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Wastewater reuse by drip irrigation

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Abstract

Agriculture is the main user of water in Italy, as in most regions of the world. Particularly in southern regions, where it is more difficult to meet the agricultural water demand with conventional resources, wastewater (WW) reuse represents a viable option. In northern and central regions, where conventional resources are usually sufficient, WW reuse plays an important role in controlling surface water pollution. Drip irrigation is particularly suitable for WW reuse because it minimises the health risks to farmers and product consumers due to contact with the WW. The performance of drip irrigation systems using WW is mainly limited by emitter clogging, and this discourages farmers from introducing it. The paper gives the results of experimental trials on the behaviour of the three kinds of filter (screen, gravel and disk) most commonly used in irrigation systems around the world and two commercial types of drip emitters (vortex and labyrinth) using dilute and non-dilute municipal WW. The results substantially confirm the possibility of using WW in drip irrigation, even if the quality of the effluent is very poor. The performance of the emitters and filters tested depends on the quality of the WW. With non-dilute raw WW drip irrigation is possible using labyrinth emitters protected by gravel filtration only. With dilute WW both vortex and labyrinth emitters assure good performance. The operating time of the filters also depends on WW quality: cleaning is required more than once a day using non-dilute WW and once a day for dilute WW.

1 Introduction

Irrigated agriculture is the biggest consumer of water in the world. It has been evaluated that in areas with dry climates, crop irrigation requires from 50 to 80-85% of total water use [1], [2].

Competition for fresh-water resources between the increasing demands of the domestic sector and those of the agricultural sector is very strong, mainly in populated arid and semi-arid regions in the Mediterranean area.

At the same time, increasing urbanisation is producing large volumes of WW that have become a serious environmental problem in most countries.

An effective solution for both needs is the reuse of sewage effluents for irrigation. Wastewater reuse in irrigation is commonly practised in many parts of the world: in Israel WW irrigation uses about 66% of total sewage [3]; in the same country Haruvy [4] evidenced a saving of about US$ 0.51/m^3 as compared with collection from streams or rivers.

In Italy there is a great discrepancy between the legal situation and the real one. Excessive microbiological restrictions imposed by current legislation represent one of the major obstacles to the diffusion of WW irrigation. Due to the difficulty of obtaining authorisation, farmers in many parts of Italy make unauthorised use of WW both as a regular supply source and as a means to mitigate drought effects. In the next few months the regulatory framework should be totally changed; the new norms are expected to be more realistic and based on the results of research carried out all over the world, particularly in Mediterranean areas [5].

Treated WW has been used to irrigate a variety of field crops and orchards and intensive effort is being made to expand the crop pattern. Unrestricted irrigation, however, may expose the public to a variety of pathogens such as bacteria, viruses, protozoa, or helminths. Transmission of disease may occur through contact with the water by farmers, aerosol spraying, the consumption of products irrigated with effluent and contaminated surface or groundwater. The irrigation method used may also significantly affect the potential spread of pathogens.

When a drip irrigation system is used no aerosols are formed, water logging by runoff and deep percolation are negligible and the only human contact with the water occurs when the product to be consumed touches the soil; products are practically devoid of infectious bacteria when the drip system is buried in the soil or covered by plastic sheets [6], [7], [8], [9], [10], [11], [12]. Drip irrigation is, however, limited by emitter clogging.

The clogging of drip emitters is universal and is considered the largest maintenance problem with drip systems [13]. It is difficult to detect and expensive to clean or replace clogged emitters. Partial or complete clogging reduces emission uniformity and, as a consequence, decreases irrigation efficiency. In many cases, to assure that irrigated plants receive their water requirement, it is necessary to put up with water loss due to overirrigation. Overirrigation causes deep percolation and consequent disadvantages, due to energy costs, fertiliser leaching, drainage needs and groundwater contamination.

