RECYCLED WASTEWATER FOR PARKLAND PLANT IRRIGATION AND SUSTAINABILITY MEASURES

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Abstract

Recycled water is one of the main water resources with substantial contribution to increase the security of future water supplies. Scientific and technical studies are required to maximize this contribution through developing water recycling opportunities and reuses particularly for green space irrigation to provide environmentally, socially and economically sustainable environments. The use of municipal recycled water for green space plants is a valuable attempt to use the easily available water resources but it requires a monitoring system to mitigate the possible inverse impacts on the soil, plants and water systems. Variables such as climate, irrigation methods and frequency, plant species and soil can have a profound effect on the sensitivities of plants to salts and toxicity. Soil drainage, irrigation application rate, water quality, rainfall characteristics and plant canopy shade can influence the long-term effects of salinity, and toxic effects of chemical compounds on the vegetation health. It is, therefore, important to have information specific to each individual plant species, as well as information on all the above-variables, specific to each locality, in order to properly plan and manage water requirements of specific landscapes. In this paper the main potential inverse impacts of reuse of recycled water for irrigation is discussed and Adelaide parklands as a case study is briefly reviewed.

Keywords: Recycled wastewater, reuse wastewater, Irrigation, Adelaide Parklands

Introduction

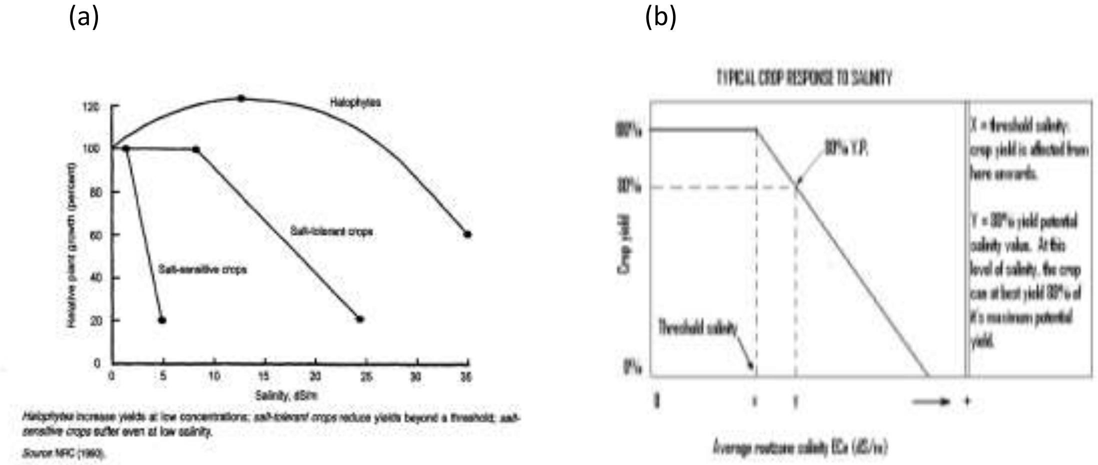
Rapid urbanization and industrialization have increased the pressure on limited existing fresh water to meet the growing needs for food production and keeping environment in a healthy condition . Utilizing efficient irrigation systems and using alternative sources of water, such as recycled wastewater, to meet the growing demands would be a positive response to this concern (Hassanli et al, 2010). The majority of urban water supplies for irrigation are used to maintain vegetation health, appearance and municipal amenity (Nouri et al, 2012). Climate change is also threatening Australian urban water supplies through increasing evapotranspiration and decreasing precipitation. The most severe climate change impact is expected in the southern and eastern regions of Australia (Collett and Henry, 2011).Increasing water use efficiency and also water efficiency in urban landscapes are achieved by supplying only the amount of water that the plants require to maintain healthiness and aesthetic appearance. The water demand of urban landscapes is quite different from agricultural crops and turf grasses due to the specific conditions in urban green spaces (Costello et al., 2000).The use of recycled wastewater has been identified as a potential sustainable irrigation practice and one of the management approaches. Recycled wastewater may potentially contain pathogens and levels of chemicals deleterious to vegetation and the environment. Although low concentrations of certain chemicals may not have immediate and obvious toxic effects on vegetation or the structure of the soil, bioaccumulation may occur, causing long-term chronic effects(Salgot et al., 2006). Continued irrigation using recycled water, in long term could exceed the soil's adsorption capacity for salts (Nable et al., 1997). Particularly during dry seasons when there are few rainfall events which could leach the salts from the soil. Soil structure can be affected by excess sodium in irrigation water (Hassanli et al, 2007) which reduces soil aeration and water filtration rates. This, in turn, leads to water logging, excess runoff and restricted root growth. In this paper the potential inverse impact of reuse of recycled wastewater for landscape irrigation is discussed and Adelaide parkland as a case study would be reviewed.

