DEPARTMENT OF
PRIMARY INDUSTRIES

Using Recycled Water in Horticulture

A Growers Guide

Victoria
The Place To Be

HAL
Know-how for Horticulture™

National Program for Sustainable Irrigation

Cooperative Research Centre for Irrigation Futures

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1. INTRODUCTION

RECYCLED WATER

Recycled water is water that has been used, captured, and used again. In many cases there is considerable treatment before it is used again. Treatment requirements and the quality of the recycled water are set by its intended use (i.e. it is fit for the intended purpose).

The source of this water may be human or animal waste, stormwater or industrial. Water quality testing will determine if treatment is required to make the recycled water suitable for a range of purposes such as irrigation (pasture, field crops and horticulture), industrial processing, residential housing (toilet flushing and gardens), and to keep our public and recreational spaces green. Recycled water is a valuable resource. It helps improve the reliability of our water supplies, frees up water for the environment and for drinking, and reduces the amount of waste water discharged into our waterways. Recycled water brings ongoing benefits to agricultural enterprises through greater certainty of water supply and an assured water quality, recycling of valuable nutrients and security of investment in irrigation activities.

ABOUT THIS GUIDE

This guide is designed to assist growers in managing irrigation with recycled water. Like any water source, you will need to ensure that the water quality and its management meet the requirements of your specific quality assurance (QA) scheme. You may also need to meet additional government regulatory requirements for the use of recycled water for horticultural crops. From a crop management perspective, you may need to make some minor changes, since the quality of recycled water is often different from other water sources (e.g. recycled water can be higher in salts and nutrients).

This guide outlines some best management practices (BMPs) that relate to the use of recycled water in horticultural production and pre-market handling of produce. The BMPs are presented in the form of a question-and-answer checklist to help you consider the important issues associated with using recycled water in horticulture. Where appropriate the information is supplemented with further explanations (light green coloured boxes) and references to information sources are given (generally in the form of website addresses).

The guide considers the requirements of popular QA schemes, codes of practice and guidelines from regulatory bodies (e.g. environment and human service authorities), along with published scientific evidence. It also outlines popular quality assurance schemes for horticulture and covers some of the key management requirements when using recycled water. Other major topics covered in this guide include: planning to use recycled water, quality of recycled water; soil salinity and sodicity; irrigation management; and fertilisation and nutrient management. Finally, some of the sources for further information are given. This guide is targeted at the horticultural industry, including service providers and growers.

2. QUALITY ASSURANCE SCHEMES AND GUIDELINES

Traditionally, many QA schemes have been based on the application of a process rather than dealing with specific issues such as quality of recycled water. Most schemes do, however, focus on the customers' requirements and compliance with legislation, for example regulatory requirements related to a particular product. In other schemes, water quality is commonly addressed through risk analysis, for example Hazard Analysis and Critical Control Points (HACCP)-based systems.

Question/Issue	Guidance/Comment	Your Checklist
Are you aware of the QA schemes, guidelines and codes of practice that are relevant to your horticultural enterprise?	A number of QA schemes cover many aspects of horticultural production and preparation of produce for marketing. Some are industry driven while others are buyer-driven. There are also a number of guidelines and codes of practice covering environmental and human health issues. For example, HACCP is an internationally recognised and recommended approach to food safety that can help anticipate and prevent hazards associated with the use of recycled water. The HACCP plan is based on seven principles identified in the Codex Guidelines for the Application of HACCP System.	☐ Not Applicable ☐ Strategy in place ☐ Need to follow up
Are you aware of the requirements of your QA schemes and guidelines specific to recycled water use?	Few QA schemes specifically refer to the use of recycled water in horticulture, while others refer only to the quality of water. Some popular QA schemes and guidelines covering recycled water use in horticulture are given on page 3.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up

QUALITY ASSURANCE SCHEMES
(process and performance based)

National

- Freshcare Code of Practice - 2nd Edition October 2004. Freshcare Limited, Sydney Markets.
- Woolworths Quality Assurance Standard - Version 1 1st December 2003. Woolworths Limited.
- Australian Certified Organic – Organic Standard - Version 6. 2003. Australian Certified Organic Pty Limited.
- NASAA Organic Standard, December 2004. The National Association for Sustainable Agriculture Australia Ltd.
- National Standard for Organic and Bio-dynamic Produce - 3rd Edition December 2002. Australian Quarantine and Inspection service.

