ON-SITE SYSTEM DESIGN FOR SEASONAL VARIATIONS IN WASTEWATER GENERATION AT CARAVAN PARKS

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Abstract

Central Queensland University (CQU) has two on-site wastewater reuse trial sites at isolated rural caravan parks. One site is located at the St Lawrence recreation area in the Broadsound Shire, and the other at the Gem-Air Village Caravan Park in the Willows gem fossicking area of the Emerald Shire. At peak times, during the autumn and winter months, the sites have an equivalent person (EP) value of 100. Over the summer period this figure falls to below 10EP for each site. This paper discusses how the sub-surface irrigation technique has influenced the transpiration rate of the treated effluent and enabled the system to cope with the variation in EP. It also investigates the changes in soil parameters over a one and two year period. Water quality figures for the treated effluent, in particular microbial data, will also be discussed. The aim of the paper is to assess the viability of the two treatment and effluent reuse schemes and how they cope with the variation of wastewater generation volumes.

Keywords

Equivalent person, evapotranspiration, hydraulic surge, reuse, sand filter, wastewater generation

1 Introduction

The two sites are in clean-water-limited areas and have been heavily affected by the drought conditions during 2002 and early 2003. The scarcity of water has made the reuse of treated effluent a priority. Different activities at the sites lead to two different wastewater treatment systems and effluent reuse options being implemented. The St Lawrence recreation area is primarily a camping ground but has community-sporting facilities attached. The effluent reuse for this site needs to be sub-surface and contained due to nearby natural waterways (Kele *et al.* 2001). The CQU enclosed design of evapotranspiration beds was selected for use at this site. The Gem-Air Village Caravan Park is also located close to a natural waterway. A CQU evapotranspiration system in conjunction with a recirculating sand and zeolite filter was installed at the site. A higher level of treatment is needed here because of the aboveground reuse. The owners provide substantial quantities of non-potable quality water each winter for their tenants' use in the sapphire mining process. The challenge for both sites is to install systems that can safely treat and reuse relatively large volumes of effluent during the winter, but survive on low volumes during the summer. Summer water-efficiency is essential, as not enough water is available locally to keep plants in the evapotranspiration channels alive. High maintenance systems are inappropriate for use due to the relative isolation of the sites and the difficulty in finding trained personal. The CQU evapotranspiration channel is designed to be environmentally friendly and low maintenance (Kele *et al*. 2000).

2 CQU system

The CQU evapotranspiration bed system uses enclosed channels to separate treated effluent from the environment. Primary treated effluent is aerated and pumped into an enclosed channel through slotted pipes that run through an aggregate layer. Terra-firma matting covers the aggregate layer and the remainder of the channel is filled and mounded over with a sandy loam soil. Plants are grown along the length of the channel and use the effluent through transpiration. Any effluent not transpired by the plants returns to the holding tank from which it was pumped for subsequent pumping to the enclosed channels again.

3 St Lawrence recreation area installation

Wastewater is generated from an amenities block containing eleven toilets, one urinal, seven hand-basins and seven showers. There is an 11 000 L septic tank, a 4500 L holding tank and a 3000 L aerated wastewater treatment system (AWTS) (Kele *et al*. 2001). The holding tank pumps to a CQU evapotranspiration bed system. The CQU system is split into three separate channels, the first being 36 m long, and the others each 18 m long. Excess effluent from the channels flows back to the holding tank. The AWTS is the emergency overflow for the CQU system. Treated effluent from the AWTS is irrigated sub-surface through a trickle irrigation tape-line attached to the top internal surface of a 100 mm PVC drainage, waste, and vent (DWV) half pipe and laid along a 400 mm deep, 200 m long trench.

4 Gem-Air village caravan park installation

The wastewater is generated from two amenities blocks and the bathrooms and kitchens of four units. The main amenities block contains a laundry. Each amenities block and unit has one or more 1800 L septic tanks attached that feed into a 3000 L all-waste septic tank with an in-line filter. The treated effluent from this tank enters a 4500 L holding tank from where it is aerated and then pumped through the CQU evapotranspiration beds. Concrete channels were not used at this site. The topsoil in the treatment area was very thin and the surface underneath was sandstone. An excavator dug four channels, each 12 m long, 2 m wide, and 700 mm deep into the sandstone. The bottoms of these channels were laid with 100 mm of sand, and a pond liner installed. The CQU evapotranspiration beds were then installed within the pond-lined channel. The aerated treated effluent can either recirculate through the CQU system or be diverted through a recirculating sand and zeolite filter. The sand and zeolite filter has a 20 KL capacity and two plastic 1600 L holding tanks are incorporated with the system. Effluent from the sand and zeolite filter can be pumped to a 22 KL storage tank for aboveground reuse. A bromine-chlorine disinfection process is used before effluent is made available for aboveground reuse in either the gem-washing process or for irrigation purposes within the park.