Salinity and general toxic effects of recycled wastewater

Fig.1: Toxic effects of salinity on leaves(Las Pilitas Nursery, n.d.)

The level of salt accumulation within the soil depends on a number of different factors: physical and chemical characteristics of the soil; annual precipitation; evapotranspiration; the annual water application and most importantly, the concentration of salts in the irrigation water(Lazarova and Bahri, 2005).When the levels of dissolved salts are high in the soil, additional energy is required for plants to take up water from this medium. The increased osmotic pressure of salty soil water is the reason for this higher demand on the plant's energy resources. Symptoms of salinity stress are similar in most plant species. These symptoms include leaf scorching, (Fig. 1) mottling or shedding and twig dieback in angiosperms (Azza Mazher et al., 2007).

Each plant species has a specific salinity tolerance level above which the growth and productivity of the plant is affected (Azza Mazher et al., 2007). The salt tolerance variation of different plants and a typical crop response to salinity are shown in Fig. 2.



Halophytes increase yields at low concentrations; salt-tolerant crops reduce yields beyond a threshold; salt-sensitive crops suffer even at low salinity.

Source NRC (1990).

Figure 2. Salt tolerance variation of different plants (a) and a typical crop response to salinity (b)

Halophytes which occur naturally in saline conditions are often not as badly affected as non-halophytes which may die more readily under excessively saline conditions. Environmental conditions may also have an effect on each species' response to salinity. In general excessive salinity inhibits vegetative and reproductive growth and sometimes induces changes to plant morphology and anatomy. The most common toxic elements in wastewater are Sodium (Na), Chloride (Cl) and Boron (B). For landscaping and agricultural purposes, the most important components are those chemical elements that have an effect on the growth of plants and the structure and permeability of the soil (Pedrero et al., 2010). Different soils, drainage, irrigation methods and amount of shade will influence the long-term effects of salinity, and chemical elements on the vegetation. Ongoing foliar irrigation can lead to toxic levels of Na, Cl and B in the leaves of plants. Although all species respond differently to foliar irrigation application, generally, the amount of foliar damage has been in direct proportion to the frequency of sprinkler treatment (Devitt et al., 2003). An excess of any irrigation can cause water logging and secondary salinity.

Toxic effects of sodium on plants

Figure3. Necrotic patches caused by sodium toxicity on a grape vine (PIRSA, n.d.)

Soil with excess sodium may exhibit changes in soil structure. These changes could reduce the rate of water infiltration and aeration of the soil. This in turn reduces the water available for uptake by plants and could also increase the amount of sodium taken up in the water by plants. The toxic effects of sodium accumulation in plants are evidenced by leaf mottling and necrotic patches (Fig.3) on the leaves (Stevens et al., 2008). High levels of sodium also cause damage to the root cells and can interfere with the photosynthetic processes of the plant. Woody plants are particularly vulnerable to the toxic effects of sodium as the symptoms are not seen for some time (Stevens et al., 2008) since the excess sodium accumulates in the roots and trunk. The uptake of essential macronutrients by the plant can also be affected when high levels of sodium are present in the soil (Stevens et al., 2008).

Toxic effects of chloride on plants

Figure4. Evidence of chloride toxicity in an aspen (Goodrich and Jacobi, 2007/2008)

Chloride is an essential micro-nutrient required in small quantities by all plants (Stevens et al., 2008). It is also one of the most common phytotoxins which is typically absorbed through the roots of the plant. It can also be absorbed through the plant leaves, and this speeds up the rate of toxic accumulation of the ion (Lazarova and Bahri, 2005). The toxicity level of chloride ions will be specific to each plant or plant group, and should be considered on an individual basis. Visible symptoms of chloride toxicity usually appear before those of sodium or boron (Azza Mazher et al., 2007). These symptoms include marginal chlorosis of the older leaves, followed by extensive leaf scorching, wilting and eventually defoliation (Fig.4). An indirect effect of excessive chloride levels is the prevention of absorption of essential nutrients such as nitrate and phosphates (Stevens et al., 2008).

