Nutrient Dynamics of Turf Grass Irrigated with Laundry and Bathtub Greywater

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Abstract

Greywater reuse is increasing as a measure to mitigate declining potable water supplies in residential areas. In Perth, Western Australia, garden irrigation with greywater has grown popular for householders to keep their plants sustained, especially during long hot summers. However, the sandy soils of the Swan Coastal Plain allow for the rapid transport of contaminants through the soil profile, potentially affecting the underlying shallow aquifer. Hence, this study was conducted to determine the nutrient leaching from the couch grass (*Cynodon dactylon L.*) sod, on a free-draining sandy soil, irrigated with laundry and bathtub greywater. The experiment was used a modified aquarium tank and the irrigation was sourced from the family house following: (i) irrigating with 100% potable water as a control (TW) (ii) irrigating with untreated full cycle laundry water (LGW) (iii) irrigating with untreated bathtub water (BGW) for 24 weeks, starting from October 2009 to March 2010. Nutrient leaching was assessed by measuring the leachate volumes and concentrations of nutrient concentration leached from the funnelled leachate to a central exit point from which leachate was collected into a 1L plastic container. The results showed that the high rates of salt; Na, Cl; macronutrient P, K, Ca and micronutrients; Al and B leaching beyond the 30cm root-zone depth. Consequently, the turf grass requires the addition of the losses nutrients in the turf grass fertilization programme to supplement growth.

Keywords: *laundry, bathtub, greywater, irrigation, nutrient, turf grass, tank*

1. Introduction

Greywater, which corresponds to wastewater produced from bathing, showering, and laundry accounts for 35% of the flows of household water [1]. Given the volume produced, it is potentially feasible for reuse for irrigation purposes; where outdoor irrigation accounts 54% of household water consumption [2]. Turf grasses are well suited irrigate with greywater, particularly considering the range of salt concentrations that turf can potentially tolerate. In Australia, using untreated greywater in sewered areas with manual bucketing and diverter valve are permitted in most states, and can be used without a permit [3]. However, an improved understanding of the effects of greywater reuse on direct disposal to a highly permeable soil which some nutrients prone to leaching is required.

Nutrients in greywater are beneficial as it increases crop yields and pathogen levels are low [4]; [5], compared to those from domestic wastewater. According to [6], elevated amount of boron (B), salts; sodium (Na) and chlorine (Cl) and phosphorus (P) were found in greywater due to ingredient in detergent and washing cleaning materials. Salts; sodium (Na) and chloride (Cl), macronutrient; P, potassium (K), calcium (Ca), magnesium (Mg) and micronutrient; B, Aluminum (Al) and Zinc (Zn) are beneficial in turf grass [7]. The excess nutrient uptake by plant can rapidly infiltrated through the sandy soil with low cation exchange capacity (CEC). [8] highlighted high levels of salt in irrigation water can affect plant growth by causing leaf burn (following sprinkler application), soil structural problem, and Ca and Mg deficiency.

Several studies reinforce the potential of domestic greywater has a promising potential for reuse as irrigation water to grow tomato [9]; lettuce, carrots, and peppers [10] and silverbeet [11]. However, [12] noticed that the elevated salinity and B levels in greywater-irrigated lettuce developed brown patches (*chlorosis*) on the tip of plants. [13] showed that salinity, sodium adsorption ratio (SAR) of soil increased as a function of time thus potentially alters the soil properties. Through the review, less extensive study was found for the effect of turf grass irrigated with greywater. Some information can be gleaned from the mixture of kitchen or wastewater recycling irrigation studies.

Therefore, the current study aims were to evaluate the nutrient supplied by the greywater is beneficial to the turf growth. It is whether it can enhanced turf grass quality or conversely has an offsite impact of leaching to the underneath water supplies system. These contribute to the overall nutrient additions and must be taken into account in the fertilization program.

2. Materials and Method

2.1 Tank Experimental Set-Up

Tank experiment was conducted at the family house occupied by two adults and two children in Hamilton Hill, Western Australia (32.08 ^{0} S, 115.77 ^{0} E), 23 km south west of Perth. Tanks were constructed using an aquarium tank with dimension of 45 cm height by 25 cm width by 25 cm length. The used of aquarium tank was devised to visually assist in the observation of dispersion behavior of the irrigation water. During the study, the triplicate tanks were subjected to each of the following irrigation sourced from the family house: (i) irrigating with 100% potable water as a control (TW) (ii) irrigating with untreated full cycle laundry water (LGW) (iii) irrigating with untreated bathtub water (BGW) for 24 weeks, starting from October 2009 to March 2010. Regular powder laundry detergents were used. The BGW were sourced from the kids' bath with regular bath cleaner and shampoo. Irrigation water quality for TW, LGW and BGW was observed to be within the recommendation limits of water used for irrigation presented in Table 1.

