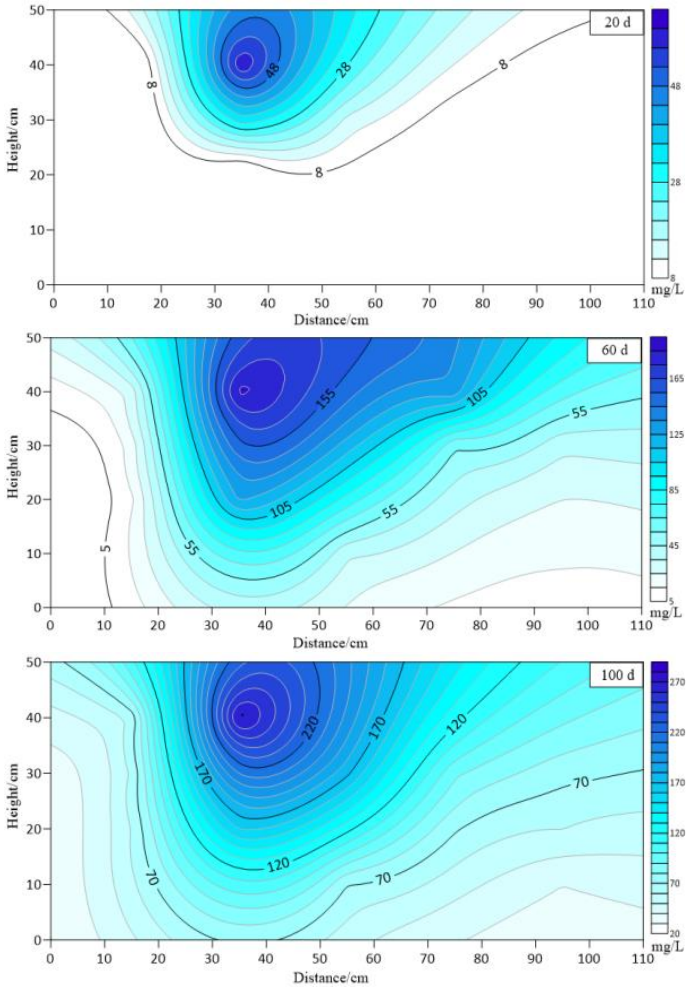

Fig. 3 Distribution of toluene concentration at different leakage times in the silt sand simulation tank.

but the concentration of pollutants was at a low level, and with the continuation of the leakage. When the pollutants were leaked for fifty days, benzene and toluene had basically spread over the whole simulation tank, and at this time, the highest concentration of benzene and toluene in the aqueous phase was 85.712 mg/L and 187.450 mg/L, and the average concentration reached 30.291 mg/L and 70.972 mg/L. After 100 days of the leakage, the highest concentration of benzene and toluene in the aqueous phase was 125.712 mg/L and 273.250 mg/L, and the average concentrations reached 54.327 mg/L and 108.578 mg/L.

The comprehensive migration law of benzene and toluene in the silt sand aquifer shows that the vertical migration velocity of benzene and toluene is obviously smaller than the lateral migration velocity, while the migration velocity of toluene is obviously larger than that of benzene, which is mainly caused by the difference in adsorption properties of organic matter on the medium. Therefore, in the remediation and treatment of benzene and toluene contaminated sites, the first thing that needs to be clarified is the hydrogeological conditions of the contaminated site and the types of pollutants, to predict the mobility of the organic matter in the site and the interaction with the environmental media, and to provide data support for defining the actual scope of the contamination and the development of the remediation program at a later stage.

3.2 Analysis of Contaminant Remediation Data from Simulation Tanks

After the contaminants in the simulation tanks continued

to be transported for a certain period of time, their concentrations were used as the initial concentrations for the GCW remediation effectiveness test, as shown in Figs. 4 and 5. The highest concentration of benzene in the aqueous phase in the silt sand simulation tank was 179.210 mg/L and toluene was 327.520 mg/L. After clarifying the prerequisite conditions such as medium properties of the aquifer, the direction and flow rate of the groundwater, the type and concentration of pollutants, and the scope of contamination, we utilized GCW to remediate the contaminated aquifer.

