THE 'FILTER' TECHNIQUE FOR YEAR ROUND TREATMENT OF WASTEWATER

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Abstract

Existing systems for land treatment of wastewater using cropping and forestry are often less economical than treatment plants. This is mainly due to the need for expensive winter and wet weather storage, when crop irrigation requirements are low. Further, conventional land application of wastewater on soils with restricted internal drainage, which occur extensively around urban areas in S.E.Australia, often leads to waterlogging and salinisation.

In order to overcome problems associated with traditional wastewater disposal schemes, the FILTER (Filtration and Irrigated Cropping for Land Treatment and Effluent Reuse) technique was developed at CSIRO, Griffith. FILTER combines the use of nutrient-rich wastewater for intensive cropping with filtration through the soil to a subsurface drainage system. This technique is also capable of handling high volumes of wastewater during the periods of low cropping activity or periods of high rainfall. Wastewater application and subsurface drainage in the FILTER system are regulated to ensure adequate removal of pollutants, thereby producing minimum-pollutant drainage water which meets NSW Environment Protection Authority (EPA) criteria for discharge to surface water bodies throughout the year.

In this paper we describe the field evaluation of the FILTER technique at the Griffith City Council Sewage works site. The trial was designed and operated as one of eight irrigation blocks of a proposed 120 ha commercial FILTER system, required for around-the-year treatment of all Griffith's sewage wastewater. The field data from the winter cropping season of 1998 including hydraulic flows and removal of pollutants such as nitrogen, phosphorus, BOD, suspended solids, oil and grease, chlorophyll-a, and *E.coli* are discussed. Results indicate that a well managed FILTER technique can reduce pollutant levels in drainage waters below NSW EPA limits, while maintaining adequate hydraulic flow, crop yields and nutrient removal to potentially make it a sustainable system.

The potential for development of a MINIFILTER system to provide environmentally acceptable on-site treatment and disposal of domestic wastewater and greywater is also discussed.

