Evaluation of emitters and water quality in trickle irrigation systems under Iranian conditions

Mohammad Zamaniyan\textsuperscript{1,}\textsuperscript{*}, Rouhollah Fatahi\textsuperscript{2}, Saeed Boroomand-Nasab\textsuperscript{3}, Shayan Shamohammadi\textsuperscript{4} and Kaveh Parvanak\textsuperscript{5}

\textsuperscript{1, 2 and 4.} Department of Water Engineering, Faculty of Agriculture, Shahrekord University, Shahrekord, Iran \textsuperscript{3.} Department of Irrigation and Drainage, Faculty of Water Science Engineering, Shahid - Chamran University, Ahwaz, Iran \textsuperscript{5.} Department of Chemistry, Faculty of Science, Shahrekord University, Shahrekord, Iran

\textit{Corresponding author email:} mohammad.zamaniyan@gmail.com

ABSTRACT: Trickle irrigation is the precise, slow application of water as discrete drops, continuous drops, small streams, or miniature sprays through mechanical devices called emitters located close to the plants. One major disadvantage of trickle systems is the tendency for emitters to clog. The field performance of 10 areas of trickle irrigation system in Iran was studied. Physical, chemical and biological analyses includes pH, EC, TSS, TDS, Fe, Mn, Mg, Ca and bacterial number were carried out of water samples from different areas. In this study percentage of completely clogged emitters ($P_{clog}$), Emission Uniformity (EU), statistical uniformity (Us), and coefficient of variation due to emitter performance in the field ($V_{pf}$) were evaluated. Results showed that performance of trickle irrigation systems in Iran is low and poor. Average EU, Us, and $V_{pf}$ in different areas is 52.8, 61.3 and 38.2\% respectively. Most of problems in irrigation units have been detected: Inadequate working pressures, emitters clogging, and lack of train for farmers.

Keywords: Emission uniformity, Emitter clogging, Uniformity coefficient, Water quality.

INTRODUCTION

Trickle irrigation is a localized irrigation method that slowly and frequently provides water directly to the plant root zone. Emitter clogging has often been recognized as inconvenient and one of the most important concerns for trickle irrigation systems, resulting in lowered system performance and water stress to the non-irrigated plants (Coelho and Resende, 2001). Partial and total clogging of emitters is closely related to the quality of the irrigation water, and occurs as a result of multiple factors, including physical, biological and chemical agents (Coelho and Resende, 2001; Ribeiro et al., 2008; Yavuz et al., 2010).

Water analysis prior to system design, a preventive maintenance programme and field evaluation of clogging and uniformity are strongly recommended (Capra and Scicolone, 1998). Bucks et al. (1979), and Capra and Scicolone (1998) proposed a classification scheme for water quality to indicate clogging potential. The evaluation have been carried out according to Merriam and Keller's (1978) recommendations, which have been followed in later works of authors (Ortega et al., 2002; Yavuz et al., 2010; Noori et al., 2012).

The objective of this study was to evaluate water quality and uniformity parameters 10 trickle irrigation systems located in different areas of Iran.

MATERIALS AND METHODS

Experimental Location

Iran with an area of 165 million ha arable land of which only 8 million ha are irrigated, 6 million ha are rain-fed, and 4.5 million ha remain in the form of fallow land. The climate of Iran is one the greatest extremes due to its geographic location and variation in topography. The summer is extremely hot in its central deserts and fall far below zero in the West Mountains. Annual rainfall ranges from less than 50 mm in the deserts to more than 1600 mm on the Caspian Plain. The average annual rainfall is 252 mm and approximately 90\% of the country is arid or semiarid. Taken as a whole, about two-thirds of the country annually receives less than 250 mm of rainfall (Aali et al., 2009).

A field study involving trickle irrigation systems was conducted in 10 locations in different areas of Iran (Figure 1) during summer 2012.
Figure 1. The location of Evaluated areas across country

Water quality
Water samples were taken during the field test to determine the most important factors affecting emitter clogging (Bucks et al., 1991; Capra and Scicolone, 1998): Electrical Conductivity (EC), pH, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Iron (Fe), Calcium (Ca), Magnesium (Mg), Manganese (Mn), Bicarbonates (Bc), and Bacterial Number (BN). Water analyses were carried out in the laboratory; chemical and microbial changes in some factors were stopped by appropriate sample treatment (APHA, 2005).

