Effect of Suspended Solids Concentration on Clogging of Porous Media

Kang Han1,*, Li Ling1, Jiao Yang2, Pan Jun1, Wang Mouwei1

1 School of Municipal and Environmental Engineering, Shenyang Jianzhu University, Shen Yang
2 School of Architecture and Urban Planning, Shenyang Jianzhu University, Shen Yang

*Corresponding author: 324807397@qq.com

Abstract. In this study, indoor sand column experiment was used to simulate the rain flood recharging groundwater, the effect of suspended solids concentration on porous media clogging was studied. The experiment set three different particle size sand columns and different concentration of suspended matter back irrigation, 50mg/L, 100mg/L, 200mg/L, and intermittent recharge respectively, analyzed the change regulation of water flux and permeability coefficient. The results showed that: Under the same particle size, porous medium was easier to be clogged by the increase of concentration of the suspended solids; Under the same condition of the concentration of suspended solids, it was easier to recharge when the particle size of the porous medium was smaller.

1. Introduction
With the development of economy, the demand for energy is increasing and groundwater is seriously overtaken. Because of low economy and low risk, the rain flood recharging groundwater has become an effective measure to alleviate the over exploitation of groundwater. Kang1 considered that (1) Physical clogging was caused by suspended particles in the reused water; (2) During the recharge of groundwater, the changes in the environment made the chemical properties of the groundwater change and produce chemical clogging; (3) The physical and chemical clogging would also be accompanied by biological clogging. Lei2 proposed that the total deposition of particulate particles in the porous medium increase with the increase of fluid concentration; Wang3 proposed that the suspended solids with median particle size of 12.9um, 7.3um and 2.3um were deposited in the surface 150cm filter medium respectively, so that the permeability of the filter layer could be completely removed after the permeability of the filter layer was reduced. Li4 illustrated that the particle size increased, infiltration capacity increased and permeability increased. In this study, indoor sand column simulation experiments were carried out to analyze the effect of suspended solids concentration on porous media clogging and provide reference for rainwater recharging.

2. Experimental Materials and Methods

2.1. Experimental installation
Three indoor contrast sand columns were made. The sand columns were made of plexiglass, the height was 100cm, and the inner diameter was 7cm. The upper and lower parts of the column had 10cm buffer
flow, and the middle part was a 65cm seepage zone, with coarse, medium and fine sand respectively. The size distribution diagram was shown in Figure 1. There are 8 manometric holes on each side of the cylinder, with a spacing of 10cm. The experimental installation was shown as in the Figure 2.

![Particle size distribution diagram](image1.png)

(a) Coarse sand particle size distribution diagram. (b) Medium sand particle size distribution diagram. (c) Fine sand particle size distribution diagram

2.2. Experimental Steps

(1) The experimental method of installing the column, just as Pan illustrated, it was described as follows: First, Vaseline was applied to the inner wall of the plexiglass column to eliminate the boundary effect. The large granular pebbles were filled at the bottom of the installation. Then the three kinds of homogeneous grains with different sizes of the sieve were filled into the organic glass column, the height of installing the columnar reactor was 65cm. Before the experiment began, the sand column was saturated with distilled water, the distilled water entered from the top until the surface of the porous medium appears water film, then the outlet valve was opened, the distilled water was emptied and the valve was closed.

(2) Three sets of suspended solids in different concentrations were set up in the experiment, the concentrations of suspended solids were 50mg/L, 100mg/L and 200mg/L respectively. The reconfigured irrigation water was placed on the magnetic stirrer, stirring continuously during the experiment to prevent the sedimentation of suspended solids. During the experiment, the water surface was kept on the 10cm scale of porous medium. This experimentation was intermittent recharge, once every 8h water,
rest 8h, and so on. During the experiment, the flow and head difference of each sand column were monitored.

3. Experimental Result

3.1. Content of the recharge of sand columns with different sizes when suspended solids concentration was 50mg/L

It can be seen from Figure 3 (a) that the water flux and permeability coefficient of coarse sand column decreased with time. At 12d, the water flux decreased to 54.8% of the initial number. The sand column was clogged at this time. With the experiment, the permeability coefficient and water flux declined continuously. After 13d, the water flux decreased to 2.5ml/s, the permeability coefficient decreased to $1.11 \times 10^{-3}$ cm/s, which decreased to 44.1% and 24.4% of the initial number respectively.

Figure 3 (b) can indicated that the water flux and permeability coefficient of the middle sand column first showed an upward trend after 4h, then decreased to a stable figure after 8d. At 10d, the water flux decreased to 49.8% of the maximum figure, the permeability coefficient decreased to 52.1% of the highest figure. At this time, the sand column was clogged. When the experiment was carried out to 11d, the permeability coefficient and water flux tend to be stable, the stable value of Q was 1.00ml/s, the stable value of K was $0.09 \times 10^{-3}$ cm/s, which was the highest spot of 36.1% and 44.3%, respectively.

According to Figure 3 (c), the water flux and permeability coefficient of the fine sand column increased first after 5h, reached the maximum value of 9h, 0.48ml/s and $0.22 \times 10^{-3}$ cm/s. Then Q and K had been steadily dropping. At 7d, Q was 0.23ml/s, K was $0.085 \times 10^{-3}$ cm/s. At this point, Q dropped to 51.8% of the maximum and K decreased to 52.4% of the maximum.