Table 1. Chemical constituents of TW, LGW and BGW compared with maximum limit for irrigation. Samples were taken on week 4, week 12 and week 24 of sampling with n=3 of each irrigation sample

	Tap water (TW)	**Laundry water (LGW)**	**Bathtub water (BGW)**	**Recom. limits for irrigation purposes**
pH	6.54 ± 0.06	6.48 ± 0.05	6.59 ± 0.06	6.5-8.5$^{(a);(b)}$
EC, μS/cm	590 ± 20	960 ± 60	630 ± 20	950-1900 μS/cm$^{(a)}$, 1.4 dS/m$^{(b)}$
Salts				
Na	48.50 ± 2.86	146.67 ± 8.82	80.33 ± 0.88	<230 $^{(a)}$, 150$^{(b)}$
Cl	40.00 ± 8.16	180.00 ± 5.77	130.00 ± 0.00	250$^{(b)}$
Macronutrients				
Ca	15.00 ± 4.08	17.00 ± 1.00	22.00 ± 1.02	20-60$^{(d)}$
Mg	3.90 ± 0.24	4.37 ± 0.07	5.17 ± 0.03	10-25$^{(d)}$
K	1.00 ± 0.16	4.07 ± 0.09	6.67 ± 0.03	5-20$^{(d)}$
P	0.001 ± 0.07	0.31 ± 0.03	0.23 ± 0.05	<12(total)$^{(b)}$, 5 (total)$^{(b)}$, 0.1-0.4$^{(d)}$
Micronutrients				
B	0.02 ± 0.10	0.54 ± 0.003	0.55 ± 0.01	0.4$^{(b)}$
Zn	0.02 ± 0.003	0.01 ± 0.001	0.03 ± 0.002	2.00$^{(b);(c)}$
Al	0.02 ± 0.004	0.06 ± 0.003	0.05 ± 0.006	5.0$^{(b);(c)}$
SAR*	4.98	15.25	5.33	5.0$^{(b)}$

(a) [14]; [15]; (b) [16]; (c) [17], (d) [18]

* SAR: sodium adsorption ratio (calculated)

Soil for the tank test was collected from native sandy soils. Soil at this site characterized as a moderately deep, sandy soil that was distributed throughout Swan Plain coastal. Turf grasses used were a family lawn of couch grass *(Cynodon dactylon L.) sod* planted in all tanks. Couch grass was the popular lawn species used in Western Australia because of excellent drought tolerance, water efficient and relatively low maintenance requirements [19]. Key properties of the soil and turf grass were determined in the laboratory to characterize the soil used, and the properties at the time of planting are given in Table 2 and 3.

Table 2. Soil physical characteristics used in the tank experiment. Soil samples (n=3) were taken from the 0-15cm depth

Org C (%)	**Water content (%)**	**Sand Fraction (%)**		**Sand (%)**	**Silt (%)**	**Clay (%)**
		Fine (20-212µm)	**Coarse (212-2000 µm)**			
0.43	0.45	49.35	47.48	96.70	0.61	2.19

Table 3. Salt and nutrient status in the soil and turf grass

	Soil	**Turf grass**
Salt		
Cl,	68.00 ± 4.00	0.16 mg/kg
Na,	30.40 ± 1.06 mg/kg	0.08 %
Macronutrients		
P	2.27 ± 0.13	0.33%
Ca	169.33 ± 5.81	0.54%
K	21.20 ± 0.61	0.85%
Mg	45.33 ± 1.33	0.12%
Micronutrients		
Zn, mg/kg	4.80 ± 0.46	123.65
Al, mg/kg	77.33 ± 1.33	N/A
B, mg/kg	1.91 ± 0.15	4.37

N/A = Not Analysed

2.2 Sample Collection

Irrigation water (inflow) and leachate (outflow): The drainage or leachate samples from each tank were collected daily from the polyethylene bottles placed in the under-tank outflow tubing system. pH and EC were measured daily. Leachate samples were then transferred to clean polyethylene containers, labeled, and stored on ice in a cooler until transported to the laboratory for analysis. The chemistry analyses of the leachate samples were taken weekly.

