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Full Length Research Paper

Evaluation of filtration and SDI application effects on treated wastewater quality index

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Before the reuse of treated wastewater in irrigation, supplementary treatment could be used for controlling pollution index. In order to evaluate the filtration and subsurface drip irrigation (SDI) application on wastewater quality index, the SDI system based on wastewater reuse and three treatments (three replications) was applied. These treatments were controlled by; drip irrigation with drinking water (CH), surface drip irrigation with treated wastewater (DI) and subsurface drip irrigation with treated wastewater (SDI). There was also a SDI filtration to improve biological index of wastewater. The results showed that the values of BOD_5, TSS and nitrogen component adequately decrease during filtration, but ideally the microbiological factors did not improve. Under this condition, injection of treated wastewater below the soil surface (SDI system) could decrease the surface microbiological pollution significantly in comparison to CH. In overall, the SDI system which applies wastewater reuse can be introduced as a substitute system for supplementary treatment unit.

Key words: Filtration, subsurface drip irrigation, biological index, treated wastewater.

INTRODUCTION

Irrigation with wastewater could raise issues relating to sanitary (risk of viral and bacterial infection both for farmers and crops) as well as agronomic nature (due to the presence of toxic substances). In order to avoid health hazards and damage to the natural environment, wastewater must be treated before using for agricultural and landscape irrigation (Pereira et al., 2002). This criterion has to comply with the reuse standards so that environmental and health risks could reduce. Accordingly, the fecal coliform content (less than 103 cfu/100mL) is of great importance (WHO, 1989). Czyzyk (1996) pointed out that wastewater irrigation has a significant effect on the groundwater contamination level. Moreover, Lauver (2000) carried out nitrate contamination of the Arizona groundwater using volume balance approach in agricultural lands in which wastewater was used for irrigation. He concluded that the extent of groundwater contamination potentially increased when irrigating by wastewater was not restricted. Furthermore, in some parts of China, the nitrate content in soil (for growing vegetable) and cadmium content in cereal farms are very high (about 0.4 - 1 mg/kg), which causes some diseases for consumers (Salmasi, 2001).

Reuse criteria can be relaxed somewhat when using drip irrigation (DI) and primarily subsurface drip irrigation (SDI) because the soil acts as a complementary biofilter and there is no contact between the effluent and workers or the plant parts above the soil. The soil contamination was also reduced by using subsurface drip irrigation (Oron et al., 1999). Heidarpour et al. (2007) revealed that the concentrations of chemical constituents in soil layers were influenced by water movement patterns, chemical concentrations in irrigation water and plant uptake. The most important concern was the increase of EC in the top soil layer with subsurface irrigation, as this might inhibit plant growth. Wastewater irrigation significantly affected potassium; however, phosphorus and total nitrogen were not notably affected.

The grain size of porous media and bacterial cell size are important factors affecting the bacteria straining, the hydraulic loading rate as well as the extent of clogging layer development in the filter. Absorption of cells to the porous media was influenced by the content of organic matter, degree of biofilm development and electrostatic

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attraction due to ion strength of the solution or electrostatic charges of cell and particle surfaces. The inactivation rate of pathogenic microorganisms in absorbed or liquid phases has been shown to be affected by abiotic and biotic factors such as: moisture content, pH, temperature, organic matter, bacterial species, predation and antagonistic symbiosis between microorganisms in the system (Stevika et al., 2004). Drip irrigation uses water precisely and uniformly in comparison with furrow and sprinkler irrigation resulting in the potential reduction of subsurface drainage, control soil salinity and increase yield (Henson and May, 2004). Subsurface drip irrigation (SDI) is defined as "application of water below the soil surface through emitters with discharge rates, generally in the same range of drip irrigation" (ASAE, S526.1 "Soil and Water Terminology, 1999). It is well documented that, the SDI has the following advantages: improved water and nutrient management, potential for improving yields and crop quality, greater control over applied water resulting in less water and nutrient loss through deep percolation and reduction of total water requirements (Ayers et al., 1999, K. State University, 2006).