Emitters
The hydraulic characteristics of the emitters for all areas were searched out from manufacturing catalog are listed in Table 1. According to ASAE Standards (2003) on manufacturing coefficient of variation for emitters, emitter types in Shahrekord, Damghan, Sari, Nahavand, and Semirom areas were classified as excellent ($CV_m<0.05$), whereas emitter types in Borazjan, Izeh, Ghom, Talesh, and Shahinshahr areas can be classified as poor and unacceptable emitter type ($CV_m>0.11$).

<table>
<thead>
<tr>
<th>locations</th>
<th>Emitter type</th>
<th>Discharge, l/h</th>
<th>Manufacturing coefficient of variation</th>
<th>Emitter discharge exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shahrekord</td>
<td>Micro Flapper</td>
<td>4</td>
<td>&lt; 0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Borazjan</td>
<td>Dripper</td>
<td>4</td>
<td>&gt; 0.15</td>
<td>0.7</td>
</tr>
<tr>
<td>Izeh</td>
<td>Dripper</td>
<td>8</td>
<td>&lt; 0.11</td>
<td>0.7</td>
</tr>
<tr>
<td>Damghan</td>
<td>Micro Flapper</td>
<td>8</td>
<td>&lt; 0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Sari</td>
<td>TORO</td>
<td>8</td>
<td>&lt; 0.05</td>
<td>0.04</td>
</tr>
<tr>
<td>Ghom</td>
<td>Dripper</td>
<td>8</td>
<td>&lt; 0.11</td>
<td>0.7</td>
</tr>
<tr>
<td>Nahavand</td>
<td>Netafim</td>
<td>4</td>
<td>&lt; 0.025</td>
<td>0.01</td>
</tr>
<tr>
<td>Talesh</td>
<td>Microjet</td>
<td>142</td>
<td>&gt; 0.15</td>
<td>0.5</td>
</tr>
<tr>
<td>Semirom</td>
<td>Micro Flapper</td>
<td>8</td>
<td>&lt; 0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Shahinshahr</td>
<td>Bubbler</td>
<td>30</td>
<td>&gt; 0.15</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Uniformity Parameters
According to the measured data, the parameters obtained to characterize uniformity were as follows (Liu and Huang, 2009):
1. The percentage of completely clogged emitters ($P_{clog}$) was calculated as:

$$P_{clog} = 100 \left( \frac{N_{clog}}{N} \right)$$

where $N_{clog}$ and $N$ are the number of completely clogged emitters and the total number of emitters in experimental manifold, respectively.
2. Emission Uniformity (EU) is one of the most frequently used design criteria for trickle irrigation systems. It is one of the recommended indices for evaluation of micro irrigation performance by the ASAE Standards (ASAE, 2003).

\[
EU = 100 \frac{\bar{q}_{1/4min}}{\bar{q}} \tag{2}
\]

where \(\bar{q}_{1/4min}\) is the mean discharge of lower quartile (l/h) and \(\bar{q}\) is the mean discharge of emitters in irrigation unit (l/h).

The evaluated systems are classified according to the EU values, following Capra and Scicolone (1998), as Table 2 shows.

<table>
<thead>
<tr>
<th>EU (%)</th>
<th>Classification of Capra and Scicolone (1998)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 66</td>
<td>Low</td>
</tr>
<tr>
<td>66-84</td>
<td>Mean</td>
</tr>
<tr>
<td>&gt; 84</td>
<td>High</td>
</tr>
</tbody>
</table>

3. The statistical uniformity (Us) between the emitters has been determined by equation (3) (Bralts and Kesner, 1983).

\[
Us = 100(1 - V_q) = 100(1 - \frac{S_q}{\bar{q}}) \tag{3}
\]

In equation (3), Us defines statistical uniformity (%), \(V_q\) describes the overall change in emitters discharge, \(S_q\) is the standard deviation of emitters discharge (l/h). Statistical uniformity is evaluated according to ASAE (2003), based on the classification criterion presented in Table 3.

<table>
<thead>
<tr>
<th>Us (%)</th>
<th>Classification of ASAE (2003)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 60</td>
<td>Unacceptable</td>
</tr>
<tr>
<td>60-70</td>
<td>Poor</td>
</tr>
<tr>
<td>70-80</td>
<td>Acceptable</td>
</tr>
<tr>
<td>80-90</td>
<td>Good</td>
</tr>
<tr>
<td>&gt; 90</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

4. Coefficient of variation due to emitter performance in the field, \(V_{pf}\), according to Bralts (1986) is:

\[
V_{pf} = 100(V_q^2 - x^2V_h^2)^{0.5} = 100(V_q^2 - x^2\left(\frac{S_h}{h}\right)^2)^{0.5} \tag{4}
\]

where \(V_{pf}\) is the coefficient of variation of emitters discharge at the constant pressure, \(x\) the emitter flow-rate exponent, \(V_h\) the coefficient of variation of the pressure head, \(S_h\) the standard deviation of pressure measured irrigation unit (bar) and \(h\) the mean pressure in irrigation unit (bar).