2.3 Sample Analysis

Irrigation water as the inflow in the tank and leachate discharges from the tank were sent to the Marine and Freshwater laboratory (MAFRL), Murdoch University for elemental analysis using ICP-AES. The pH of irrigation water and leachate were measured daily with a pH probe and meter (AQUA, TPS Australia) fitted with calibrated electrodes following the manufacturer instructions. Soil and turf grass tissue were analyzed by the CSBP laboratory using Australian Laboratory Handbook of Soil and Water Chemical Methods [20]. Both MAFRL and CSBP are NATA (National Association of Testing Authorities) registered for analytical procedures.

3. Result And Discussion

3.1 Changes of pH and EC

The application of the LGW and BGW had smaller changes on pH (Figure 1). The pH value for both inflow and outflow in all tanks were neutral. [21] claimed irrigation water of the range of 6.5 to 7.5 was normal. According to [22], the pH of greywater was generally circumneutral, but tends to be slightly higher than the source water due to addition of detergents [23]. The pH of wash cycle suspected to contribute a higher pH and alkalinity as high as 10 and alkalinity as high as 200 mg/L as $CaCO_3$ [23].

The EC increased greatly after the LGW and BGW irrigation, 960 µS/cm and BGW EC respectively (Figure 1). This was attributed to the large concentration of salt ions of Na^+, K^+, Cl^- in irrigation water [21]. This value was higher than [9] whose reported EC value of 653.3 ± 3.1 µS/cm in laundry greywater. However, referring to [14], water salinity rating was included in the low rating (0.65-1.3 dS/m) where the water can be irrigated in moderately sensitive crops.

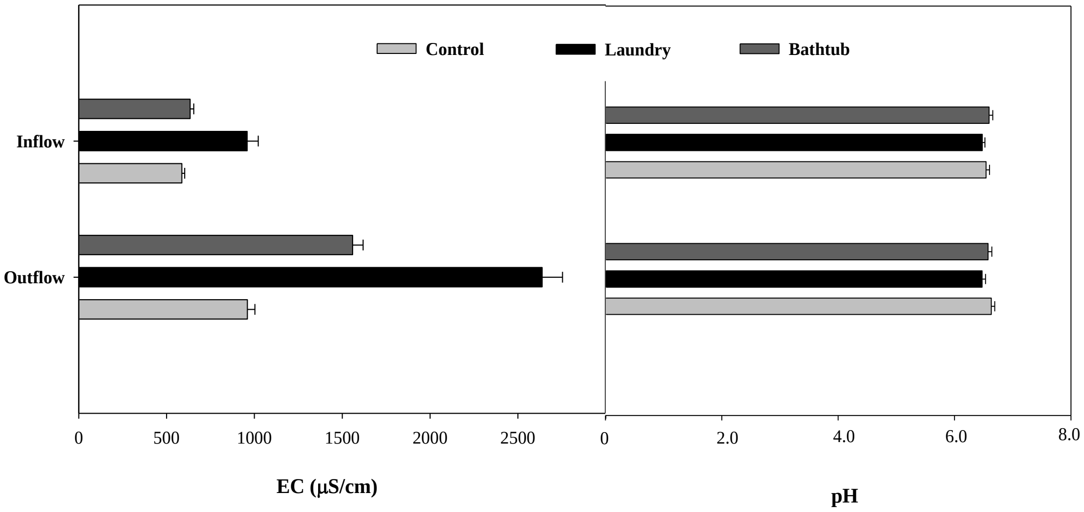

Figure 1. Dynamic of EC and pH

3.1 Hydrologic Model Analysis Using HEC-HMS

The Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) model version 3.2 is used to analyze the hydrologic behaviour of the Pulai River basin characteristics, together with the present river condition. The hydrologic analysis can be used as an analysis to develop a relationship between precipitation and runoff for the study area. In order to evaluate the spatial distribution of rainfall, the study area was divided into a few sub-catchments based on the river network. The derived temporal pattern of rainfall and IDF relationships for Pulai River catchments will be used in the modelling works. The storm duration was taken equal to the time of concentration and the runoff hydrograph for each subcatchment were generated.

3.2 Nutrient dynamics from LGW and BGW irrigation

Salts and nutrients leached from the tank irrigated with TW, LGW and BGW for 24 weeks sampling are shown in Figure 2-4. LGW irrigation resulted in an increase in the mass leaching of salt in the order of K (100% leached)> Al (100% leached)> Na (54.17% leached)> Cl (50% leached)> Ca (37.5% leached) and from the soil tank experiment compared to the concentration values obtained for the irrigation. Irrigation of BGW increased the mass leaching in the order of Al (100% leached)>K (37.5% leached)>P (37.5% leached) and B (20.83% leached) from the tank system.