Tabatabaei and Najafi (2009) showed that in the case of SDI with its minimal leaching and prevalence contamination (such as N-NO3), it was minimized as a result of the usage of wastewater at depth and in groundwater. Moreover, in SDI treatments, the maximum EC and SAR leaching are observed at 60 cm depth, whereas in the FW this leaching is observed deeper than 90 cm. Filtration of water in the irrigation system could enhance the water quality with regards to health concerns and also to protect emitters in irrigation system from clogging. Thus, filtration (thickness, 610-910 mm) with a 1 to 6 mm diameter sand filter and a discharge of 244 - 406 $Lm^{-2}d^{-1}$ decreases the bacterial index in wastewater, plus a reduction (75%) of total nitrogen (TN) (Piluk 1995). Moreover, Venhuizen (1996) obtained a sand filter with 1.04 mm effective diameter and a discharge of 561.5 $Lm^{-2}d^{-1}$, which decrease (96%) BOD_5 in wastewater. Geoflow Institute (2000) advises a filter (with a 0.1 mm diameter) to obtain a BOD_5 less than 25 mg/L. Furthermore, Ruskin (2000) indicated that using one emitter with a discharge rate of 43 $Lm^{-2}d^{-1}$ was suitable for heavy soil and a BOD_5 less than 30 mg/L. In vast majority of Iran cities, municipal wastewater is used for irrigation in agricultural lands. For instance, the Firuzabad water canal (located in Tehran) is a crucial part of the municipal and industrial waste. This wastewater is widely used for irrigation of fruit and vegetables. Of the 9,700 hectares of Tehran's cultivable lands, almost 6,900 hectares (nearly 70%) are irrigated by wastewater. In addition, the main discharge of Khoshg River (in Shiraz) in arid seasons is wastewater which is ultimately used in agriculture. In Tabriz, municipal and industrial wastewater enters the Ajichai River and is eventually used for agricultural irrigation, (Tabatabaei, 2001). Therefore, evaluation of the wastewater quality is of great importance. The objective of this study was to investigate SDI filtration on wastewater quality for irrigation.

MATERIALS AND METHODS

Characteristics of SDI system

The southern sewage treatment plant (in Isfahan, Iran) treats sewage of approximately 128,000 M^3/day. Most of the treated effluent flows into the Zayandehrood River and a low amount is used for irrigation of suburban farms and gardens. The treatment plant uses activated sludge and secondary treatment processes. A plot was selected close to the treatment plant where the treated wastewater was accessible and a small control station was designed and connected to the outlet of a treated wastewater pump. The SDI filtration system comprised a sand and screen filter in the control station. The sand filter contains two layers of fine and medium sands. The upper-layer sands had an effective diameter of 0.5 mm with a thickness of 60 cm and the lower layer had an effective diameter of 1 mm with a thickness of 30 cm. As a result of this filtration, clogging was not seen during irrigation.

The screen filter is cascaded with a 100 micron (150 meshes) steel screen placed after the sand filter. System outflow was regulated for a 2.5 m^3 hr^{-1} m^{-2} and 4.7 drippers m^{-2}. A study field was designed with three treatments and replications with a dimension of 3 m × 3 m (9 m^2) plots during the winter of 2003. The treatments were as follows: 1) Irrigation with fresh water (control, CH), 2) SDI system in depth of 30 cm with wastewater (SDI) and 3) surface drip irrigation with wastewater at the soil surface (DI). Duration of experiment was 12 months.

Wastewater analysis

Wastewater samples were collected at the end of each month. For the drip irrigation, systems (DI and SDI). The samples were taken before and after the filtration system and all wastewater samples were analyzed immediately after sampling. There were some obtainable properties such as; five day biological oxygen demand (BOD_5), total suspended solids (TSS), nitrate-N (NO_3-N), nitrogen of ammonium-N (NH_4-N), TN, total bacterial count (TBC), total number of coliform (TC), number of fecal coliform (FC) and number of nematodes (NE). Analysis of wastewater was performed according to APHA (1995).

Soil analysis

Soil surface samples from the 0 - 5 cm depth were collected immediately after the final irrigation at the end of each month. Samples from the soil's surface (0 - 5 cm) were analyzed for total number of coliforms (TC) and fecal coliforms (FC). Some other parameters such as EC, amount of nutrient and agronomical parameters of water were measured for other aspects of research that are not presented here. The sand of the system's filtration part was cleaned with backwash performance each time before irrigation.

