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Bibliographic Review

Ferrous water in drip irrigation

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Abstract

Water quality is a fundamental aspect for the successful utilization of irrigated systems, being necessary analysis so that there is no obstruction in the system. The physical, chemical and biological properties that are related to risk of obstruction according to the quality of the irrigation water are: dissolved and suspended solids, pH, total iron, manganese, hydrogen sulfide and bacteria population. Currently the iron is a major problem in irrigation water, due to the capacity of physically obstruct the pipes and emitters of drip irrigation systems decreasing the uniformity of application, creating financial losses due to excessive spending with water, because farmers tend to leave the system turned on for more time due to obstruction of the drippers.

Key words: Water quality, iron, obstruction.

Água ferrosa na irrigação por gotejamento

Resumo

A qualidade da água é um aspecto fundamental para o êxito da utilização de sistemas irrigados, devendo ser feito análises para que não ocorra a obstrução do sistema. As variáveis físicas, químicas e biológicas que estão relacionadas com risco de obstrução segundo a qualidade da água de irrigação, são: os sólidos suspensos e dissolvidos, pH, ferro total, manganês, sulfito de hidrogênio e população de bactérias. Atualmente o ferro é um dos principais problemas na água de irrigação, devido à capacidade de obstruir fisicamente as tubulações e emissores dos sistemas de irrigação localizada diminuindo a uniformidade de aplicação. Fatores que geram prejuízos financeiros devido ao gasto excessivo com água, pois os produtores tendem a manter o sistema ligado por mais tempo devido à obstrução dos gotejadores.

Palavras-chave: Qualidade da água, ferro, obstrução.

Agua ferrosa en el riego por goteo

Resumen

La calidad del agua es un aspecto clave para el uso exitoso de los sistemas de regadío, debiéndose hacerse análisis para que no ocurra la obstrucción del sistema. Las propiedades físicas, químicas y biológicas que están relacionados con el riesgo de obstrucción de acuerdo con la calidad del agua de riego son: los sólidos suspendidos y disueltos, pH, hierro total, manganeso, sulfito de hidrógeno y población de bacterias. Actualmente hierro es un problema importante en el agua de riego, debido a la capacidad para obstruir físicamente tuberías y los emisores de los sistemas de riego por goteo, disminuyendo la uniformidad de la aplicación. Estos factores generan pérdidas económicas debido a un gasto excesivo de agua, ya que los productores tienden a mantener el sistema encendido durante más tiempo debido a los emisores obstruidos.

Palabras clave: Calidad del agua, obstrucción, hierro.

Introduction

Water constitutes the most important natural resource for the development of agriculture in the world, being that new technologies for increasing the productivity of agricultural areas are dependent on it and the scarcity of this resource is a limiting factor for economic and social development of a region.

Irrigation is recognizably the human activity that consumes more water, on average 70% of the entire volume collected (CHRISTOFIDIS, 2001). In areas of dry climate, irrigation is responsible for consuming 50 to 85% of available water resources (CAPRA and SCICOLONE, 2004). In

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Brazil agriculture uses 61% of the entire volume collected (CHRISTOFIDIS, 2001; SANTANA, 2002). Nevertheless, currently 18% of the agricultural areas worldwide, around 275 million hectares are irrigated. Which are responsible for producing 42% of food consumed by man (CHRISTOFIDIS, 2002).

One of the most important aspects to be observed in irrigation management is the uniformity of water distribution by system, because in microirrigation various factors compromise such uniformity. The clogging of emitters can result from physical causes, biological or chemical.

In Southeastern region of Brazil, often are found waters presenting high levels of total iron, this element that can cause serious clogging problems to drippers, especially when present in reduced form and may precipitate within the pipes when oxidized, favoring also the development of Iron Bacteria (CORDEIRO, 2002).

Considering these aspects, the objective of this literature review is to discuss the use of ferrous water used for irrigation and its effect on the system.

Localized Irrigation

The localized irrigation was developed mainly in the 60s and 70s, although some irrigation systems, which operated under this concept of applying small flows of water located directly on the root system of the plants, had been developed since the early of the twentieth century (SOUZA, 2008).

According to HOWELL (2000) the Israeli Engineer SynchaBlass developed in England the technology for irrigating plants in greenhouses in a localized manner. In the 50s this engineer returned to Israel where he successfully applied the technology developed in food production, in the Negev desert, using highly saline waters.

Starting in the 60s, there was a great impetus in the development of the drip irrigation. Since then, swiftly, the dripping spread to several countries (BUCKS and NAKAYAMA, 1986).

The two major localized irrigation systems are: the drip irrigation and the microsprinkler, and there are numerous emitters for the most diverse crops and production systems, which have allowed large expansions in the use of this irrigation system.