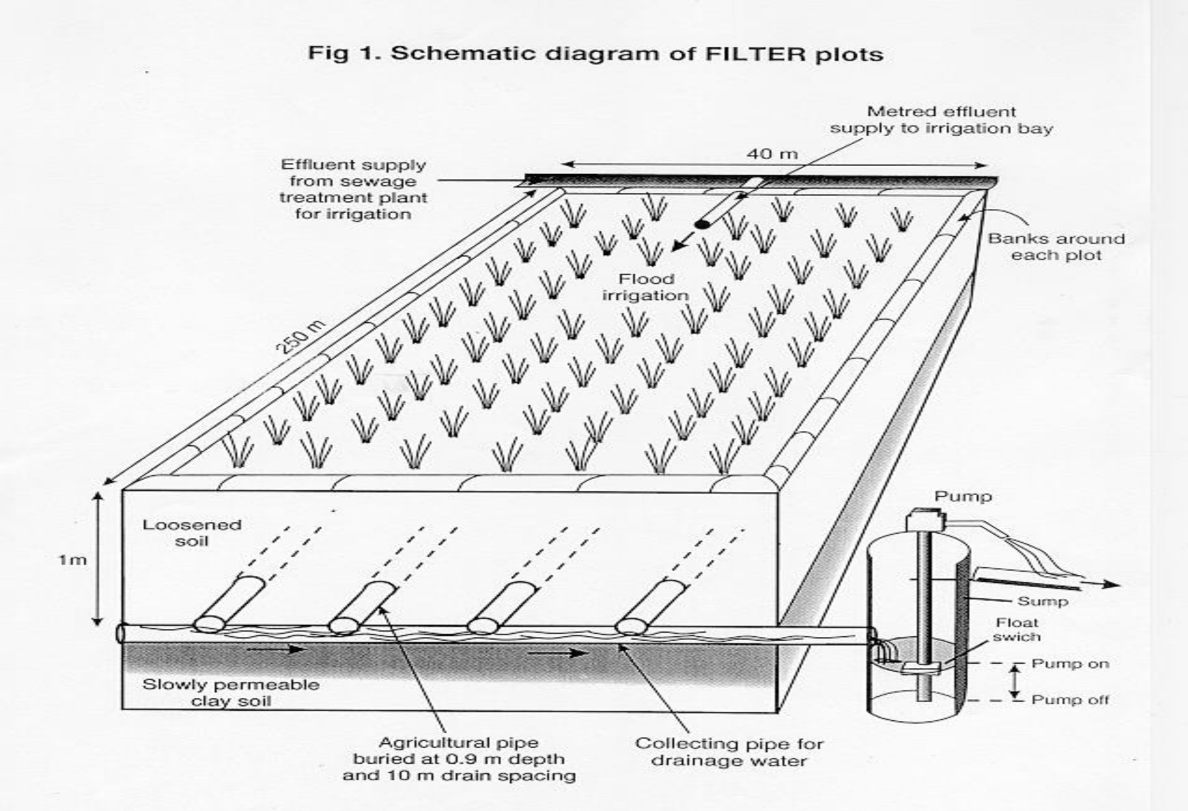
Keywords

wastewater treatment, pollutant removal, hydraulic properties, controlled subsurface drainage.

1 Introduction

The FILTER (Filtration and Irrigated cropping for Land Treatment and Effluent Reuse) technique was developed as a new approach for sustainable and around-the-year effluent treatment from Griffith Sewage Works (Jayawardane *et.al,* 1997a). The main objective being to reduce phosphorus and nitrogen content in the discharge water below Environmental Protection Authority (EPA) limits.

In this technique, the use of the nutrient-rich effluent to grow crops is combined with filtration through the soil to an intensive subsurface drainage system as shown in Fig. 1. FILTER is also capable of handling high volumes of wastewater during periods of low cropping activity and/or high rainfall.

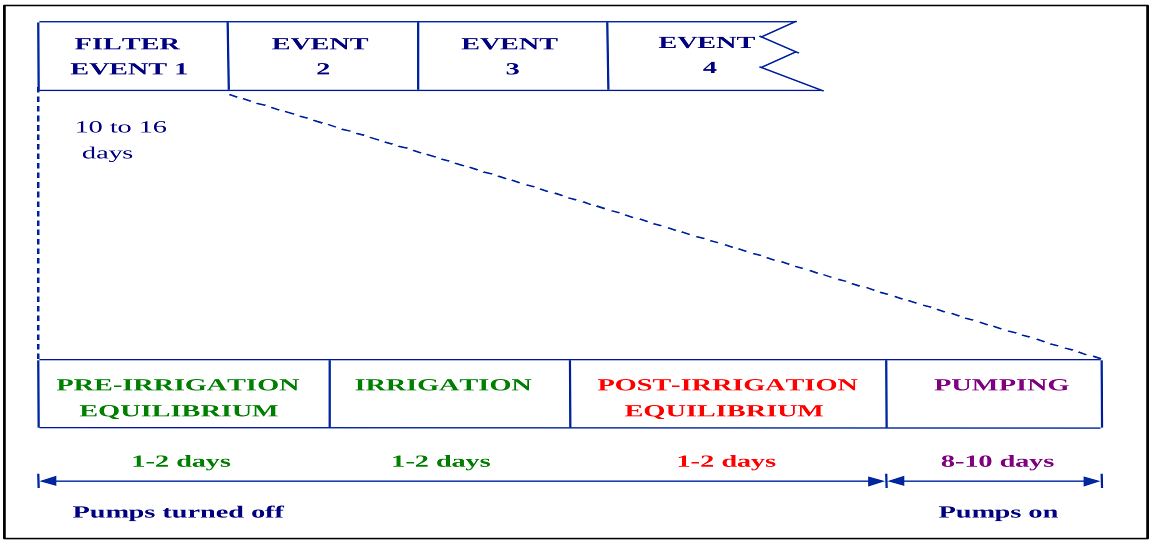


This system controls the rate of subsurface drainage in order to achieve adequate nutrient removal by crops and soil bio-chemical processes, thereby producing low-nutrient drainage. This drain water meets EPA criteria for discharge to surface water bodies or EPA criteria for non-potable reuse. This system provides for full manipulation of the watertable depth above the subsurface drains by controlled pumping from the drainage system. The drains are located at about 1.2 m deep at a spacing of 8-10 m, thereby providing optimum conditions for crop growth and pollutant removal.