From Figs. 6 and 7, it can be seen that the concentrations of benzene and toluene in the silt sand simulation tank began to decrease after the startup of GCW. At 1 h of reaction, the highest concentration of benzene has decreased to 112.714 mg/L, with an average concentration of 70.803 mg/L, and the highest concentration of toluene has decreased to 205.790 mg/L, with an average concentration of 133.284 mg/L. At 3 h of reaction, the highest concentration of benzene has decreased to 78.922 mg/L, with an average concentration of 50.281 mg/L, and the highest concentration of toluene has decreased to 155.172 mg/L, with an average concentration of 97.505 mg/L. At 5 h, the highest concentration of benzene decreased to 50.271 mg/L and the average concentration was 26.622 mg/L, the highest concentration of toluene decreased to 115.174 mg/L and the average concentration was 73.170 mg/L; At 8 h of reaction, the maximum concentration of benzene decreased to 35.270 mg/L, the average concentration was 13.112 mg/L, the maximum concentration of toluene decreased to 80.791 mg/L, the average concentration was 49.342 mg/L; at 12 h of reaction, the maximum concentration of benzene decreased to 15.273 mg/L, the average concentration was 6.060 mg/L, the maximum concentration of toluene decreased to 40.270 mg/L, the average concentration was 6.060 mg/L.The concentrations of benzene and toluene in the simulation tank were below the detection limits at 24 h.

From Figs. 8 and 9, the average concentrations of benzene and toluene in the silt sand showed a decreasing trend over time, with the decrease in benzene concentration being more pronounced.

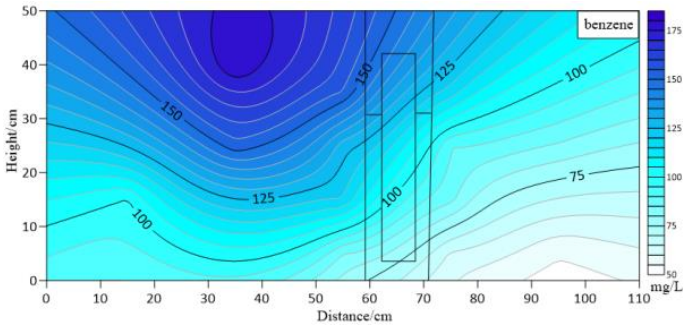

Fig. 4 Plot of initial benzene concentrations in the silt sand simulation tank.

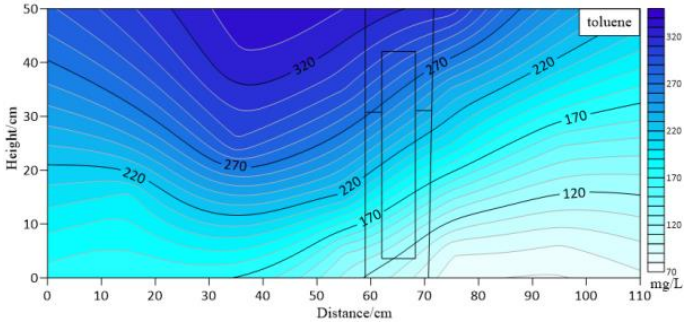

Fig. 5 Plot of initial toluene concentrations in the silt sand simulation tank.