The localized irrigation comprises the application of water in only a grown fraction, in low volume of water keeping the soil and the root zone of plants under high moisture regime (PENTEADO, 2007).

Among the methods of irrigation, the localized is the method that has more developed the past decades, due to a rational and economical manner of water use. According to PIZARRO (1996), a study released by the International Comission on Irrigation and-Drainage ICID in 1991 showed a growth of global irrigated areas by methods of localized irrigation in 63% in relation to the previous 5 years and 329% for the 10 years that proceeded.

This irrigation method is used for a wide variety of crops, especially of higher economic yield, since its initial fixed cost is elevated (SAHIN et al. 2004). According to CHRISTOFIDIS (2002), the incorporation of irrigated areas by the localized irrigation method increased from 112,730 ha in 1996 to 248,414 ha in 2001, resulting in a relative increase of 4.24% to 7.88% of the total irrigated area in the country, in the period mentioned.

Furthermore, the drip irrigation presents a number of potential advantages over other methods of irrigation. According to BERNARDO et al. (2005), the localized irrigation has the following main advantages: high efficiency in water use: which allows control of the applied water depth; higher productivity: with drip irrigation has increased frequency of irrigation per day at lower flow rates; greater efficiency in the phytosanitary control: only irrigating the root system range enables more efficient use of pesticides; adaptable to different soil types and topographies: by applying water at low intensity this method adapts to any terrain. Therefore, the choice of this technique also becomes a key measure for the preservation of water resources.

BERNARDO et al. (2006) describes the irrigation as an agribusiness, a strategy to increase the profitability of the agricultural property through the increase in the production, what formerly the technique of irrigating was aimed basically to combat drought.

Water and Iron Quality

According to MANTOVANI et al. (2006) water quality is a key aspect for the successful use of irrigated systems, however, the evaluation of the quality of it is often neglected at the moment of elaboration of project.

However, in order to be able to make the correct interpretation of water quality for irrigation, the analyzed parameters should be related to its effects on soil, crop and in the irrigation management, which will be necessary to control or compensate for problems related to water quality (BERNARDO et al., 2006).

For the assessment of quality of water for irrigation should be defined standards and criteria of physical, chemical and biological variables and the risk of damage that these interfere in the irrigation systems. NAKAYAMA and BUCKS (1986) reported that physical, chemical and biological variables which are related to risk of obstruction according on the quality of the irrigation water, are: the suspended solids and dissolved, pH, total iron, manganese, hydrogen sulfide and population of bacteria.

The iron is a micronutrient and has its origin in the dissolution of compounds of rocks and soils, and is an abundant element found in natural waters, surface and groundwater (ESTEVES, 1998). Presenting itself in insoluble form (Fe^{+3}) and dissolved (Fe^{+2}), the dissolved form occurs where there is a low concentration of dissolved oxygen (LIBÂNIO, 2005). The iron concentration in the aquatic depends on several factors environment, being the pH, the temperature and the potential redox the most important (ESTEVES, 1998).

Nowadays the iron is a major problem in irrigation water, due to the ability to physically obstruct the pipes and emitters of drip irrigation systems. According to MARTINKO et al. (1997), the clogging occurs due to bacterial action in association with the iron, which when oxidized in ferrous form (Fe^{+2}) to the ferric form (Fe^{+3}) form precipitates of ferric hydroxide ($Fe(OH)_3$) very insoluble in water. GILBERT and Ford (1986); NAKAYAMA and BUCKS (1986) presented a classification of water quality in relation to the potential clogging of drippers based on physical-chemical and biological factors (Table 1).

In accordance with MARQUES JÚNIOR (1998), the problems produced by iron complexes are especially severe when the water pH is between 7.0 and 7.8, indicating the importance of the knowledge of this parameter in the study of the process of clogging of emitters. The high temperatures and high pH values favor the chemical precipitation, which originates by excess of carbonates or sulfates of calcium or magnesium, or by oxidation of iron to form a ferric insoluble precipitation of reddish brown coloration (HERNANDEZ; PETINARI, 1998).

According to CORDOVILLE (2005), the Iron Bacteria of the genera *Sphaerotilus, Gallionella* and *Crenothrix* use the energy resulting from the conversion of ferrous oxide to ferric hydroxide, forming compounds which deposit on the microorganism in the form of sheaths, which in turn accumulate on the walls of the pipes. These bacteria have economic and health importance, causing the formation of crusts rusts on the inside of pipes. They come to form extensive geological deposits of iron and, in plumbing, constitute frequent causes of obstructions, besides giving a reddish brown color to water.