Preliminary testing of the FILTER technique on one-hectare plots showed that the FILTER system met its objectives of reducing nutrient in drainage waters below EPA limits, while maintaining adequate drainage rates (Jayawardane *et.al*, 1997a, b). In addition, significant crop yields were obtained, which could be used to offset costs in a commercial system. The other beneficial effects were reduced suspended solids, oil and grease, increased N: P ratio and the potential to use the technique to ameliorate saline soils as well as handling saline effluent. Initially, the concentrations and loads of salt were increased in the drainage waters compared to incoming effluent load and was due to leaching of accumulated salts which had built up in the soil profile through previous effluent application without subsurface drainage. However, after a certain period an equilibrium will be reached and there will be no additional leaching of salt from the profile. Salt in the drainage water will be due to the incoming effluent.

After the successful and encouraging results of the preliminary FILTER trials a commercial FILTER system was planned on Griffith city council's land which is located close to its sewage works site. The commercial FILTER system is planned to be easily operated and managed by council staff. This system will consist of eight irrigation blocks of which six will be located on a 100 ha allotment at the experimental site. Each irrigation block is approximately 15 ha. It is proposed that each of the eight irrigation blocks will be irrigated with sewage effluent for two days on a sixteen-day rotation as shown in Fig. 2. The irrigation rotation period will be shortened if one or more blocks are out of rotation for agronomic management practices, such as planting or harvesting. This will allow for continuous land treatment of the Griffith City Council sewage effluent throughout the year.

Fig 2. The FILTER operation procedures



2 Materials and Methods

Presently we are researching the management and functioning of one (15 ha) of the proposed 8 irrigation blocks when it is managed according to the plans for running a commercial FILTER system at the site. For this pilot FILTER trial, the site was laser levelled to provide an irrigation slope of 1:4000. Four irrigation bays (430 m long by 82, 80, 86 and 102 m wide) with 0.4 m banks were constructed to provide good control of irrigation. A subsurface drainage system was installed within the pilot trial area, which was connected through the collector drains and the main drain to the main sump, fitted with an electric pump and flow meter. The subsurface drains were spaced 8 m apart at a depth of 1.2 m. The irrigation channels and associated structures for controlling and monitoring irrigation were installed.

In autumn 1998, two of the bays were sown with Coolibah Oats (90kg/ha) and 150kg of diammonium phosphate (N:P is18:20) fertiliser was drilled in with the seed. The other two bays were planted with ryegrass pasture mix; 17 kg multimix, 6 kg demeter fescue, 8 kg Victorian rye and 5 kg guard rye per ha.

Eight irrigation/FILTER events were carried out during that winter cropping season. Each FILTER event consisted of four stages, namely a two-day effluent application period, a one-day post-irrigation equilibrium period, a 8-10 day pumping period and finally a no-pumping equilibration period to allow a flattening of the water table.

A dethridge wheel, MACE flow and current meters were used to measure irrigation and drainage volume. The plots were instrumented with tensiometers, neutron probe access tubes, piezometers and test wells to monitor soil water content, water potential, water table and ground water potentials.