International

- AS/NZS ISO 9001:2000 Quality Management Systems – Requirements. International Organisation of Standardisation, Geneva, Switzerland.
- Hazard Analysis and Critical Control Points System and Guidelines for its Application - Annex to CAC/RCP 1-1969, Rev 3 1997. Codex Alimentarius Commission.
- AS/NZS ISO 14001:1996, Environmental Management Systems – General guidelines on principles, systems and supporting techniques. International Organisation of Standardisation, Geneva, Switzerland.
- British Retail Consortium Global Standard Food - Issue 3 March 2003. British Retail Consortium, UK.
- EurepGAP - General Regulations Version 2.1 – January 2004. EUREPGAP Secretariat, Cologne, Germany.
- SQF 2000 Code - 5th Edition – Issued November 2005. Food Marketing Institute, Washington DC.
- SQF 1000 Code - 4th Edition – Issued November 2005. Food Marketing Institute, Washington DC.
- ISO 22000:2005 Food Safety Management System - Requirements for any organisation in the food chain. International Organisation of Standardisation, Geneva, Switzerland.

GUIDELINES
(principle based)

National

- Guidelines for On-Farm Food Safety for Fresh Produce 2004, Second edition. Department of Agriculture, Fisheries and Forestry, Australian Government.
- Guidelines for the Management of Microbial Food Safety in Fruit Packing Houses - Bulletin 4567 November 2002. Department of Agriculture, Western Australia.
- Safe Vegetable Production - A Microbiological food Safety Guide for the Australian Vegetable Industry 2002.
- Guidelines for Environmental Assurance in Australian Horticulture 2005. Horticulture Australia Limited.
- National Integrated Fruit Production Guidelines for Pome Fruit - Final Report 2000.
- EnviroVeg Program - March 2001. AUSVEG: Australian Vegetable and Potato Growers Federation.
- NIASA Best Practice Guidelines - 2nd Edition 1997. Nursery Industry Accreditation Scheme Australia.

Note: For website addresses of some of the QA schemes and guidelines, please refer to Section 8, page 22.

3. PLANNING TO USE RECYCLED WATER

This section covers general issues associated with the use of recycled water. These include the suitability of the recycled water, infrastructure requirements, market acceptance of produce, health and safety issues and general compliance.

MARKET REQUIREMENTS

Question/Issue	Guidance/Comment	Your Checklist
Will organic markets accept produce grown with recycled water?	In Australia, recycled water can be used for growing organic produce if it is treated appropriately and has re-entered a natural public waterway system (Section 3.5.4 of the Australian National Standard for Organic and Bio-Dynamic Produce). There may, however, be other requirements specific to your situation. The Australian Organic and Bio-dynamic program is managed by the Australian Quarantine and Inspection Service (AQIS). It is responsible for the management of organic and bio-dynamic produce via a co-regulatory arrangement with AQIS approved certifying organisations. More information and a list of approved certifying organisations can be found in the following website: www.affa.gov.au/content/output.cfm?ObjectID=43E732B6-D4AF-43EE-8F71C0E5E1F50550	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Will my buyers accept the produce grown with recycled water?	The majority of QA schemes accept the use of recycled water in horticultural production provided the water meets certain minimum quality criteria and auditing/certification requirements. Auditors can request evidence of the quality of water used in crop production and post harvest handling.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up

REGULATORY REQUIREMENTS

Question/Issue	Guidance/Comment	Your Checklist
Have relevant state authorities approved the recycled water (e.g. EPA, DHS) for the intended use? Is it fit for purpose?	Generally, new recycled water schemes in Australia obtain a 'fit for purpose' approval from state regulatory authorities like the Environment Protection Authority (EPA) and/or Department of Human Services (DHS). However, this varies from state to state. Depending on the level of treatment, recycled water is generally categorised into four classes in Australia: A, B, C and D, with Class D the lowest quality. The quality criteria for different classes of water and the permitted uses also vary from state to state, for example in Queensland A+ is of highest quality which is equivalent to Victoria's Class A. From a human health perspective, Victorian Class A, or equivalent, recycled water generally has no restrictions on the method of irrigation or crops grown. The new draft National Guidelines for Water Recycling used 'fit for purpose' in place of the Class A to D System. Website addresses for different state guidelines are provided in Section 8, page 21.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Can recycled water be used for post-harvest produce washing and processing?	Recycled water is not to be used in any food processing (peeling, slicing) or cooking. Guidelines vary from state to state in relation to final washing of the produce with recycled water. The interpretation of what is 'on-farm' washing and what is 'food processing' is critical. For example, in Victoria, the Victorian Food Act states that only potable water (water you can drink) can be used for food processing. Victorian DHS advice to farmers is that recycled water (Class A) can be used for on-farm washing of produce before packing and marketing. However, if the food is chopped or packaged (e.g. salad mixes) for direct consumption then this is deemed food processing and falls under the Victorian Food Act, which states that potable water must be used during this process. Class A recycled water is not considered drinkable and therefore cannot be used.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Do you have an agreement in place for the use of recycled water with the provider and do you understand the conditions of supply?	Generally, water suppliers will require that you enter into an agreement. Make sure you understand the terms and conditions and your rights and responsibilities. Recycled water scheme managers and suppliers of water are an important source of information and have responsibility to ensure their users are sufficiently equipped with knowledge.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Have you attended the relevant workshops or training sessions on the use of recycled water?	For some new recycled water schemes it is a condition of water supply that you attend information or training sessions on the use of recycled water. Even if training is not a formal requirement, attendance is still helpful to understand the nature and use of recycled water.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Are you aware of any compliance and monitoring requirements?	Generally, the agreement covering recycled water supply will indicate if there are any compliance and monitoring requirements for using recycled water. As the supply of recycled water is linked to environment and human service authorities, it is important that you understand the compliance and monitoring requirements.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up