Toxic effects of boron on plants

Boron is an element that is actually required for good plant growth (Lazarova and Bahri,2005). The range between acceptable and toxic levels of Boron is quite small (Stevens et al., 2008) and plants respond differently to specific levels of boron. These toxic levels do not often occur in arable soil, making it necessary to ensure the water used has minimal levels of boron. Plants are able to withstand higher soil boron levels in soils with a pH range of 7.5-9.5 (Stevens et al., 2008). Another factor influencing increased uptake of boron is the method of irrigation. The visible symptoms of toxic levels of boron are typically leaf burn and necrotic patches as shown in Fig.5. Other less typical symptoms are yield reductions (Stevens et al., 2008).

Effects of water logging

Figure5. Necrotic effects of boron on apple tree leaves (University of Georgia Plant Pathology Archive, n.d.)

Water logging has different effects on different plant species. The effects also vary depending on the salinity of the soil and water surrounding the plant. Kozlowski (1997) explains in great detail multiple physical and physiological effects of water logging on woody plants. Plant growth, reproduction and photosynthetic capabilities are all adversely affected by water logging. In addition, plants that have experienced water logging become more prone to drought because of their shallow and small roots (Kozlowski, 1997). The increased water uptake under waterlogged conditions also increases the salt ion uptake in the plant. Water logging also affects plant aeration and root penetration and root distribution. Visual evidence of water logging can be leaf tip burn as shown in Fig. 6.

Glenelg wastewater for Adelaide parklands

Urban land scapes impact on the microclimate, hydrological cycle, biodiversity, water quality, air pollution, removing significant amounts of pollutants such as nitrogen, phosphorus and fine sediments and in general have environmental, social and economic benefits. There is currently a lack of adequate information specific to the Adelaide Park Lands vegetation, their tolerance to salinity and toxicity and their threshold levels. There is little research to investigate water requirements of mixed vegetation in urban landscapes such as plantings in the parkland systems. However, currently a research using WOCULS approach for estimating parkland plants water requirement is curing out at UniSA. Adelaide Park Lands, with an area of 720 ha are a core component of Adelaide, brings environmental, social, cultural and financial benefits for the people of Adelaide. The average main element concentrations in the Glenelg recycled wastewater is given in Table 2. The variation of concentration of these elements, coupled with irrigation application rate and the other management measures are important for long term sustainable irrigation management.


Figure6. Leaf damage as a result of water logging (Manitoba Agriculture Food and Rural Initiatives,n.d.)

Table 2. Annual average concentration of some main elements in Glenelg recycled wastewater (REM et al., 2008)

	Chloride (mg/l)	Boron (mg/l)	Sodium (mg/l)	SAR	Total N (mg/l)	Total P (mg/l)	EC (dS/m)
Annualaverage	389	0.281	261	7.50	15.8	6.74	1.8