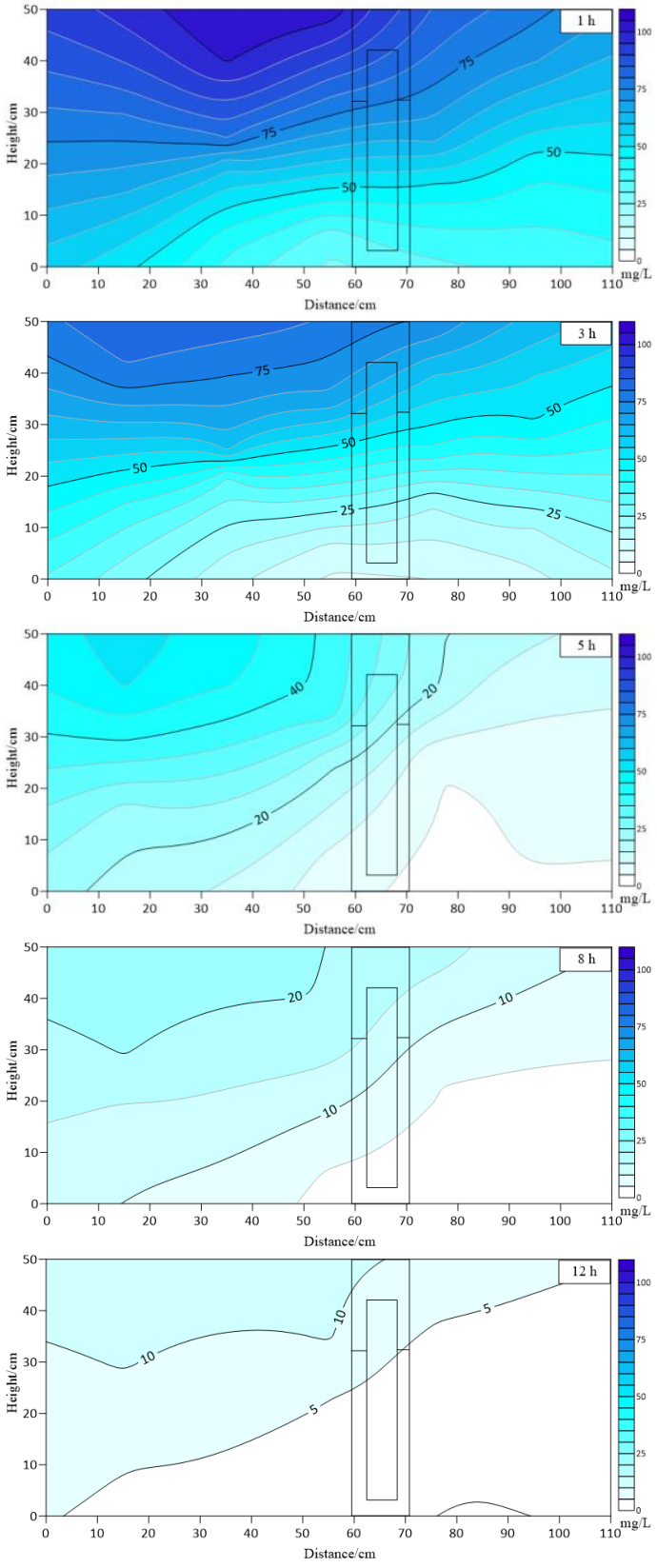

Fig. 6 Effect of benzene remediation in silt sand simulation tank.