Na is highly susceptible to leaching from the sandy soil as minimal clay content with the negatively charged layer is not sufficient to interact with positively charged cation of Na. [24] stated the excess may be in the form of high concentrations of Na ions in solution, usually accompanied by chloride (Cl^-). According to [7], conditions on low CEC (or low clay content) soils but receiving high Na levels or with high Al lead to potential high leaching. K and Ca are essential nutrient for the growth of turf grass, along with N and P and also main nutrient in the ‘complete’ fertilizers. Most K compounds are highly soluble in water, and K^+ are withdrawn from solution by adsorption to cation exchange sites [25]. [26] added that K is a mobile ion in soils and consequently significant amounts can be lost by leaching. However, little attention has been paid to this element because its leaching does not result directly in eutrophication.

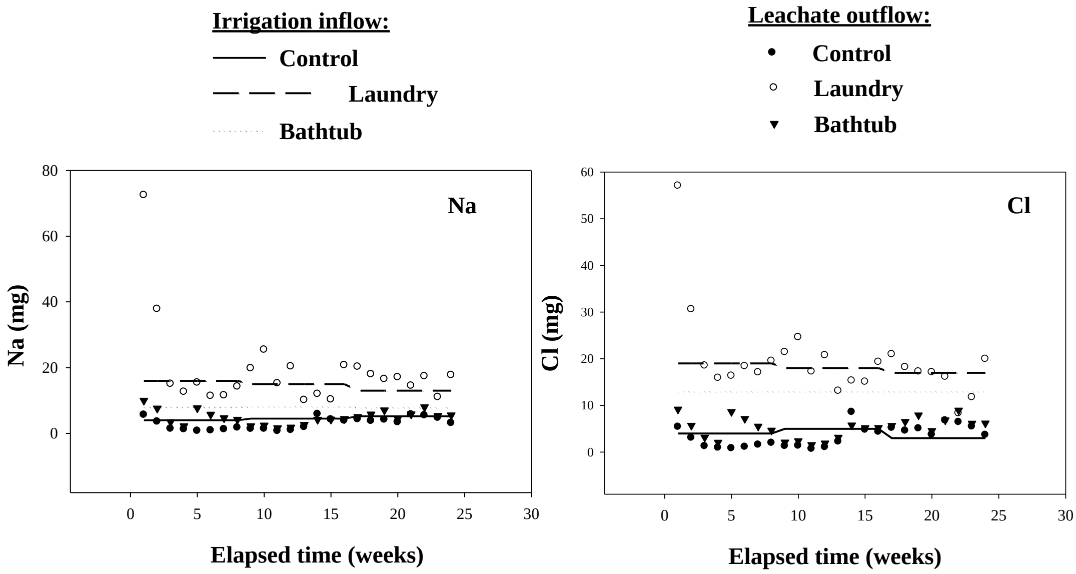

Figure 2. Salts of mass leaching

Ca is the main exchangeable base of clay minerals and, as such, is a major component of soils. [25] stated Ca dissolved in the soil solution can move by mass flow and by diffusion, but exchangeable Ca has a very low mobility. Monovalent ions such as Na^+ and K^+ are more mobile, because they are less strongly attracted to cation-exchange sites than Ca^{2+} ions. [27] found that 5% of the Ca fertilizer they added to an Indonesian Ultisol moved down into the 30-90 cm depth and 26% of it was lost. The leaching of soil amendments is enhanced by the high annual rainfall of 2750 mm and the low effective cation exchange capacity (ECEC) of these soils.

Boron, like Na and Cl is soluble and tends to accumulate where salts accumulate is highly mobile in soils [28]. Boron can leached from soil by rainfall or irrigation leaching fractions. However, leaching can be difficult because B is often adsorbed onto soil particles, requiring about three times more water than more soluble species such as Cl^- and Na^+. [29] studied B in irrigation waters and soil in a reclaimed water system in South Australia. Reclaimed water from the scheme had a higher concentration of B (average of 0.36 mg/L). In the subsoil, irrigation with reclaimed water led to decreases in B concentration and probably a result of B leaching. In acidic soils that produce pH readings of less than 5.5, Al toxicity is a universal problem. According to [30], the mobilization of Al from acidic forest soils is arguably the most ecologically important consequence of acid deposition in the environment. Conversely, here we show that the neutral soil pH (data not shown) response to increased the Al concentrations in leachate of all irrigation types.

