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Research Paper

Influence of flushing pressure, flushing frequency and flushing time on the service life of a labyrinth-channel emitter

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A set of orthogonal experiments using three factors (flushing pressure, flushing frequency, and flushing time) was used to study the anti-clogging performance of a patch-type dentation labyrinth-channel emitter. After irrigation, the change in the emitter discharge was tested, and the discharged particle size distribution was measured using a laser particle size analyser. The results showed that the flushing treatments had a significant effect on the anti-clogging performance of the emitter and extended the emitter's service life by 35.2% on average. Among the three factors, the flushing pressure lengthened the emitter's service life most. With more irrigation events, the discharged particle sizes *V*10, *V*50, and *V*90 (i.e. the particle size with accumulating particle volumes of 10%, 50% and 90%, respectively) decreased under different flushing treatments. However, particle sizes were still larger than those without the flushing. Particles of all sizes could be trapped in the emitter channel. However, coarse particles were trapped more easily, which was the major reason for emitter clogging. Flushing treatments helped the discharge of sediments. The analysis of variance indicated that the flushing pressure had a significant effect on the discharge of coarse particles and flushing time had an obvious impact on fine particles. Elevating the flushing pressure was the major method to extend the life of emitters for water with large particles >18.04 μm diameter and extending the flushing time was the main way for water with particles <1.20 μm diameter.

1. Introduction

Drip irrigation systems have been set up in many places, such as Ningxia and Inner Mongolia in China where they alleviate the problem of water shortage in the Yellow River irrigation district. Drip irrigation technology is often recommended as the most suitable irrigation method where water is scarce due to its highest water use efficiency. However, water abstracted from the Yellow River has a high sediment concentration, 35 kg m^{-3} on average, and numerous sands enter into drip irrigation system even after prefiltration and deposition

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Nomenclature

D1	Sediment size distribution for particle size 0.275–2.512 (μm)
D2	Sediment size distribution for particle size 2.512–5.012 (μm)
D3	Sediment size distribution for particle size 5.012–8.710 (μm)
D4	Sediment size distribution for particle size 8.710–15.136 (μm)
D5	Sediment size distribution for particle size 15.136–106.00 (μm)
h	Working pressure (MPa)
K	Flow coefficient
M1	Lateral without flushing
M2, M3, M4, M5, M6, M7, M8, M9, and M10	Laterals with different flushing treatments
q	Rated flow ($l\ h^{-1}$)
*V*10, *V*50, and *V*90	Particle sizes with accumulated volume is 10%, 50%, and 90%, respectively in measured sediments
X	Flow index

measures are taken (Li, Liu, & Li, 2012). Emitter clogging is a key problem in the operation of drip irrigation systems. Many studies tried different ways to analyse and solve the clogging problem caused by sand deposits in drip irrigation systems. Nakayama, Boman, and Pitts (2007) reported that opening the end of the laterals and flushing it with high-speed water flow ranged from 0.5 to 0.6 m s^{-1} could help to reduce clogging. However, Wang, Zhu, and Zhang (2014) discovered that only 40% of the sand particles that entered a drip irrigation system were deposited in the trap, the other 60% of the sand particles needed to be discharged through the emitter channel. Thus, studying how to discharge sand particles through laterals has become a focus of research. The American Society of Agricultural and Biological Engineers (ASABE) Engineering Practice, EP-405, recommended a minimum flushing velocity of 0.3 m s^{-1} (ASAE Standards, 2003), but Hills and Brenes (2001) suggested that a flushing velocity of 0.5–0.6 m s^{-1} is necessary when larger particle sizes need to be discharged, such as used after coarser filters. Puig-Bargués, Arbat, et al. (2010) found greater emitter clogging at the distal end of the dripline without flushing than a monthly and seasonal flushing with the latter two intervals not being significantly different. Concerning flushing time, Feng, Kang, and Wan (2017) proposed that the ends of the laterals were opened and left open for 3 min until the outflow appeared clear. These aforementioned studies indicated that the flushing velocity should be high, and therefore flushing pressure should be high, Also, higher flushing frequency helped reduce the clogging.

In this study, the working pressure was considered as being the rated pressure, rather than the flushing pressure, since increased pressures significantly increase irrigation cost and energy consumption. Flushing pressure, flushing frequency and flushing time all influence the behaviour of the emitter channel when using muddy water before each normal irrigation.

However, the effect of flushing on emitter clogging before irrigation is still unclear, particularly at standard pressures. A technique to alleviate drip emitter clogging is required. Therefore, the objective of this study was to evaluate different flushing pressures, flushing frequencies, and flushing times and determine a suitable irrigation techniques to improve the service life of the emitters.

2. Material and methods

2.1. *Emitter characteristics*

A patch-type lateral with non-pressure-compensating labyrinth-channel emitters was used (Dayu Water Conservation Ltd. Jiuquan City, Gansu, China) in this study. The external diameter of the lateral was 16 mm and the wall thickness was 0.3 mm. The working pressure was 0.1 MPa. The rated flow (q) was 1.32 $l\ h^{-1}$. This type of product is widely used in Ningxia, Neimenggu, and several other locations in China. Each test lateral was randomly cut from the same roll of irrigation lateral s. The flow coefficient (*K*) and flow index (*X*) were 0.52 and 0.47, respectively.

2.2. *Test device*

The test platform is shown in Fig. 1. A water tank, with 1.0-m height and 0.5-m bottom diameter, was used to deliver the test water. The depth and volume of muddy water were 0.8 m and 0.628 m^3, respectively. The muddy water was well stirred manually. The working pressure was provided by a 1.25 kW submersible pump with a rated head and rated discharge of 0.4 MPa and 2.5 $m^3\ h^{-1}$, respectively. The pressure adjustment valve and manometer were mounted on the main pipeline. The manometer range was 0.16 MPa, and its precision was 0.25%. Ten laterals were set up on the test platform with control valves installed at the front and back ends of each lateral. The total length of each lateral was 4.4 m, the spacing between the laterals was 0.18 m, the spacing between the emitters was 0.30 m, and every lateral had 15 emitters. The total flow rate was about 195 $l\ h^{-1}$. The muddy water returned to the water tank via return line. When all the laterals were opened, 92% of the flow discharge returned to the water tank at high pressure. The water and sand mixture was agitated evenly by an ejecting action of return water to prevent deposition.

2.3. *Measurement of sediment size distribution and test water*

The sediment size distribution was analysed using the Malvern laser particle size analyser 2000 (Malvern Instruments Ltd., Malvern, UK). The measuring size range of the particle analyser was from 0.02 to 2000 μm. Tap water was used in this study. The irrigation test was performed using 18 events with 10 laterals, and the average discharge of all emitters in each