5 Wastewater generation

The St Lawrence recreation area generates, on average, 2000 L of wastewater per day during the winter and autumn months. The amenities block uses water-efficient infrastructure and the absence of laundry and kitchen facilities lowers the volume of wastewater produced. The average length of stay at the recreation area is 2 days. As the amenities block is near the Bruce Highway there is some usage by travellers over the spring and summer months. No one lives at the recreation area year-round. For risk management purposes all treated effluent is kept underground.

The Gem-Air Village Caravan Park has wastewater generation figures listed in Table 1. The average length of stay in this park is over two weeks; and the owners live on-site year round. The non-transpired effluent is used for washing the overburden off in the gem mining process, or for aboveground irrigation. There is very little wastewater generated over the spring and summer months. Towards the end of the winter, non-transpired effluent is stored and used to irrigate the plants in the CQU evapotranspiration channels during the spring and summer. Over 60 KL of treated effluent was used for this purpose during the 2002-2003 spring/summer periods.

Table 1. Average water usage volumes in relation to occupancy at Gem-Air Village Caravan Park

Number of People in the Park	Average Daily Water Use (L)	Average Non-transpired Treated Effluent (L)
20	2000	<100
40	3000	1000
80	5000	2000

6 Soil analyses

The soil in the CQU evapotranspiration beds was analysed to determine if there had been an accumulation of nutrients, metals and salts over time. The soil at the Gem-Air Village Caravan Park was examined after it had been in the channels for 1 year. It was compared with results from composite samples of the original soil before it was submitted to effluent irrigation. All soil analyses were performed through an NATA accredited laboratory.

The results in Table 2 show the changes that occurred with some of the macronutrients and soil pH over the course of the year. Organic carbon analysis was performed using the Walkley and Black method and determined colorimetrically (Incitec 2003). The pH was determined using a 0.01 M calcium chloride method and read with a combination electrode (Incitec 2003). Potassium levels were obtained through an ammonium acetate reaction and measured on an ICP AES (Incitec 2003). Nitrate was measured colorimetrically in a segmented flow analyser (Incitec 2003). Phosphorus was determined by the Cowell method and measured colorimetrically in a segmented flow analyser (Incitec 2003).

Table 2. Macronutrients and pH of soil of the Gem-Air evapotranspiration channels after 1 year

Soil Sample	Organic Carbon %C	Soil pH (1:5 $CaCl_2$)	Potassium meq/100g	Nitrate mg/kg	Phosphorus mg/kg
Original Soil	0.95	7.4	0.36	68.8	19.75
Channel 1	0.4	7.7	0.66	2.38	17
Channel 2	0.8	7.7	0.97	2.5	16.1
Channel 3	0.6	7.8	1.00	0.4	22
Channel 4	0.5	7.7	1.05	0.3	22

The organic carbon percentage has declined in all four channels. This may be because carbon is needed in some chemical reactions, such as those in the nitrogen cycle (Cochet *et al*. 1990). As time progresses the system may need to have some organic carbon added, perhaps in the form of charcoal. The pH of the soil has increased and in all four channels is still in the acceptable range for plant growth. In channel 1, potassium level has doubled, in the three remaining channels it has tripled. It has not reached toxic levels, and may decrease when the plants reach maturity and begin to flower and fruit in large quantities (Hopkins 1999). Nitrate levels have dramatically decreased in all four channels. Analyses of nitrite and ammonia levels need to be conducted to determine total nitrogen levels. Phosphorus levels have on average gone down slightly in the channels compared to the original soil. The results in Table 3 show the changes that have occurred in some of the trace elements.

Calcium and magnesium levels were obtained through an ammonium acetate reaction and measured on an ICP AES (Incitec 2003). Copper, zinc, manganese, and iron were determined using a DTPA, triethanomaline and calcium chloride method and measured on ICP AES (Incitec 2003). Boron was determined using a 0.01 M calcium chloride method and measured on ICP AES (Incitec 2003).

Table 3. Trace Elements in soil of the Gem-Air evapotranspiration channels after 1 year

Soil Sample	Calcium meq/100g	Magnesium meq/100g	Copper mg/kg	Zinc mg/kg	Manganese mg/kg	Iron mg/kg	Boron mg/kg
Original Soil	7.71	3.34	0.6	1.4	9	38	0.6
Channel 1	33.91	15.68	0.5	<0.1	3	6	0.8
Channel 2	25.72	11.87	0.9	0.9	6	30	1.1
Channel 3	31.52	14.47	1.0	0.3	7	15	1.2
Channel 4	32.15	13.95	1.5	0.3	13	19	1.1

Calcium and magnesium have both increased substantially. The reason for this is not clear. The non-potable water at the site has kaolite added to it as a settling agent and this may be the source. The cations may also come from the reuse of the effluent that has passed through the sand and zeolite filter. Zeolite can be a source of cations, but whether they are leaching into the effluent in this case is yet to be determined. Copper and boron levels have on average risen but not to toxic levels. Zinc concentrations in the soil have fallen to the point where the plants may in the future suffer a zinc deficiency (Hopkins 1999). Manganese and iron levels have fallen overall but are present in high enough concentrations to ensure plant health (Hopkins 1999).

