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An in-situ accelerated experimental testing method for drip irrigation emitter clogging with inferior water

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ABSTRACT

Emitter clogging has become a bottleneck in the application and promotion of inferior water drip irrigation technology. Understanding the detailed emitter clogging process is the precondition and basis for solving clogging issue. However, the existing indoor simulated experiments have the disadvantages in unnecessary effect on the results, and the in-situ experimentation is difficult due to the long experiment period. Therefore, this paper proposed an in-situ accelerated (ISA) experimental testing method for studying the emitter clogging behaviors in drip irrigation systems with inferior water source. Its feasibility was verified in Dengkou in Inner Mongolia, and a comparative study was performed to examine the differences and correlations between the ISA method and the normal intermittent (NI) method for drip irrigation using Yellow River water (YRW) and brackish water (BRW). The results indicated that the drip irrigation emitter clogging behaviors via the ISA method were relatively conservative. The values of randomness of clogging occurrence ($\triangle F_Q^t$), emitter clogging degree (EC), emitter discharge variation (q_{var}), clogging substance on the internal laterals (CSL) and clogging substance inside emitters (CSE) were lower than those of the NI method by 24–57, 64–110, 58–121, 16–38 and 14–32%, respectively. The average discharge variation ratio (Dra), Christiansen coefficient of uniformity (CU) and statistical uniformity coefficient (Us) were 7–13, 15–23 and 17–39% higher than those of the NI, respectively. Besides, the experimental results under the two modes (ISA and NI) had significant linear correlation ($0.98 > R^2 > 0.75$). Thus, the ISA experimental results could be converted into those under NI mode using the linear model, without considering the effects of emitter type nor the water quality. This result indicated that the ISA method could accurately reflect the clogging behaviors of the drip irrigation emitter.

1. Introduction

Drip irrigation is regarded as the ideal irrigation method for inferior water due to its precision and controllable characteristics. However, inferior water sources usually contain large quantities of suspended solid particles, salt ions, algae, microorganisms and organic pollutants (Stefanie et al., 2004; Yan et al., 2009; Wang et al., 2014a), which can easily cause emitter clogging (Bucks et al., 1979; Nakayama and Bucks, 1991; Ravina et al., 1997). The emitter clogging problem has become a bottleneck for the application and promotion of inferior water drip irrigation technology (Song et al., 2017; Feng et al., 2018).

Understanding emitter clogging behaviors is the precondition and basis of solving the emitter clogging issue, and related scholars mainly use two testing methods to study the anti-clogging properties of emitters. The method most commonly used is the simulated indoor testing method. The related studies have yielded large quantities of experimental data, which has been of great significance in determining emitter clogging characteristics (Hills et al., 1989; Puig-Bargués et al., 2010; Niu and Liu, 2011; Puig-Bargués and Lamm, 2013; Wang et al., 2014a; Pei et al., 2014). However, the water used for the indoor simulated experiments is stored in the tank and affect the water quality, and the indoor environment is obviously different from the real conditions. These factors lead to experiment errors, which draws great attention from related researchers. Therefore, several researchers began conducting the in-situ recycling experiments to study emitter clogging behaviors (Zhang, 2016; Zhou et al., 2017a), which are limited by the long experiment period, heavy workload and large space needed. Therefore, an accelerated experimental method is needed that can not only represent real environmental and water quality conditions, but also provide a high-efficiency and accurate reflection of emitter

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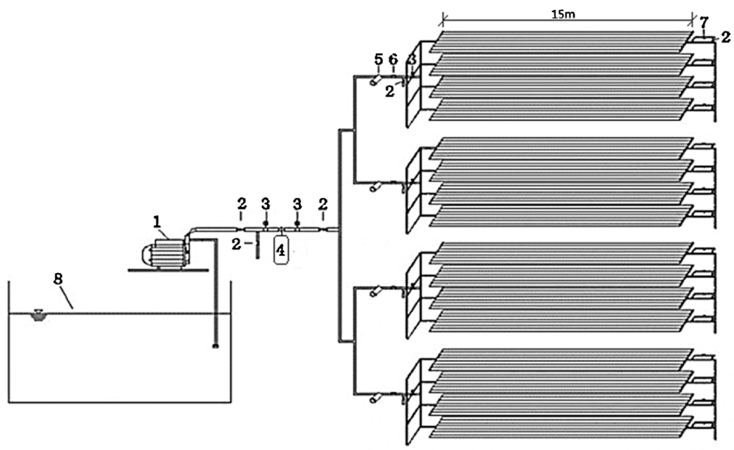
Table 1
Water quality parameters of the water sources.