Obstruction of Emitters

According to COELHO (2007), several factors can affect the uniformity of water distribution in localized irrigation systems (operating pressure of the emitter, water velocity in the pipe, aligning of the sideline, and clogged emitters, among others).

Due to the small diameters of the hole, the clogging of the drippers appears as one of the main problems related to the method (BATISTA et al., 2006).

Table 1. Classification of water quality in relation to the clogging emitters potential.

Clogging factor	Clogging risk		
	Low	**Medium**	**Severe**
Phisical (mg L^{-1}):			
Suspended Solids	<50	50-100	>100
Chemical (mg L^{-1}):			
pH	<7.0	7,8-8,0	>8.0
Dissolved Solids*	<500	500-2.000	>2.000
Manganese	<0.1	0.1-1.0	>1.0
Total Iron	<0.20	0.20-1.5	>1.5
Hydrogen Sulfide	<0.20	0.20-2.0	>2.0
Biological (Bacterial Number L^{-1}):			
Bacterial Population	<10.000	10.000-50.000	>50.000

Source: GILBERT and FORD (1986); NAKAYAMA and BUCKS (1980).

** Maximum concentration measured with a representative number of water samples, using standard procedure for testing, in mg L^{-1}.*

The clogging of emitters is directly related to the quality of irrigation water and the internal architecture of the drip pipe. Therefore, suspended solids, chemical composition and microbiological activity dictate the type of treatment of water necessary to the prevention of obstructions (DAZHUANG et al. 2009).

BARROS et al. (2009) states that the obstructions caused by chemical precipitations occur more often and, therefore are more difficult to locate. Obstructions arising from suspended matter (solid particles) are the easiest to deal with, given that an efficient filtration system can significantly reduce the problem (SOUZA et al., 2006).

The prevalence of the use of surface water sources, allied with the high frequency of optimum temperature range for growth of microorganisms results in elevated risk of clogging of biological origin for irrigation systems (RESENDE et al., 2001) also favoring the Iron Bacteria develop, thus causing the low distribution uniformity.

SANTOS et al. (2003) argue that a low uniformity of water distribution means that certain plants irrigated by the system receive more water and fertilizer than others, resulting in an uneven development within the plantation. They add that the excess of water in the soil causes the leaching of nutrients, reduction in the concentration of available oxygen to the roots and can increase the incidence of pests and diseases, while the shortage increases the risk of soil salination and inhibits the production potential of the plant.

Uniformity of Application

RIBEIRO et al. (2010) argue that changes in the coefficient of variation of flow rate is related to the process of obstruction, whose primary responsibility is the quality of the water used for irrigation, since the problem does not equally affects all the drippers along the lateral line, being also dependent upon the coefficient of variation of the manufacturing.

The clogging leads to a decrease in Emission Uniformity (EU) and an increase in the Coefficient of Variation of flow (CV), causing a significant reduction in the uniformity of distribution of water along the lateral lines (CARARO et al. 2006).

According to BERNARDO (1995); DENÍCULI et al. (1980); KARMELI and KELLER, (1974), the uniformity of water application on drip irrigation systems can be expressed through various coefficients, highlighting the Coefficient of Uniformity of Christiansen (CUC), the Coefficient of Uniformity of Distribution (CUD), and the Coefficient of Variation of Manufacturing (CVM). The uniformity of water to plants is directly linked to the problem of clogging of the drippers, where a small percentage of clogged emitters can significantly reduce the uniformity of water application. The poor distribution of water, measured in terms of CUC can change the wetting profile, regardless of irrigation system used. Studies on the uniformity of distribution and storage of water above and below the surface were conducted by VANZELA et al. (2002) and ZOCOLER et al. (2002).

It is common to express the uniformity of water distribution by a coefficient of uniformity. When this coefficient is greater than or equal to a certain arbitrary value, the uniformity of distribution of irrigation depth applied to the surface soil. Many coefficients of uniformity were proposed, however the oldest and most widely used is proposed by CHRISTIANSEN (1942), (equation 1).

Equation 1. Christiansen Uniformity Coefficient.

$$CUC = 100 \times \left[1 - \frac{\sum_i^n = 1|Y_i - \bar{Y}|}{n \times \bar{Y}}\right] \quad (1)$$

Where:
CUC: Christiansen Uniformity Coefficient (%);
n : Number of samples in the lateral line;
Y_i : Emitter flow (L h^{-1});
$\bar{Y}$: Average flow of emitters (L h^{-1}).

Although many coefficients have been presented as alternatives to Christiansen, none presented significant advantages (FRIZZONE, 1992).

Another measure of uniformity of distribution used CUD is the relation between the average of 25% lower values of irrigation depths and the average depth applied to the surface of the soil (equation 2).