Coefficient of variation due to emitter performance in irrigation unit is evaluated according to ASAE (2003), following the classification criterion shown in Table 4.

<table>
<thead>
<tr>
<th>V_{pf} (%)</th>
<th>Classification of ASAE (2003)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 20</td>
<td>Unacceptable</td>
</tr>
<tr>
<td>15-20</td>
<td>Poor</td>
</tr>
<tr>
<td>10-15</td>
<td>Acceptable</td>
</tr>
<tr>
<td>5-10</td>
<td>Good</td>
</tr>
<tr>
<td>&lt; 5</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

**RESULTS AND DISCUSSION**

The physical, chemical and biological properties of water in the experimental areas were compared with the water quality criteria for emitter clogging proposed by Bucks et al. (1979) and Capra and Scicolone (1998). According to Bucks et al. (1979) the tested irrigation waters, based on properties (pH, TDS, TSS, Fe, Mn) can be classified, in general, as minor hazardous to severe hazardous in some cases. According to Capra and Scicolone (1998), the hazard rating is, in general, from minor to moderate for EC except Ghom that was severe, minor for TSS, from minor to moderate for Ca except Ghom that was severe, from minor to severe for Mg, minor for Fe and Mn. The bicarbonate values for Izeh, Damghan, Sari, Ghom, Nahavand, and Talesh was high. Bicarbonate concentrations of more than 5 meq/l, or 305 mg/l, caused serious problems due to precipitates in the irrigation system (Ayers and Westcot, 1985). In Talesh, large formations of biological biofilm were observed as well as the occurrence of the same formation in the micro jet orifice.
The percentage of completely clogged emitters ($P_{clog}$) for all areas is presented in Figure 2, indicated by the blank bar. Results show that $P_{clog}$ in Shahrekord, Borazjan, Sari, and Shahinshahr is high. Most sensitive emitters to clogging were found in Shahrekord and Borazjan areas that had the lower discharges among studied areas. Liu and Huang (2009) found that emitters with higher discharge are clogged less than those with lower discharge.

![Figure 2. Percentage of completely clogged emitters in different areas](image)

Emitter clogging greatly reduces the water distribution uniformity in irrigated fields (Capra and Scicolone, 1998; Liu and Huang 2009), which negatively influences crop growth and yield. Ortega et al. (2002) evaluated local trickle irrigation units and calculated average emission uniformity, average absolute emission uniformity, and system emission uniformity. According to the criteria proposed by Capra and Scicolone (1998), values EU of Shahrekord, Borazjan, Izeh, Sari, Nahavand, and Shahinshahr was low (Figure 3). Average EU in different areas of Iran is 52.8% that according to Capra and Scicolone (1998) was low. In most cases an incorrect management of the maintenance led to low emission uniformity. Thus, several important problems in the equipment evaluated have been detected: inadequate working pressures, high pressure differences in subunits, emitters clogging, and high manufacturing coefficient of variation of emitters. Inadequate working pressure values are often due to malfunctioning installation and management (pumping station regulation, cleaning status of the filters, etc) and are, occasionally, a consequence of installation design problems.

![Figure 3. Emission uniformity of different areas](image)

According to ASAE (2003), values Us of all sites except Damghan, Ghom, Talesh, and Semirom was unacceptable and poor (Figure 4). Average Us in different studied sites of Iran is 61.3% that according to ASAE (2003) considered as poor.
According to ASAE (2003), values $V_{pf}$ of all areas except Semirom and Shahinshahr classified as unacceptable and poor (Figure 5). Average $V_{pf}$ in different studied sites of Iran is 38.2% that according to ASAE (2003) considered as unacceptable.

The following suggestions and causes of reduction of performance in Iranian trickle irrigation systems were identified:

Inadequate working pressures and high pressure differences in subunits that are often due to malfunctioning installation and management (pumping station regulation, cleaning status of the filters, etc) and are, occasionally, a consequence of installation design problems.

Farmers were not trained on how to maintaining trickle irrigation systems (filtration, acidification and chlorination).

Emitters discharge must be controlled constantly during the process of irrigation and in case of the determination of clogging flushing or acid injection or chlorination processes must be reported.

REFERENCES


Coelho RD, Resende RS. 2001. Biological clogging of netafim's drippers and recovering process through chlorination impact treatment. ASAE Paper Number: 012231, Sacramento, California, USA.