RESULTS AND DISCUSSION

The results showed that the average values of BOD_5 were about 34.6 and 15.3 mg/L before and after SDI filtration respectively. EPA (2004) presented 30 and 20

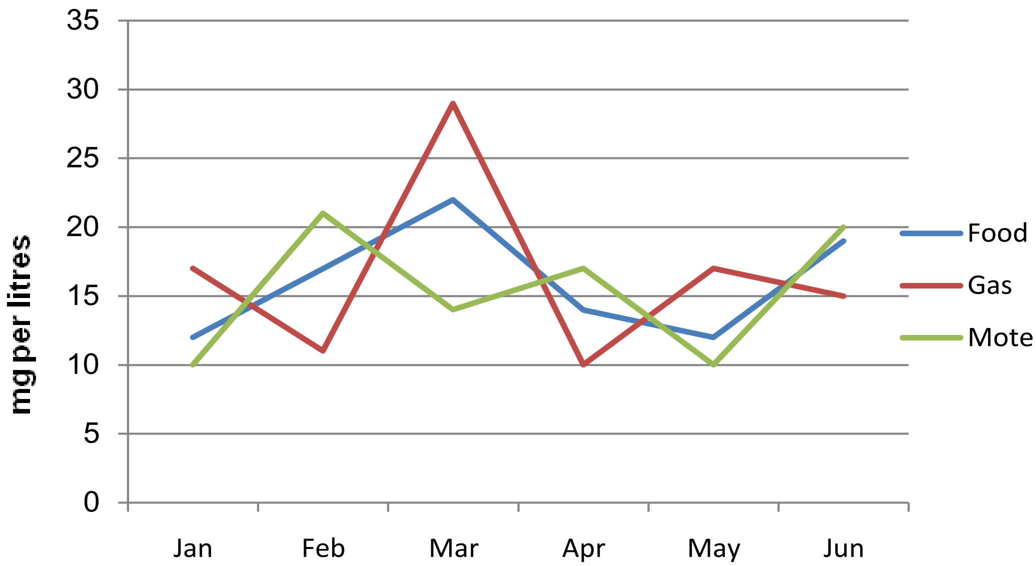

Figure 1. BOD_5 variation before and after the SDI filtration.

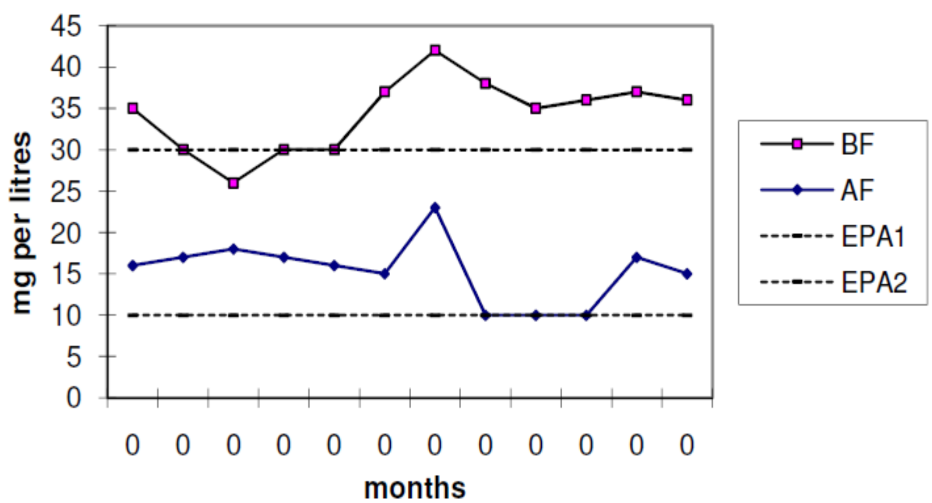

Figure 2. TSS variation before and after the SDI filtration.

mg/L as two standard levels for industrial and salad (uncooked) crops. Based on those levels and Figures 1 and 2, 66.7% of all samples before SDI filtration were greater than EPA standard level of industrial crops. It should be noted that the BOD_5 of all samples decreased in the SDI filtration (lower than the first standard level, EPA1). The average and standard deviation of the removal efficiency of SDI filtration were about 54.6 and 14.7%, respectively and as a result, the SDI filtration could improve the effluent for irrigation of industrial crops. The total suspended solides (TSS) should be 30 mg/L or less before application of wastewater for irrigation of agricultural crops according to EPA (2004). The TSS values were higher than the EPA level (2004), which is equivalent to the reduction of 44% of it. The removal efficacy of TSS was ranged between 13 and 65 % and depends on backwash performance and volume of suspended solids during the filtration. Because of the variability for inflow TSS, constant period for backwash performance caused different range for RE and outflow TSS. There was also no sign of clogging in the emitters. Figure 3 shows the variation of TSS before and after the SDI filtration.