The annual average salt concentration in the Glenelg recycled wastewater is nearly 1.8dSm^{-1}. Although the salinity variation in usual irrigation water is expected to vary up to 3 dS/m, irrigation with Glenelg recycled wastewater with an annual application rate of 4500m^{3}ha^{-1} would cause annual accumulation of nearly 9 tha^{-1} salts to the soil. In the lack of efficient irrigation management salinity build up hazard would be problematic in the long term. Toxicity often accompanies or complicates a salinity or infiltration problem although it may appear even when salinity is low. The toxic ions sodium and chloride can also be absorbed directly into the plant. In cases where the toxicity problem is not too severe, relatively minor changes in farm cultural practices can minimize the impact. An alternative water supply may be available to blend with a poorer supply to lower the hazard from the low quality water (Ayers and Westcot, 1994). A good indicator of sodium tolerance would be the presence of low sodium content in the plant leaves, in combination with high potassium content in the roots, stems and leaves (Adrover et al., 2008). Plant species that have high tissue calcium content in their leaves and stems would also be sodium-tolerant as calcium has been shown to neutralise the deleterious effects of various salts (Kozlowski, 1997).Typical toxicity symptoms are leaf burn, scorch and dead tissue along the outside edges of leaves in contrast to symptoms of chloride toxicity which normally occur initially at the extreme leaf tip. The average sodium level in the Glenelg recycled wastewater is 261mgl^{-1} and the amount of SAR is 7 (REM and SRHS, 2007). However, the sodium concentration in usual irrigation water is expected to be 0-920 mgl^{-1}. This shows that the sodium concentration in the Glenelg recycled wastewater is considerably below the maximum allowable level. However, it does not mean that accumulation of this toxic ion in the long term without considerable attention to sustainable irrigation management would not be a hazard for Adelaide Park Land plants, particularly for those that are sensitive to sodium. Wu et al. (1995) gathered experimental evidence from a number of landscape plants and suggests that plants with high concentrations of tissue calcium exhibit tolerance to chloride. Therefore, chloride-tolerance is positively correlated to tissue calcium percentages. Not much research has been done on Australian landscape plants and it is important to have knowledge specific to each plant species, before assuming chloride tolerance.

Chloride toxicity Boron toxicity management

Tolerances to chloride are not nearly so well documented as crop tolerances to salinity. Chloride moves readily with the soil-water, is taken up by the crop, and accumulates in the leaves. If exceeds the tolerance of the crop, injury symptoms develop such as leaf burn or drying of leaf tissue. With sensitive crops, the symptoms occur when leaves accumulate from 0.3 to 1.0 % chloride on a dry weight basis. Many tree crops, for example, begin to show injury above 0.3 % chloride. Chloride toxicity can occur by direct leaf absorption through leaves wet during overhead sprinkler irrigation. (Ayers and Westcot, 1994). Toxic levels of boron are usually related to soil types associated with low rainfall areas. As with sodium and chloride, boron-tolerance is specific to individual species and water application method. Research suggests that boron tolerance is at a genetic and cellular level (Nable et al., 1997). For example, differences in phloem mobility result in different accumulations of boron in the leaves, fruit and cambial tissue of a plant (Nable et al., 1997). It is therefore difficult to identify boron-tolerant plants from any physiological attribute. The allowable level of boron in the irrigation water is between 0-2 mgl^{-1}. The level of boron in the class A Glenelg recycled wastewater is 0.4 mgl^{-1} (REM and SRHS, 2007). Boron therefore is not a concern in the Glenelg recycled wastewater at least in the short term.

Conclusion

A wide variety of plants are used in the Adelaide Park Lands, each with a specific tolerance for high levels of salinity, sodium, chloride and boron. This further complicates the task of providing the correct amount of water without causing toxic levels of any of the above mentioned elements. It is important, therefore, to provide irrigation water that has salt concentrations suitable to a large number of plant species (Wu et al., 2001). Using recycled wastewater is a sustainable option for irrigation of the Adelaide Park Lands. It is however important to maintain a healthy and diverse collection of plants within the parklands in order to achieve one of the goals of creating habitat for native fauna. To this end, it is important to understand the nutrient requirements and characteristics for each species found within the parklands and to manage the care of the parklands accordingly. The amount of nutrient loadings using recycled water should be taken into consideration by monitoring the amount of nutrients are loaded by recycled water and are taken up by the plants. Previous reports have developed adaptive management frameworks designed to address the potential impacts of using recycled wastewater from Glenelg Wastewater Treatment Plant. A plant's salt tolerance is variable depending on the climate, weather, genetic variation, soil health, texture and structure and irrigations methods and frequency (Wu et al., 2001). Investigation undertook in a study (Hassanli and Kazemi, 2012) indicates that the average level of three main plant toxic elements, sodium, chloride and boron is lower than the maximum allowable level recommended in the guidelines in Water Quality for Agriculture developed by FAO (Ayers and Westcot, 1994). The average Na^+ and Cl^- level in the Glenelg recycled in 2005 was 242 and 364 mgl^{-1}, respectively (REM and SRHS, 2007). This shows that the Na^+ and Cl^- concentration in the Glenelg recycled wastewater is below the maximum allowable level. However, it does not mean that accumulation of these two toxic ions in the long term without considerable attention to sustainable irrigation management would not be a hazard for the Adelaide Park Land plants particularly those that are sensitive to toxicity of these elements. Findings suggest that further research would be needed to clarify the benefits of the irrigation of urban green spaces by recycled water and improve irrigation management to mitigate the possible inverse impacts of recycled water for a sustainable environment to ensure having a healthy plant, soil and water system across the Adelaide Parklands.