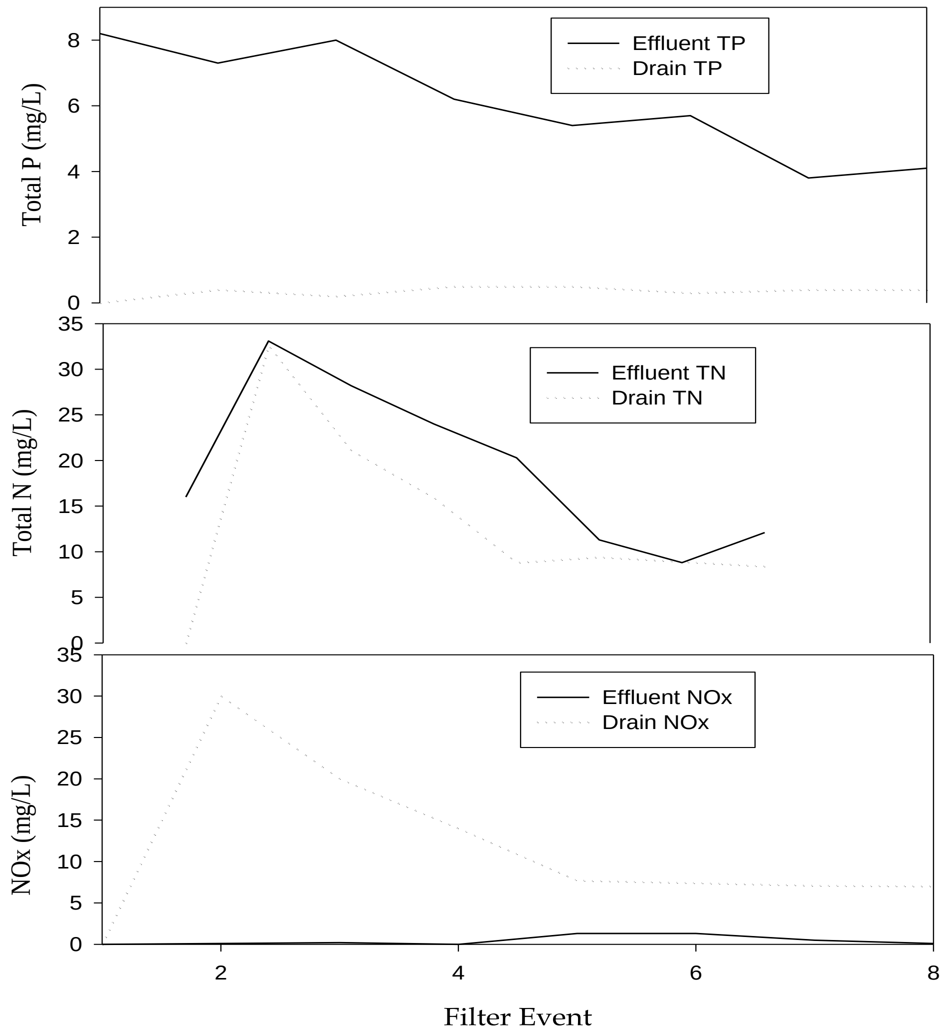
Continuous irrigation and drainage water samples were collected using a GAMET auto sampler and a sample bleeding tube arrangement, respectively. Samples were stored at 4°C before analysis for pH, electrical conductivity (EC), biochemical oxygen demand (BOD_5), total suspended solids (TSS), ammonia, nitrogen oxides (NO_x), total kjeldahl nitrogen (TKN), total phosphorus (TP), Chlorophyll$_a$, total faecal coliforms, and oil and grease.

The soil profile was sampled up to a depth of 2 m at intervals of 20 cm for ammonia, NO_x, Colwell extractable P, pH and EC to assess nutrients and salt in the profile, at the beginning and end of the cropping season. The pasture and oats were cut for hay in November 1998, dry matter yields were recorded and analysed for macro- and micronutrients to estimate nutrient removal.