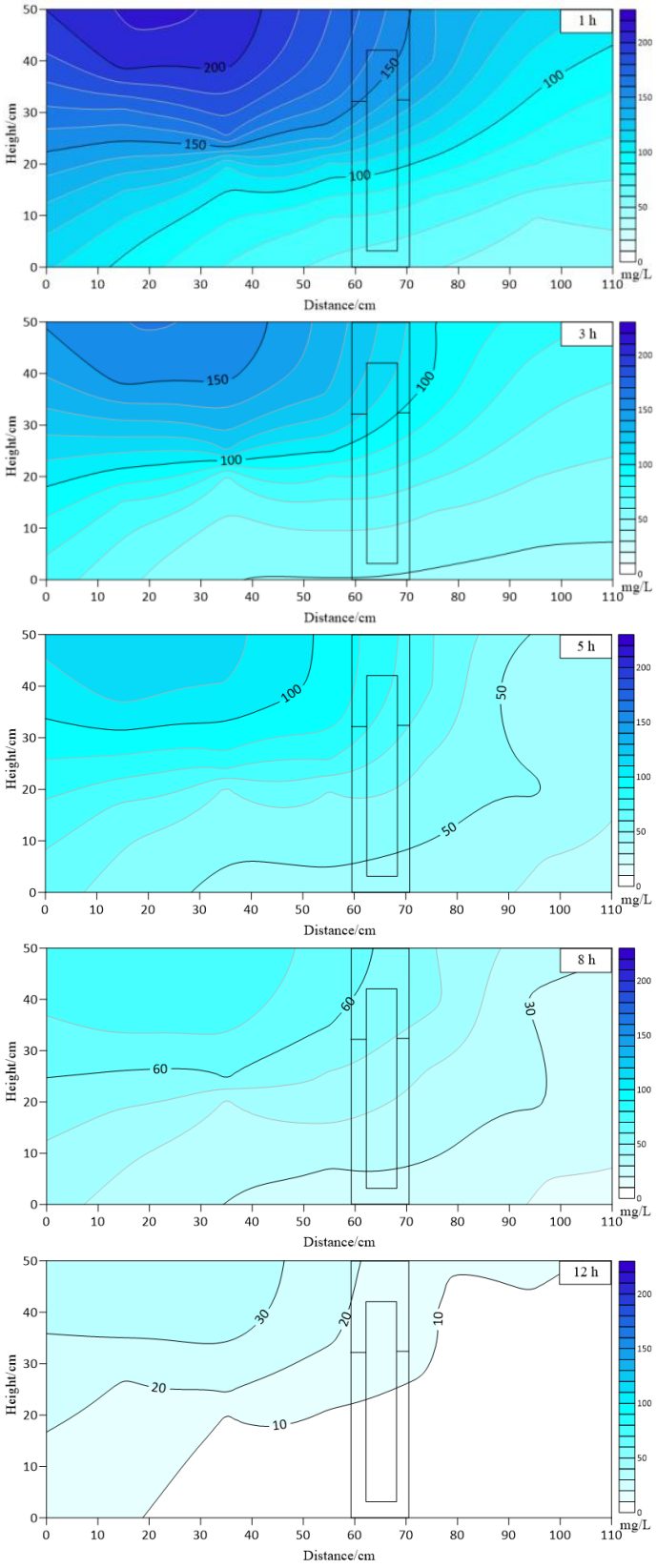

Fig. 7 Effect of toluene remediation in silt sand simulation tank.

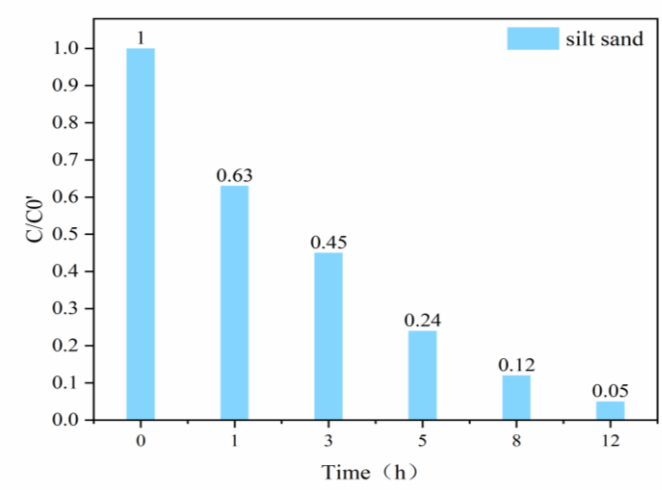

Fig. 8 Relative values of average benzene concentration in silt sand simulation tanks versus remediation time.

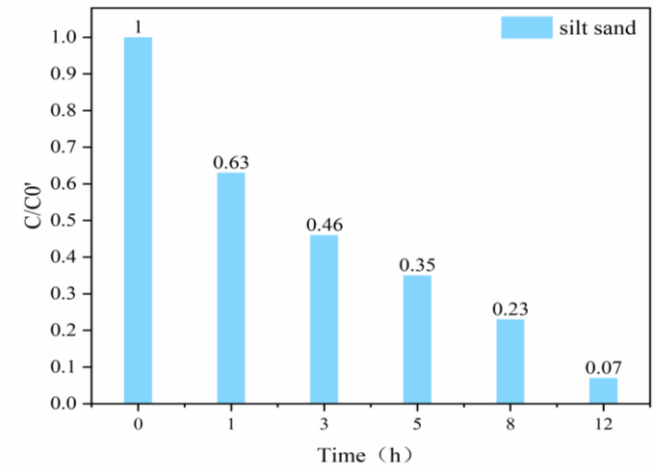

Fig. 9 Relative values of average toluene concentration in silt sand simulation tanks versus restoration time.

4. Conclusion

In this study, silt sand was used as the aquifer media, and benzene and toluene were used as the target pollutants, and simulation experiments were conducted in the laboratory to study the effect of the aqueous media on pollutant transport during a point source leak. After the transport experiments, GCWs were turned on and remediation experiments were conducted to investigate the effect of the aqueous media on the remediation effect of GCW. Through data analysis, the following main conclusions were drawn.

Due to the small permeability of the chalk sand, at 100 d, the maximum concentrations of benzene and toluene in the aqueous phase in the silt simulation tank were 125.712 mg/L and 273.25 mg/L, and the average concentrations were 54.327 mg/L and 108.578 mg/L.

The vertical migration rate of benzene and toluene was significantly smaller than the lateral migration rate, and the migration rate of toluene was significantly larger than that of benzene.

The study shows that GCW has good remediation effect on the benzene and toluene contaminated silt sand aquifer. Due to the small porosity and poor permeability characteristics of the chalk sand medium, the pollutants in the chalk simulation tank dropped below the detection limit 24 h after starting the GCW.

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