Equation 2. Coefficient of Uniformity of Distribution

$$CUD = \frac{Average\ 25\%\ \ of\ flow\ with\ lowest\ values}{Average\ of\ all\ flows} \times 100 \quad (2)$$

The CUD and CUC have a classification regarding their application uniformity according to the authors KELLER and KARMELI (1974); MERRIAM and Keller, (1978); ASAE (1996); MANTOVANI (2002) (Table 2).

Table 2. Classification of the Coefficient of Uniformity of Distribution (CUD) and Christiansen (CUC).

CUD (%)	Uniformity	CUC (%)	Uniformity	Source
>90	Excellent			KELLER and KARMELI, 1974.
85<CUD<90	Good			
70<CUD<80	Regular			
<70	Bad			
>90	Excellent			MERRIAM and KELLER, 1978.
80<CUD<90	Good			
70<CUD<80	Regular			
<70	Bad			
87<CUD<100	Excellent	90<CUC<100	Excellent	ASAE, 1996.
75<CUD<87	Good	80<CUC<90	Good	
62<CUD<75	Reasonable	70<CUC<80	Reasonable	
50<CUD<62	Bad	60<CUC<70	Bad	
<50	Unacceptable	<60	Unacceptable	
		90<CUC<100	Excellent	MANTOVANI, 2002.
		80<CUC<90	Good	
		70<CUC<80	Reasonable	
		60<CUC<70	Bad	
		<60	Unacceptable	

It is common to CUD be less than the CUC, this behavior is expected, by the fact that the first considers the average of the 25% lower depths collected and the Christiansen considers the average of the depth collected in all collectors causing to a flow to compensate the other. To REIS et al. (2002), the evaluation of the performance of an irrigation system is an essential step before any irrigation management strategy is implemented. ZOCOLER (1999) recommends values between 70 to 80% and 82 to 88% to CUD and CUC respectively; to crops whose root system explores, basically, the first 40 cm of soil.

The CVM depends entirely on the process and the care at the time of manufacture, because the emitters are all made of plastic, which are subject to considerable variations. Besides being a statistical measure that evaluates the variation of the manufacturing process of the emitters, is also used to evaluate the change in flow of the transmitter along a lateral line of localized irrigation.

According to the ABNT (1986), the coefficient of variation of manufacture is obtained through the relation between the standard deviation and average flow rates of the sampled emitters (equation 3).

Equation 3. Coefficient of Variation

$$CV = \frac{S}{\bar{X}} \times 100 \quad (3)$$

Where:

CV : Coefficient of Variation (%);

S : Sample standard deviation;

$\bar{X}$: Average of the emitters flow (L h^{-1}).

In accordance with SOLOMON (1979); HILLEL (1982); ABNT (1986), KELLER and BLIESNER (1990) shows the classification of CVM (Table 3).

Table 3. Classification of Fabrication Variation Coefficient (*CVf*) of drip emitters.

	Uniformity	Source
≤0,03	Excellent	SOLOMON, 1979.
0,05< ≤0,07	Medium	
0,08< ≤0,10	Marginal	
0,11<≤0,14	Poor	
>0,15	Unacceptable	
Till 10%	Good	HILLEL, 1982.
10% <<20%	Medium	
Above 20%	Deficient	
≤10%	Good	ABNT, 1986.
10%<<20%	Medium	
20%<<30%	Marginal	
>30%	Unacceptable	
<0,05	Excellent	KELLER and BLIESNER, 1990.
0,05<≤0,07	Medium	
0,07<≤0,11	Marginal	
0,11<≤0,15	Poor	
>0,15	Unacceptable	

The clogging of emitters is considered the most serious problem in localized irrigation. Adversely affecting the rate and uniformity of water application, occurring the reduction of production and damage the crops, if the obstructions are not detected and eliminated in a timely manner (PENTEADO, 2007).

In the literature, are extensive the quotes from equipment and processes applied to monitoring with the objective of irrigation management (BERNARDO, et al. 2006). The distribution uniformity and control of water application are generally the two biggest technical prerequisites for a good irrigation.

The evaluation of irrigation is the fundamental part of the process, the knowledge of the characteristics, of operating and potentialities of an irrigation system and a fundamental aspect on the influence of a management and control of irrigation (MANTOVANI et al., 2007).

Conclusions

The quality of water is of extreme importance in irrigation, ferrous water is now the largest concern over the clogging of emitters. To avoid this problem it is necessary to make chemical, physical and biological analyses of the water before scaling an irrigation system, so there are no future problems. The tests of uniformity of application are an excellent method to prevent and control the obstruction in the system, avoiding excessive expenses.

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