3 Results and Discussion

The results from the pilot trial during the winter cropping season showed that when the pilot FILTER area was managed as one of eight blocks in a commercial system, it was possible to maintain adequate hydraulic flow rates to the subsurface drains, even during periods of unusually high rainfall. The drainage flow rates from the pilot trial, matched hydraulic flow and nutrient removal expectations from the preliminary trials. For instance, the total-phosphorus (TP) concentrations were reduced from a mean value of 6.1 mg/L in the applied effluent to a mean value of 0.39 mg/L in drainage waters as shown in Fig. 3. Total nitrogen (TN) concentrations were initially high due to leaching of pre-FILTER soil accumulated nitrogen, but fell below 10 mg/L from FILTER event 5 to 8 as shown in Fig. 3. During the following summer season drainage water always had TN below 10 mg/L. Figure 4 shows the incoming and outgoing load of pollutants at the FILTER site as well as the pollution load reductions for TP, TN, BOD_5, $chlorophyll_a$, and oil and grease which were 96, 57, 95, 100 and 100%, respectively.

Fig 3. Total P, total N and NOx in effluent and drainage



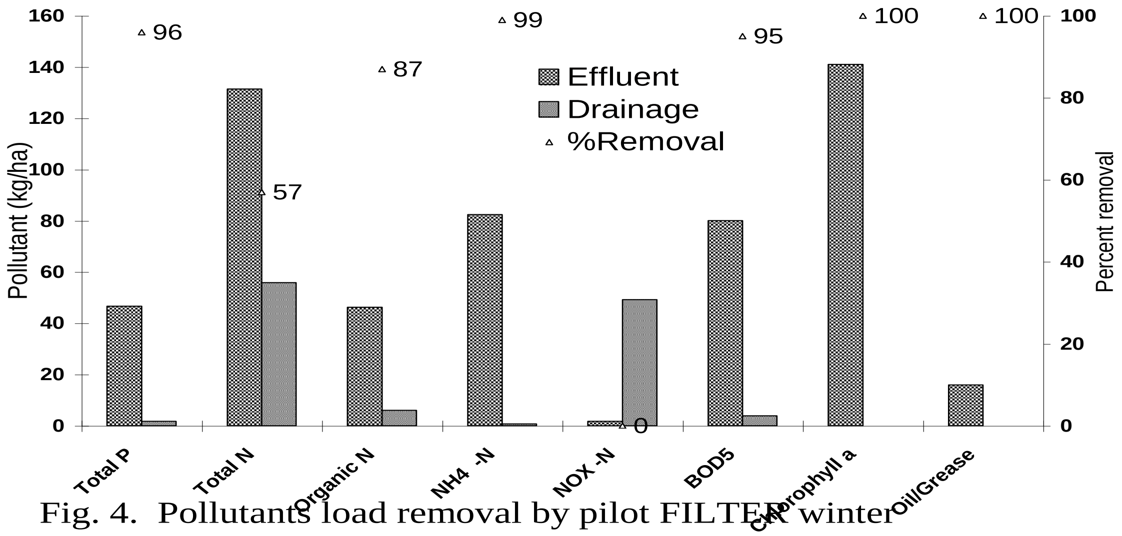
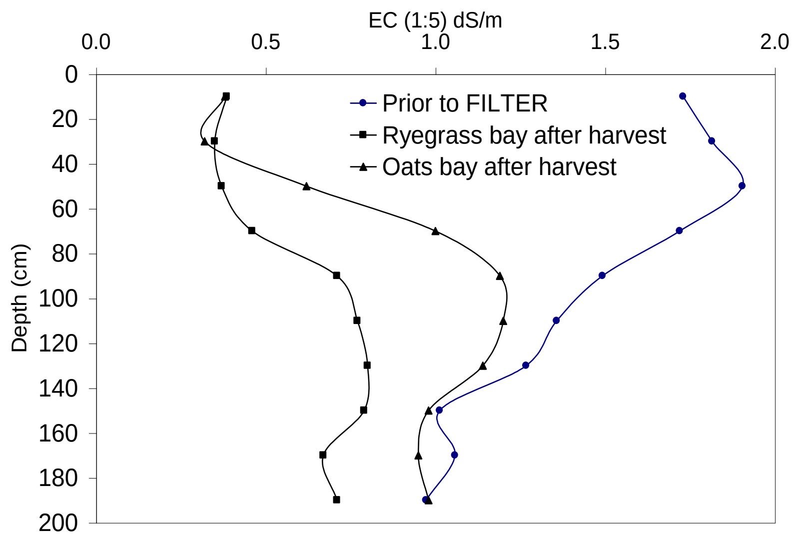


Fig. 4. Pollutants load removal by pilot FILTER winter 98

Salt concentrations and loads in the drainage water were higher than the effluent largely due to leaching of the pre-FILTER soil profile salt. As a result, the salinity of the soil layers above the drains in the pilot trial were reduced as shown in Fig. 5. This gives FILTER an advantage over traditional land application in that FILTER can not only operate without building up salt in the soil profile but can also ameliorate previously salinised sites.