Water source	pH	Suspended matter mg/L	Conductivity μS/cm	Degree of mineralization mg/L	COD $_{Cr}$ mg/L	BOD_5 mg/L	Total phosphorus mg/L	Total nitrogen mg/L	Ca mg/L	Mg mg/L
BRW	8.9-9.2	< 5	9453–9460	4757–4760	15–17	2.6–2.9	0.09–0.12	1.6–2.0	321–323	121–126
YRW	7.2–7.9	38.2–43.7	781–799.8	476–493	5.9–7.2	1.5–1.9	0.04–0.08	1.3–1.5	53.6–55.4	24.6–26.7



1-Water pump; 2-Butterfly valve; 3-Pressure gauge; 5-Laminated filter; 6-Fine tuning valve; 7-Electromagnetic flow meter; 8-

Impounding reservoir

Fig. 1. Schematic diagram of platform structure for drip irrigation emitter clogging experiment.

Table 2
Drip Emitters used in the experiment.

Emitter	Flow Rate /L·h^{-1}	Geometric parameters of flow pass /mm			Flow coefficient	Flow regime index	Structural diagram of the emitter
		Length	Width	Depth			
FE1	0.8	21.5	0.50	0.45	2.36	0.505	
FE2	1.0	23.0	0.50	0.52	3.14	0.506	
FE3	1.2	23.0	0.63	0.52	3.64	0.503	
FE4	1.4	25.0	0.63	0.52	4.64	0.508	
FE5	1.6	29.7	0.63	0.52	5.13	0.507	
FE6	2.8	41.1	0.67	0.56	8.27	0.504	

clogging characteristics. However, the alternate wet-dry environment inside the drip irrigation laterals under accelerated operation conditions is different from the normal mode, and the results turned out that the drip irrigation emitter clogging behaviors under different operation frequencies varied to a certain degree (Zhou et al., 2015; Zhang et al., 2016; Han et al., 2018). Whether the experimental results obtained by the in-situ accelerated operation overestimate or underestimate emitter clogging degree in drip irrigation systems, and how to evaluate their effects on the experimental results are in great needs for further studies.

Two inferior drip irrigation water sources—Yellow River water (YRW) and brackish water (BRW)—in the Hetao irrigation area of Inner Mongolia were applied in the in-situ drip irrigation experiment, to study the effects of two different operation modes—accelerated operation (ISA) and normal operation (NI)—on the clogging characteristics of the single emitter, the whole system and the clogging substance components. The study aims to propose a high-efficiency and accurate in-situ accelerated experimental method and contributes to improve the related drip irrigation clogging experiments.

2. Materials and methods

2.1. Experimental designs and system layout

This experiment was conducted in an irrigation experiment station located in northern Wulan Buh, Dengkou County, Bayan Nur City, Inner Mongolia, China (N 40 °24′32 ″ , E 107 ° 02′19), which belongs to the western part of the Hetao irrigation area with the altitude of 1072 m. Two locally representative inferior drip irrigation water sources were used as experimental water sources—YRW with high sediment concentration and BRW containing large quantity of salt. The water quality characteristics are shown in Table 1.

Gravel and laminated filters were applied at the head part of the experimental system, and the system which was built in 4 layers. The pressure at each layer was 0.1 MPa, the head of the dripline adopts a two-stage pressure regulating valve, which is used to maintain the stable working pressure of the drip irrigation system, and internal laterals were 15 m in length (Fig. 1). Six types of flat emitters (recorded as FE1-FE6) were used in the experiment, and the characteristic parameters of the emitters are shown in Table 2. There were 8 replications of each type of drip irrigation emitters, and sampling was carried out for 8 times in total. The in-situ accelerated operation method (ISA) was set as irrigated every day, while the normal intermittent operation method (NI) proceeded according to the drip irrigation frequency applied in actual field and greenhouse crops: once every 4 days or 7 days ($NI_{1/4}$, $NI_{1/7}$). The total irrigation quota was the same under three operation modes, and the irrigation periods were 3 h, 12 h and 21 h, respectively. The experiment was performed from June 15, 2016 to October 21, 2016, totaling 360 h in operations. The amount of drip irrigation system water used in each flow test cycle was about 1331 m^3, and the total amount of system water consumption was about 2.27×10^4 m^3.