References

Adrover, M., Forss, A., Ramon, G., Vadell, J., Moya, G. & Taberner, A. 2008. Selection of woody species for wastewater enhancement and restoration of riparian woodlands. Journal of Environmental Biology, 29, 357-361.

Algot, M., Huertasa, E., Weberb, S., Dottb, W. & Hollenderb, J. 2006. Wastewater reuse and risk: definition of key objectives. Desalination, 187, 29-40.

Azza Mazher, A., Fatma el-Quesni, E. & Farahat, M. 2007. Responses of ornamental plants and woody trees to salinity. World Journal of Agricultural Sciences, 3, 386-395.

Ayers, R.S. and Westcot, D.W. 1994. Water Quality for Agriculture, Food and Agriculture Organization of the United Nations, FAO, Paper No.29, Rome

Collett, B., Henry, N., 2011. Urban Water Supply and Use. The Australian Collaboration – A Collaboration of National Community Organizations.

Costello, L.R., Matheny, N.P., and Clark, J.R. 2000. WUCOLS III: A guide to estimating irrigation water needs of landscape plantings in California: the landscape coefficient method. San Mateo and San Francisco Counties: University of California Cooperative Extension, California Department of Water Resources, 160.

Hassanli, A. M., Ahmadirad, Sh. and Beecham, S. 2010. Evaluation of the Influence of Irrigation Methods and Water Quality on Sugar Beet Yield and Water Use Efficiency. Agric. Water Manage. Vol. 97:357-396.

Hassanli. A.M. and Javan, M. 2005. Evaluation of municipal effluent quality as an appropriate alternative for green space development and mitigating the environment effects, Tehran University, J. of Environment, No.38.

Hassanli, A.M., Ahmadirad, Sh., Maftoon, M. and Masoudi, M. 2007. The Effect of Municipal Effluent Using Pressure and Surface Irrigation Methods on Selected Soil Chemical Properties in an Arid Region, J. of Agrochimica, Vol.51(6):329-337.

Kozlowski, T. T. 1997. Responses of woody plants to flooding and salinity, Tree Physiology Monograph No. 1, Heron Publishing, Victoria, Canada.

Lazarova, V. & Bahri, A. 2005. Water reuse for irrigation: agriculture, landscapes and turf grass, Florida, CRC Press.

Nable, R., Bañuelos, B. & Paull, J. 1997. Boron Toxicity. Plant and Soil, 193, 181-198.

Nouri, H., Beecham, S. Kazemi, F. and Hassanli, A. 2012. A Review of ET Measurement Techniques for Estimating the Water Requirements of Urban Landscape Vegetation, Urban Water, Taylor and Francis, doi:10.1080/1573062X.2012.726360. pp1-13

Pedrero, F., Kalavrouziotis, I., Alarcón, J., Koukoulakis, P. & Asano, T. 2010. Use of treated municipal wastewater in irrigated agriculture—Review of some practices in Spain and Greece. Agricultural Water Management, 97, 1233-1241.

REM & SRHS 2007. Environmental assessment of potential reuse of treated wastewater from the Glenelg WWTP within the Adelaide park lands.

REM, SRHS & SE 2008. An adaptive management framework for the reuse of treated wastewater from the Glenelg WWTP within the Adelaide Park Lands.

Salgot, M., Huertasa, E., Weberb, S., Dottb, W. & Hollenderb, J. 2006. Wastewater reuse and risk: definition of key objectives. Desalination, 187, 29-40.

Stevens, D., Smolenaars, S. & Kelly, J. 2008. Irrigation of amenity horticulture with recycled water.

WU, L., Chen, J., Lin, H., VAN Mantgem, P., Harivandis, M. & Harding, J. A. 1995. Effects of wastewater irrigation on growth and ion uptake of landscape plants. Journal of Environmental Horticulture, 13, 92-96