Clogging and mitigation procedures are closely related to the quality of the water used [14], [15]. Due to the suspended solids and organic matter content, municipal WW can cause emitter clogging problems [16], [17], [18], discouraging its use mainly in Southern areas where, except for Israel, farm water treatment systems are generally very elementary and irrigators prefer large-sized emitters such as sprayers and sprinklers.

The objects of the trials were:

- to select emitters and filters commonly used with clear water which can assure satisfactory performance if used with water of poor quality like urban wastewater;
- to show the influence of differences in WW quality on filter and emtter performance.

2 Materials and methods

The test was conducted using two kinds of municipal WW, two kinds of emitters and three kinds of filters.

Both kinds of WW were submitted to simple screening only; the first was used without dilution after gravity flow filtration (size 3 mm) and the second was diluted with about 50% of stream water and accumulated in a settling basin. The relevant WW characteristics used to evaluate the plugging potential [14], [15], are shown in Table 1.

Table 1. Characteristics of wastewater

Characteristic	Non-dilute wastewater	Dilute wastewater
Suspended solids, mg/l	376	3
pH	7.8	7.5
Electrical conductivity, dS/m	1.7	1.5
BOD_5, mg/l O_2	200	15
Sodium, mg/l	209	107
Calcium, mg/l	64	24
Magnesium, mg/l	81	90

Potential emitter clogging by non-dilute WW can be classified as severe for suspended solids and BOD_5, moderate for pH, dissolved solids (electrical conductivity) and magnesium, and low for calcium; the clogging risk for dilute WW can be classified as low for suspended solids, BOD_5 and calcium, and moderate for pH, dissolved solids and magnesium.

The emitters tested were:

- labyrinth type, discharge 4.1 l/h at a pressure of 100 kPa, and emitter discharge exponent of 0.6;
- vortex type, discharge 4.1 l/h at a pressure of 100 kPa, and emitter discharge exponent of 0.5.

The filters tested were:

- gravel filter, depth 1.20 m, diameter 0.40 m, with crushed granite n. 8 (actual size 1.5 mm), followed by a 120 nylon mesh screen filter to catch particles escaping during back washing;
- disk filter, 120 mesh;

- screen filter, 120 nylon mesh, filtration area 0.12 m^2.

Each filter was doubled; during cleaning one filter was operating while the other was cleaned by reversing the flow of water (back flushing).

Four hundred emitters (two hundred per kind) connected on-line to 4 low-density polyethylene lateral lines (one hundred per lateral) were tested for each filter.

Pressure gauges installed before and after each filtration group and flow-meters completed the experimental system.

The system was in operation for 4-6 hours twice a week for 2 months.

On each day of operation and for each kind of filter, the total flow volume, the number of totally clogged emitters and the number of filter cleaning operations were recorded.

The filters were cleaned by back flushing whenever the pressure drop caused by partial clogging of the filter increased by 20 kPa. Disk and screen filters were also manually cleaned, by pulling out the filter basket and washing it, when the pressure drop did not diminish after two minutes of back flushing. The filters were cleaned and dried after each day of operation.

3 Results

Table 2 shows the percentage of totally clogged emitters for each kind of filtration, emitter and WW at the end of the first and last operation and the mean of all the trials.

Table 2 . Totally clogged emitters (%)

Filter	Emitter	Non-dilute wastewater			Dilute wastewater		
		First op.	Last op.	Average	First op.	Last op.	Average
Gravel	Vortex	4.0	18.5	11.0	0.0	0.5	0.3
	Labyrinth	0.0	1.0	0.4	0.0	0.0	0.0
Screen	Vortex	23.0	68.5	64.0	1.0	4.5	3.7
	Labyrinth	18.5	72.0	62.0	0.0	0.0	0.0
Disk	Vortex	49.1	93.5	72.0	2.0	28.0	18.8
	Labyrinth	13.0	83.0	66.0	0.0	1.0	0.2