Fig 5. Changes in soil profile EC by FILTER



Good dry matter yields of oats (8.9 t/ha) and pasture (14.3 t/ha) were obtained with large removal of N, P, K, Ca, Mg, Na, boron and heavy metals including copper, manganese, and zinc (Table 1). Figure 4 shows that during the same timeframe net addition (effluent minus drainage) of N and P was 76 and 45 kg/ha respectively. These results show not only the use of nutrient from wastewater but also the economic benefit of the FILTER technique when these crops are grown commercially. Further, through the combination of treatment and cropping it is possible to avoid build up of nutrients and heavy metals in the reuse site.

Table 1. Removal of nutrient and heavy metals by FILTER crops

Crops	**DM yield (t/ha)**	**Nutrient and heavy metal removal (kg/ha)**									
		N	P	K	Ca	Mg	Na	Cu	Mn	Zn	B
Ryegrass	14.3	182	21.4	142	19.8	12.3	47.8	0.03	0.56	0.21	0.08
Oat	8.9	76	19.9	131	12.1	8.82	69.2	0.03	0.63	0.34	0.08

4 FILTER: Potential Application to Domestic Wastewater

On-site treatment of sewage effluent and greywater from single dwellings or groups of dwellings could provide considerable cost savings in transport of effluent to treatment plants. It is proposed that the FILTER system described above for large treatment works could be scaled down to a small scale system 'MINIFILTER' for on-site treatment of domestic effluent and greywaters.

On-site treatment of effluent by a MINIFILTER system will be more difficult than large scale FILTER systems due to the additional constraints of restricted available area, restricted choice of site and soil, restricted choice of 'crops' and strong social and health restrictions on the use of effluent in residential areas. These conditions will require that the MINIFILTER be of sufficiently robust design, with sufficient buffering or margin of safety, to treat household effluent under variable climatic, soil, site and effluent load conditions. For long term use the MINIFILTER design must minimise the management required and continuously meet EPA conditions regarding discharge/reuse water, soil, human contact and odour.

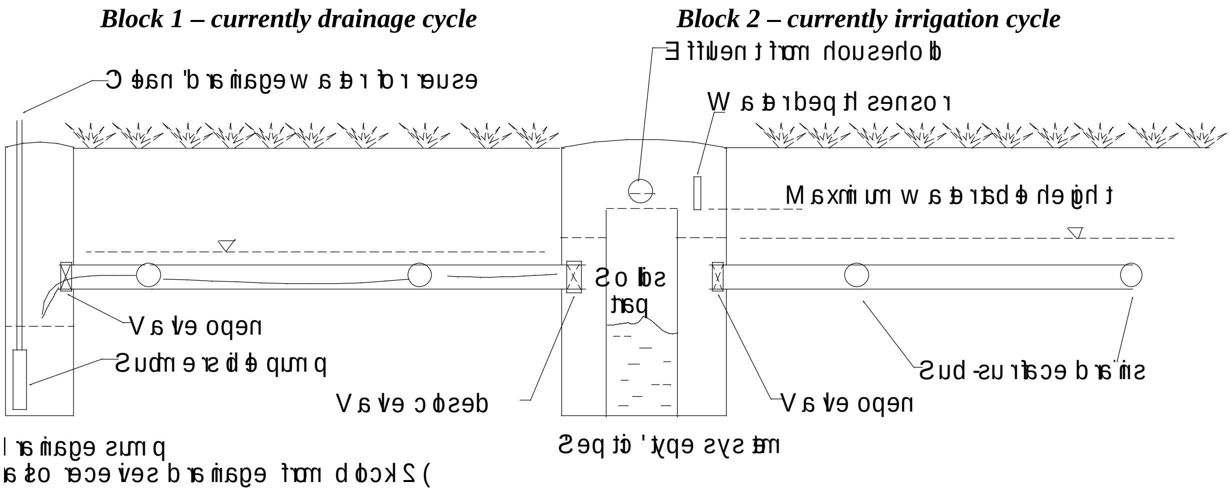
As the FILTER system relies upon using the soil as a nutrient stripping and storage mechanism, it requires soils that have high chemical adsorption capacity such as clays. This places constraints upon site suitability in regard to MINIFILTER systems, soils with low adsorptive capacity such as sands may not be capable of supporting a MINIFILTER system.