The data in Table 4 are related to salinity and may give an additional indication of the sustainability of the soil in the evapotranspiration channels. Sodium was determined through an ammonium acetate reaction and measured on an ICP AES (Incitec 2003). Chloride was prepared and measured colorimetrically in a segmented flow analyser (Incitec 2003). Electrical conductivity (EC) was measured with a conductivity meter. The EC of saturated extract (se) is based on conversions of EC (1:5) and soil texture class, to obtain a more meaningful determination of the soil salinity hazard (Incitec 2003).

Table 4. Salinity and Cation Exchange Capacity of soil of the Gem-Air evapotranspiration channels after 1 year

Soil Sample	Sodium meq/100g	Chloride mg/kg	EC dS/m	EC (se) dS/m	Cation Ex. Cap. meq/100g	Sodium% of Cations (ESP)
Original Soil	3.08	420	0.57	5.9	14.13	23.4
Channel 1	1.41	650	1.21	8.9	51.66	2.74
Channel 2	1.15	185	0.29	2.1	39.71	2.9
Channel 3	2.2	145	0.32	2.4	49.19	4.47
Channel 4	1.94	270	0.39	2.9	49.09	3.95

The sodium levels in the soil have fallen. They may have leached out and passed into the next treatment stage. The high chloride levels, EC and EC (se) in channel 1 are of concern, but overall the amount of chloride ions and the EC readings in the channel soil have decreased. The cation exchange capacity has increased and the sodium percentage of cations decreased, most likely due to the large increases in calcium and magnesium.

The soil analysis for the St Lawrence recreation area follows the same methods and materials as those conducted and described for the Gem-Air Village Caravan Park. All samples were analysed in a NATA accredited laboratory. Samples taken from the start of the channel and the end were taken, approximately 300 mm depth, after two years of effluent irrigation.

Table 5. Macronutrients and pH of soil of the St Lawrence recreation area evapotranspiration channels after 2 years

Soil Sample	Organic Carbon %C	Soil pH (1:5 $CaCl_2$)	Potassium meq/100g	Nitrate mg/kg	Phosphorus mg/kg
Original Soil	1.35	6.8	0.31	41.8	15.05
Channel 1 Start	1.2	5.1	0.26	6.6	12
Channel 1 End	1.1	4.9	0.12	34.3	13
Channel 2 Start	1.2	5.5	0.2	5.7	17
Channel 2 End	1.0	5.8	0.12	17.2	15
Channel 3 Start	0.9	6.6	0.24	16.9	16
Channel 3 End	1.1	6.4	0.18	32.9	18

Organic carbon percentage has fallen overall with no real difference between the start and end of the channels. The acidic pH in channel 1 and 2 are of concern. The aeration systems for these channels needed and received maintenance when the soil samples were taken. The aeration system of channel 3 was in good repair. It is thought that due to the lack of aeration the soil in channels 1 and 2 is anaerobic. Soil samples taken from these channels previously when the aeration system was working were not below pH 6.5. The Gem-Air installation has a new aeration design that requires less maintenance and this may need to be retrofitted at the St Lawrence site. Potassium, nitrate, and phosphorus levels have on average fallen in all the channels. Nitrate levels are higher at the end of each channel than the start. This may be because ammonia is being transformed into nitrate via the nitrogen cycle as the effluent passes down the channel.

The data in Table 6 show the level of some trace elements in the soil at the St Lawrence recreation area. The calcium and magnesium levels have increased slightly, but not be the same order of magnitude as occurred at Gem-Air (Table 3). Very little change has occurred to copper, zinc, and boron levels, with no toxic accumulations or nutrient deficiencies detected (Hopkins 1999). Manganese and iron have increased, but with a relatively large variation in the channels. No pattern between the start and the end of the channels can be firmly established. Toxic levels of these elements have not been reached (Hopkins 1999).