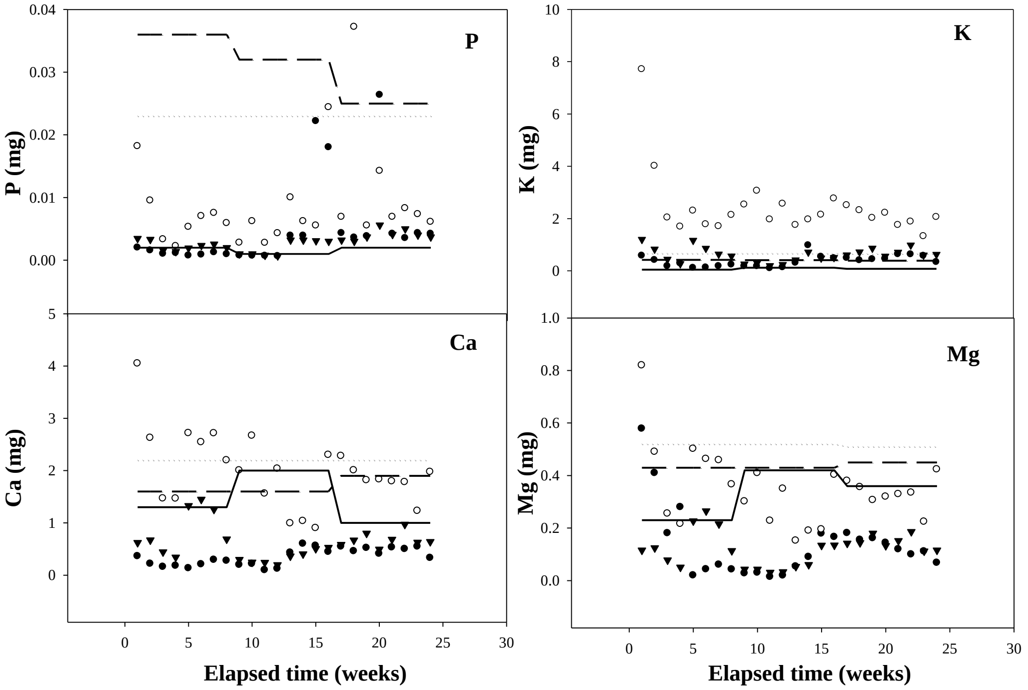

Figure 3. Macronutrients of mass leaching

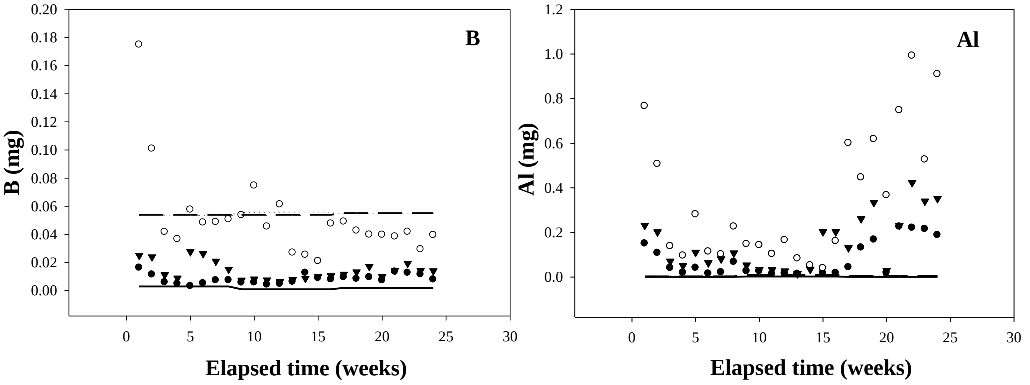

Figure 4. Macronutrients of mass leaching

4. Conclusion

The results presented here show that irrigation with LGW and BGW greywater can result in high rates of salt; Na, Cl; macronutrients; P, K, Ca and micronutrients; Al and B leaching beyond the 30cm root-zone depth. These are elements can be consider by many turfgrass managers to determine fertilization needs when irrigation with greywater is applied. Thus, the capacity to cope with restrictions to both quantity and nutrient quality of irrigation, whilst minimise nutrient leaching to the groundwater, is an important management objective for turf grass areas.

5. References

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