Thus, on clayey soils it is proposed that a MINIFILTER system, as shown in Figure 6, would consist of two identical blocks with subsurface drains in an intensive network, 3 – 5m apart, about 1m deep connected to the household effluent system via a solids trap 'septic' system. This network of subsurface drains would serve as both the irrigation and drainage system. The wastewater, after passing through the solids trap, would move under gravity into the subsurface drainage system. At this stage the outlet to the drainage system is closed and thus water builds up in the drains and percolates into the soil. On clay soils a perched watertable should develop with little water passing below the drains. Once this watertable builds up to within about 0.3m of the soil surface, the inflow to the drainage block is stopped and switched to the second block. The drainage in the first block remains closed for about 48 hours to allow adsorption and denitrification to occur in the 'filter stage,' and then the drainage outlet is opened. The subsurface drainage water is then pumped out and can be reused for domestic or industrial purposes, as non-potable water. Whilst the second block is taking the effluent the nutrients are being removed from the first block by the crop. Crops need to be those that will transpire and grow, using nutrients, all year round. This may need a mix of summer and winter active grasses on the two blocks. However, if there is sufficient buffering in the system then the winter period can be a mainly filtering time and summer the dominant nutrient stripping time.

This MINIFILTER system can be easily automated using water level sensors and solenoid valves and the cropping could simply be grasses that can be mown, collected and composted. This system keeps all effluent below ground level thus minimising the risk to human health. Depending upon site and soil conditions there may be some potential for water to escape below the intensive network of drains and contaminate groundwater. To prevent this may require some deeper drains around and below the MINIFILTER system. In situations where high rates of leakage below the network of shallow drains is possible in soils with low clay content, then a more elaborate (costly) arrangement of a shallow subsurface irrigation system and deeper intensive drainage network below, may be required. Irrespective of the soil types, such an arrangement will also reduce the risk of direct contamination of the subsurface drain water with untreated effluent applied as irrigation.

Based on previous field experience with the FILTER technique, the MINIFILTER system can be expected to meet the requirements for maintaining hydraulic flow rates and EPA specifications for pollutant removal from sewage effluent and greywater for local treatment of household effluent, especially on clay soils. However, further research is needed to test such systems in the field. Field testing could be combined with the current FILTER modelling studies to assess how the MINIFILTER design proposed above can be modified to suit different local site conditions.

Fig 6. Conceptual diagram for a possible MINIFILTER system



5 Conclusion

The results from the pilot FILTER trial during the winter 1998 cropping season showed that a well managed system can maintain adequate hydraulic flow rates to the subsurface drains, even during periods of unusually high rainfall and reduce pollutant levels in drainage water below NSW EPA limits. The FILTER provides economic benefit when crops are grown commercially. Through the combination of land treatment, drainage and cropping it is possible to avoid build up of nutrient, heavy metals and excessive salt in the reuse site.

The encouraging results from the FILTER trials suggest that this system has potential for adaptation to the on-site treatment of household sewage effluent and greywater. This would require a scaling down of the system to 'MINIFILTER' from the experimental and pilot commercial trials already undertaken.

6 Acknowledgements

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