Table 6. Trace Elements in soil of the St Lawrence recreation area evapotranspiration channels after 2 years

Soil Sample	Calcium meq/100g	Magnesium meq/100g	Copper mg/kg	Zinc mg/kg	Manganese mg/kg	Iron mg/kg	Boron mg/kg
Original Soil	2.40	1.80	0.41	2.7	8	43	0.9
Channel 1 Start	2.14	2.94	0.3	1.9	10	100	0.8
Channel 1 End	1.52	1.67	0.4	1.1	14	255	0.4
Channel 2 Start	3.06	1.67	1.4	2.7	31	212	0.7
Channel 2 End	4.41	1.47	1.0	1.5	8	110	0.5
Channel 3 Start	4.02	1.27	0.7	1.3	9	54	0.6
Channel 3 End	4.39	1.11	0.9	1.7	10	109	0.7

Table 7 presents data on salinity and the cation exchange capacity for the soil of the St Lawrence recreation area evapotranspiration channels. The sodium and chloride levels in some parts of the channels have risen, while in others it has fallen. Overall the sodium and chloride levels have fallen, but only slightly. An accumulation of these two salts has not occurred. The EC and EC (se) readings also exhibit a small overall drop, and no generalized increase over the channels. The average cation exchange capacity in the channels has been slightly raised over the two years. The rise at the Gem-Air site was higher; this was most likely due to the source of calcium and magnesium ions at that site. The sodium percentage of cations has on average fallen by approximately one-third. This can in part be accounted for by the small fall in sodium ions and the slight increases in calcium and magnesium ions. No pattern can be discerned between the start and the end of the channels.

Table 7. Salinity and Cation Exchange Capacity of soil of the St Lawrence recreation area evapotranspiration channels after 2 years

Soil Sample	Sodium meq/100g	Chloride mg/kg	EC dS/m	EC (se) dS/m	Cation Ex. Cap. meq/100g	Sodium% of Cations (ESP)
Original Soil	1.97	390	0.39	4.1	7.02	29.72
Channel 1 Start	0.67	120	0.12	1.2	9.81	6.83
Channel 1 End	2.58	440	0.49	4.9	7.07	36.47
Channel 2 Start	1.09	205	0.21	2.2	6.29	17.32
Channel 2 End	0.97	205	0.24	2.5	6.96	13.92
Channel 3 Start	3.40	570	0.58	6.0	8.94	38.08
Channel 3 End	1.77	350	0.37	3.8	7.44	23.72

7 Microbial analysis

Table 8. Microbial Water Values for the St Lawrence recreation area

Sample	Non Fastidious Heterotrophic per 1 ml at 28°C/48 hrs	Escherichia coli per 100 ml at 37°C/48 hrs	Total coliforms per 100 ml at 37°C/48 hrs	*Salmonella* spp. per 100 ml at 37°C/48 hrs
Septic before CQU retrofit	38 750 000	327 000	4 627 000	3 918 000
AWTS before CQU retrofit	32 250 000	994 500	2 079 500	3 643 000
Septic after CQU retrofit	29 000 000	127 000	983 700	1 543 900
AWTS after CQU retrofit	10 257	70	420	18 900
CQU Holding Tank	1 257 000	161 000	225 500	140 600
CQU Channel	1 912 570	150	9 850	34 500

Standard techniques were used for the analysis of the non-fastidious heterotrophic organisms (Csuros and Csuros 1999). The faecal coliforms, total coliforms, *Escherichia coli*, and *Salmonella* spp. tests were performed following the materials and methods prescribed for Merck Chromocult agar (Frampton *et al*. 1988; Manafi and Kneifel 1989).

The microbial quality of the effluent was tested before the CQU system was retrofitted at the St Lawrence recreation area and after. The septic tank and AWTS were the original treatment system at the area. Table 8 shows the data from the septic tank, the disinfection chamber of the AWTS, the CQU holding tank, and effluent samples taken from the CQU channels. The installation of the CQU system increased the detention capacity of the wastewater treatment and effluent reuse system by approximately 16 KL. This doubled the existing capacity of the system and minimised the impact caused by hydraulic surges at the site. The data in Table 8 clearly show an increase in the performance of the septic tank and the AWTS after the CQU retrofit. With subsurface irrigation only being used, the CQU system does not have a disinfection process and does not require aboveground reuse water quality. It is thought that *Salmonella* spp. numbers do not decline as significantly as do numbers of *E. coli*, and total coliform numbers, because they are more thermotolerant at the lower water temperatures within the treatment and reuse systems.

8 Conclusion

In general the soil data show no toxic accumulations of nutrients, salts, or metals. They do show that aeration is important in the contained sub-surface irrigation of effluent. Elements such as zinc, and the organic carbon percentage have fallen in both systems. This indicates that the reuse of effluent for irrigation does not provide all the nutrient requirements for plant growth and that some fertilizers will still need to be applied. The microbial water values for the St Lawrence site meet the required guidelines for subsurface effluent irrigation.

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