Table 1 shows the nitrogen content of wastewater before and after the SDI filtration. Avg and Stdv indicate average and standard deviation respectively. BF, AF and RE represent before filtration, after filtration and removal efficiency, respectively. The removal efficiency of total

Table 1. Effects of the SDI filtration on Nitrogen content.

Index	Parameters	NO_3 (mg/L)	NH_4 (mg/L)	TN (mg/L)
BF	Avg.	1.28	29.16	60.3
	Range	1.1- 1.5	21-35	51 - 75.4
	Stdv	0.19	6.5	10.7
AF	Avg.	0.61	4.6	33.9
	Range	0.55-0.8	3.7 - 6.5	27 - 44
	Stdv	0.13	1.3	7.3
RE	Avg.	53	82	44.1
	Range	48-55	82-84	41.6-47
	Stdv	3.1	0.7	2.3
Standards	Rowe-A[1]	5	50	60
	Rowe-B[1]	10	50	70
	FAO-1[2]	5	5	-
	FAO-2[2]	30	30	-

1- Rowe and Abdel (1995); 2- Pescode (1992).

Table 2. Effects of the SDI filtration on microbiological index of wastewater.

Index	Parameters	TBC (N/ml)	TC (MPN/100ml)	FC (MPN/100ml)	NE (N/L)
BF	Avg.	8.6×10^6	4.6×10^6	3.4×10^4	3.5
	Range	6.9×10^6 - 1.1×10^7	3.4×10^6 - 6.2×10^6	2.7×10^6 - 4.6×10^6	0 - 6
	Stdv	1.8×10^6	1.1×10^6	8.4×10^3	2.5
AF	Avg.	9.3×10^4	1.1×10^5	2.3×10^3	1.5
	Range	7.4×10^4-1.3×10^5	8.8×10^4-1.5×10^5	1.8×10^3 - 3.2×10^3	0 - 3
	Stdv	2.3×10^4	3.1×10^4	6.5×10^2	1.3
RE	Avg.	98.9	97.6	93.2	55.6
	Range	98.87 - 98.98	97.4 - 97.8	92.9 - 93.6	50 - 66
	Stdv	0.04	0.18	0.26	9.6
Standards	Nakayama[1]	10^4	NA[4]	NA	NA
	WHO[2]	NA	NA	1000	1
	EPA[3]	NA	NA	200	0

1- Nakayama (1983); 2- WHO (1989); 3- EPA (2004); 4- NA = Not applicable.

nitrogen is nearly 44 percent. The nitrogen's average from ammonium is obtained as 29 mg/l before the SDI filtration; however, 82% of the nitrogen content is removed during the SDI filtration. The BF value of NH4 was more than FAO standard level for sensitive plants (Pescod, 1992). Consequently, the SDI filtration resulted

Table 3. Average values of TC in the 0 - 5 cm soil depth (MPN/100ml).

Treatment	First sampling	Second sampling	Average
CH	10^7	2×10^5	6×10^{6a}
DI	10^{11}	2×10^6	6×10^{10b}
SDI	7×10^5	3×10^5	5×10^{5a}

a ,b are Duncan level at 5%.

Table 4. Average values of FC in the 0-5 cm soil depth (MPN/100ml)

Treatment	First sampling	Second sampling	Average
CH	3×10^4	1×10^3	$1 \times 10^{4\,a}$
DI	2×10^{10}	2×10^5	$1 \times 10^{10\,b}$
SDI	4×10^4	2×10^3	$2 \times 10^{4\,a}$

a ,b are Duncan level at 5%.

in decreasing the BF value less than the standard level. On the whole, the nitrogen concentration had lower value than the standard one. Biological pollution is one of the main problems in realation to wastewater reuse for agriculture. The average values of removal efficiency using the SDI filtration on TBC, TC, FC and nematods were 98.9, 97.6, 93.2 and 55.6%, respectively (Table 2). All values were higher than the standard ones; therefore, applications of the SDI filtration have no effects on these values. Tables 3 and 4 show the average values of TC and FC of soil surface. The results showed that TC and FC values differ significantly ($P<0.05$) with the ones of DI. The SDI system in 30 cm below the soil decreases soil surface pollution considerably, nevertheless, the SDI filtration does not change microbiological values.

Conclusion

In conclusion, application of SDI can decrease the wastewater reuse problems (for example, health concerns). This system is suitable for irrigation of landscapes, agricultural farms and gardens by wastewater. In this method, it is very crucial to inject wastewater through the root zone area for improving its quality and therefore, new drilling system such as trenchless technology should be used for installing, monitoring and maintenance of the SDI system.

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