The emitters were better protected from total clogging by gravel filtration: practically no totally clogged emitters were observed when the labyrinth type was used with both kinds of WW and vortex emitters with dilute WW; an average of 11% of vortex emitters functioning with non-dilute WW were totally clogged during the test. The worst emitter performance was observed in disk filtration for both kinds of WW and emitters. This result is surprisingly bad as compared with the results of other similar trials reported in literature [19]; it may be accounted for by the fact that the disk filters tested were manufactured locally; partial results of trials in progress with treated WW show that the performance of internationally available disk filters is better than that of locally

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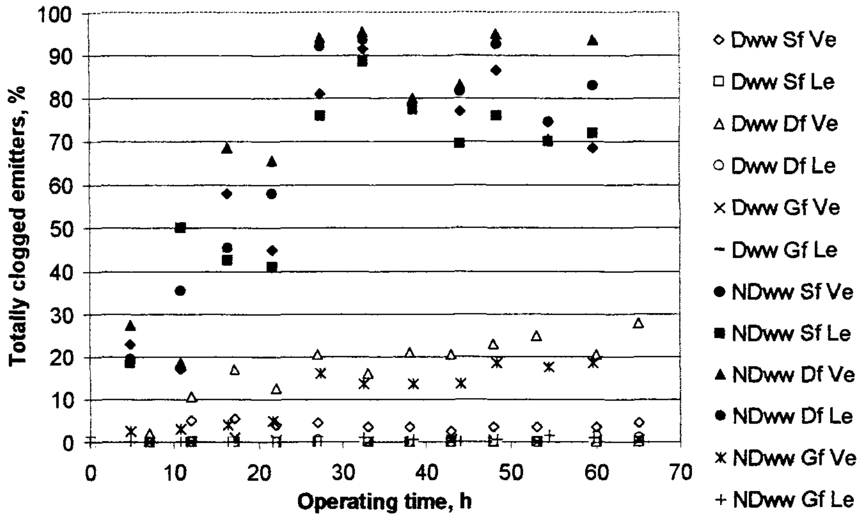
manufactured filters of the same kind and screen filters, and similar to that of gravel filters. The performance of emitters protected by screen filters depends on the kind of WW and emitter: good or acceptable behaviour was observed in both kinds of emitter with dilute WW; a very high percentage of totally clogged emitters was observed with non-dilute WW.

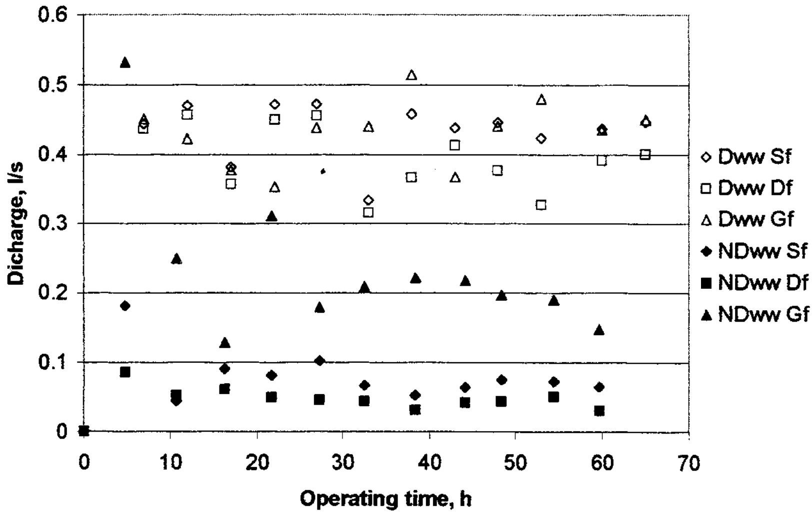
Figure 1 shows that the percentage of totally clogged emitters reached maximum values after 30-35 hours of operation with non-dilute WW and at the end of the trials (65 hours) for vortex emitters with dilute disk-filtered WW.