3.2. Content of the recharge of sand columns with different sizes when suspended solids concentration was 100mg/L

From Figure 4 (a), it can be seen that the Q and K showed a downward trend of coarse sand columns. At 11d, Q decreased to 56. of the initial value, K dropped to 51.3% of the initial value, the sand column clogged. After that, K and Q had been steadily decreasing, and 11d basically stabilized. Q was 2.33ml/s and K was 0.001cm/s, decreased 43.1% and 22.9% of the initial value respectively.

From Figure 4 (b), it can indicated that the Q and K of medium sand columns show an upward trend when the experiment ran to 4h, and 9h began to decreased. The experiment ran to 9d, Q and K to 54.8% and 52.1% respectively, the sand column clogged. The experiment ran 1d, Q and K were basically stable.
The 1.00ml/s and $0.11 \times 10^{-3}$ cm/s decreased to 36.8% and 22.5% respectively.

According to Figure 4 (c), the Q and K of fine sand columns showed an upward trend after the experiment ran to 5h, they had been steadily dropping after 11h. When the experiment ran to 5d, Q decreased to 57.9% of the initial value, K decreased to 57.9% of the maximum number, when the sand column was clogged. When the experiment ran to 6d, Q and K tended to been stable, K decreased to 17.9% of the maximum permeability coefficient, Q decreased to 20% of the maximum water flux.

Figure 4. Variation of water flux and permeability coefficient of sand columns with different particle sizes at 100mg/L concentration

3.3. Content of the recharge of sand columns with different sizes when suspended solids concentration was 200mg/L

As it can describe from Figure 5 (a), the overall Q and K of the coarse sand columns tended to decline. At 9d, Q decreased to the initial 51.8%, K dropped to 56.3% of the initial value. After that, the water flux and permeability coefficient had been steadily decreasing, and after 10d, it became stable. Q was 2.07ml/s, K decreased to $0.86 \times 10^{-3}$ cm/s, which was 37.1% and 19.5% of the initial value respectively.

According to Figure 5 (b), the Q and K of the sand column increased first and then decreased after 4h. When the experiment was ran at 7d, Q decreased to 53.9% of the maximum value, K decreased to 58.8% of the maximum value, when the medium sand porous medium was clogged. The experiment continued to run 8d, the permeability coefficient and water flux basically stabilized, which were $0.15 \times 10^{-3}$ cm/s and 0.9ml/s respectively.

From Figure 5 (c) that the K of fine sand column increased continuously after 8h and decreased continuously after 16h. When the experiment ran to 4d, Q, K decreased to 59.9% of the maximum value and 53.1%, the fine sand column began to clogged. When the experiment ran to 5d, Q and K tend to be stable, K decreased to 11.8% of the maximum permeability coefficient, Q decreased to 14.3% of the maximum water flux.
4. Discuss

4.1. Clogging time comparison of different particle size clogging
When the concentration of suspended substance was 50mg/L, as the experimental operation time increased, the fine sand was clogged at 7d, the medium sand was clogged in 10d, and the coarse sand was clogged at 12d; when the concentration of suspended substance was 100mg/L, the experiment of the fine sand ran 5d, the medium sand was clogged in 9d and the coarse sand was clogged at 11d; When the concentration of the suspended substance was 200mg/L, the experiment ran to 4d fine sand clogged and 7d time the sand was clogged and the coarse sand was blocked at 9d. As it can be seen above, under the condition of different particle size contrast, fine sand clogged earlier than medium sand and coarse sand. Compared medium sand with coarse sand, it had a short clogging time. At all conditions, coarse sand took the longest time to clogged.

4.2. Clogging Time comparison of different concentration of clogging
When the concentration of suspended solids was 50mg/L, compared with other concentration, the initial value of Q and K of coarse, medium and fine sand were the largest. When the suspended solids concentration was 100mg/L, the Q and K of coarse sand, medium sand and fine sand decreased slowly. When the concentration of suspended solids was 200mg/L, the initial values of Q and K of different sand columns were the smallest and the rate of descent was the fastest. In summary, when the suspended solids concentration was the highest, the clogging time of each sand column became shorter.

4.3. The reasons for the rise of K and Q in the early recharge
When the middle sand and fine sand began to run for a period of time, both K and Q increased, and the water flux increased by 4% and 4.6% respectively. The permeability coefficient increased by 3.5% and 2.4% respectively. There may be several reasons: (1) The condition of bubble discharge: the bubble was not completely eliminated, resulting in the formation of gas clogging in the early stage of the experiment (2) Side wall effect: the recharging water flows to the side wall of the plexiglass column, not completely saturated with the porous medium (3) Sand column was not completely saturated: the saturated time of sand column was short and the porous medium was not fully saturated before the experiment begins. Medium sand and fine sand have smaller particle size and smaller porosity, which would take longer time to saturate.
5. Conclusion

(1) Under the same particle size, porous medium was easier to be clogged by the increase of concentration of the suspended solids; Under the same condition of the concentration of suspended solids, it was easier to recharge when the particle size of the porous medium was smaller.

(2) With the increase of suspended solids concentration, the water flux and permeability coefficient of porous media gradually decreased. The larger the particle size of porous medium was, the greater the initial figure of water flux and permeability coefficient. On the contrary, the smaller the initial value of Q and K was.

(3) Medium sand and fine sand have a tendency to rise in K and Q for a period of time, there were some reasons for it; It had produce gas clogging in porous medium. Due to the smaller size of medium sand and fine sand, they need more time to saturated than the coarse sand. The side wall effect, the recharging water did not completely saturated with the porous medium.

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