Dww = Dilute wastewater; NDww = Non-dilute wastewater; Sf = Screen filter; Df = Disk filter; Gf = Gravel filter; Ve = Vortex emitters; Le = Labyrinth emitters

Figure 1: Totally clogged emitters during the trials

Figure 2 shows the mean discharge of each kind of filter (calculated as total volume/operating time) during the trials. Part of the mean discharge variation can be accounted for by a certain variation in pressure due to lather formation mainly in non-dilute WW. The mean discharge of both screen and disk filters operating with non-dilute WW was very low, respectively 18 and 11% of the theoretical discharge (equal to 0.45 l/s) from the $1^{st}/2^{nd}$ operation onwards; the mean discharge of the gravel filter with the same WW was reduced by about 50% after 25-30 hours of operation. Gravel and screen filters with dilute WW guaranteed a substantially acceptable mean discharge; a slight reduction in mean discharge (about 10%) was observed with disk filters.



Dww = Dilute wastewater; NDww = Non-dilute wastewater; Sf = Screen filter; Df = Disk filter; Gf = Gravel filter

Figure 2: Mean discharge per filter

The discharge reduction due to totally clogged emitters is not sufficient to account for the reduction in the mean discharge, so there must be problems of partial clogging as well. The data given in Table 3 shows that at the end of the trials no, or very few, partial clogging problems were observed in labyrinth emitters with dilute WW filtered by all the kinds of filter, or in labyrinth emitters with non-dilute WW filtered by gravel only. With vortex emitters there was a reduction in the mean discharge of less than 10% only with dilute gravel- and screen-filtered WW. Partial and total clogging accounts for the very low mean discharge values in the other conditions.

Table 3 . Mean discharge (l/h) of not totally clogged emitters at the end of the trials

Wastewater	Gravel filter		Screen filter		Disk filter	
	Vortex emitters	Labyrinth emitters	Vortex emitters	Labyrinth emitters	Vortex emitters	Labyrinth emitters
Non-dilute	1.4	4.4	1.4	3.6	2.1	3.1
Dilute	4.0	4.1	3.6	4.0	3.2	3.9

Table 4 shows the mean operating time of the filters (period between cleaning operations) and the mean volume filtered during the same operating time, distinguished by cleaning method (backwashing or manual). With non-dilute WW both the operating time and the filtered volume were very small for gravel and screen filters. The operating time of disk filters, significantly longer than that of the other filters, shows some operational defects: considering the

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great emitter clogging problems this means that clogging particles are not blocked by the filter. With dilute WW all the filters need a number of cleaning operations compatible with the normal operation of drip systems.

Table 4 . Mean duration of operation and mean filtered volume between cleanings

Filter	Non-dilute wastewater				Dilute wastewater			
	Duration of operation, h		Filtered volume, m^3		Duration of operation, h		Filtered volume, m^3	
	bw	m	bw	m	bw	m	bw	m
Gravel	0.4	-	0.4	-	21.7	-	34	-
Disk	6.6	9.9	1.1	1.7	21.7	65	31	92
Screen	0.8	1.8	0.2	0.5	21.7	65	34	101
Screen after gravel	-	1.4	-	1.1	-	65	-	101

bw = backwashing system; m= manual system

4 Conclusions

The performance of the emitters (labyrinth and vortex) and filters (gravel, screen and disk) tested depends on the WW characteristics. With non-dilute raw WW drip irrigation is only possible using labyrinth emitters protected by gravel filtration. With dilute WW both vortex and labyrinth emitters assure good performance if gravel and screen filters are used. The behaviour of disk filters requires further verification. The operating time of gravel and screen filters is very short with non-dilute WW; considering that cleaning is required more than once a day, automatic cleaning systems should be used. Automatic flushing systems are also preferable to avoid contact between the WW and the irrigator.

The trials substantially confirm the possibility of using municipal WW by drip irrigation, even if the quality of the effluent is very poor. The results can be considered encouraging for the spread and, in regions where WW irrigation is already used, the rationalisation of this practice. This may contribute towards solving both water shortages and environmental problems, minimising the health risk to irrigators and product consumers due to the infectious micro-organisms contained in municipal wastewater.

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