Planning to use recycled water continued

MANAGEMENT REQUIREMENTS

Question/Issue	Guidance/Comment	Your Checklist
Do you have a map or schematic layout of your property with prominent features marked?	It is a good practice to have property maps showing irrigated areas, property boundaries, buildings and water storage facilities, water supply pipes, drainage points, soil types etc. Besides improving general access to the property this will facilitate the assessment and decision making if reportable incidents like off-site movement of recycled water occurs. Your recycled water supplier should tell you if there are any specific requirements relating to the identification of prominent features on a map/sketch.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Do you have appropriate signage where recycled water is being, or will be, used?	Many schemes require strategic and prominent signage where recycled water is used in accordance with Australian Standard 1319 – 1994, Safety Signs for the Occupational Environment. The current requirement is that the pipes carrying recycled water should be painted lilac and that appropriate signage, e.g. 'Recycled Water – Do Not Drink', is used to advise everyone concerned.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Have you advised your family members and employees about the use of recycled water on the property?	Recycled water users must ensure they are complying with Occupational Health and Safety requirements. Growers need to make sure all family members, employees and other people entering the property are made aware of the use of recycled water on-site. They must also ensure that employees, family members and others concerned are aware that this water is not suitable for drinking.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Are you aware of your first point of contact in case of any concerns or incidents in relation to recycled water use?	In most cases, your water supplier will be the first point of contact if there are any concerns or incidents. For example, contamination of the potable water supply by recycled water; significant leaks or overflows from the recycled water storage dams; discharges of recycled water to rivers or creeks; and soil salinity, sodicity or acidity problems caused by the use of recycled water.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up

Question/Issue	Guidance/Comment	Your Checklist
Do any of your management practices need to be changed because you are using recycled water?	The use of recycled water may require you to make changes to current management practices. If they are required, the scheme operator should make you aware of them. Some of the changes required may include better record keeping and monitoring of soil condition under recycled water use.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Do you have an on-farm storage facility for recycled water?	If you need to store recycled water make sure you have appropriate controls in place to prevent seepage, leaks or overflows. There could also be requirements for fencing the storage and warning signs to control access.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Do you have an algal management plan in place?	Algae are free floating plant-like organisms that may grow rapidly under ideal conditions of warmth, sunlight, high nutrients and still waters to form blooms or surface scums. Blue-green algae are of primary concern because some species can produce toxins. An algal outbreak can occur in any water body, not just with recycled water, and should be dealt with caution. Algal outbreaks may be prevented or reduced by controlling the environment and avoiding conditions that promote algal growth. Prevention of algal blooms is preferred to chemical control. If you must use chemical control, seek expert advice as the chemical recommendations may vary according to situations. Chemical label recommendations and directions must be strictly followed. Website for more information: http://www.dpi.vic.gov.au/dpi/nreninf.nsf/FID/-5B5AD19175F347E9CA256BCF000AD50B?OpenDocument	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Are you aware of where you can find further information?	Every recycled water scheme will have communication strategies and information sources available to its users. Your water supplier and government agencies should be able to provide all the information you need or advise you where to find it. Refer to Section 8 - Further Information for some information sources, page 21.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up

4. QUALITY OF RECYCLED WATER

The recycled water supplied at the farm gate should have met pre-determined standards that ensure it is fit for the intended purpose. It is important for the user to understand the different quality issues associated with recycled water that will help the user make informed management decisions on-farm.

Question/Issue	Guidance/Comment	Your Checklist
Do you understand the issues associated with the quality of recycled water?	By nature, the primary sources of recycled water (human or animal waste, stormwater, rainwater or industrial) have different contaminants, pathogens and varying loads of salts and nutrients. While salts are generally harmful to plants, nutrients can be beneficial. The level of treatment will determine what, and how much, remains in the recycled water at the point of supply.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
What salts and nutrients are generally present in recycled water?	Generally the most common salt in recycled waters is sodium chloride or table salt. Magnesium, calcium and potassium salts are also present in significant quantities and there may be small amounts of other salts. The proportion of various salts will largely depend on the source of recycled water and the nature of treatment. In addition, nitrogen and phosphorus are also present in significant quantities. Recycled water also has most of the micronutrients required by crop plants (e.g. iron, manganese, zinc, copper, molybdenum, boron, chlorine, nickel and cobalt) in varying quantities. The presence of nutrients in recycled waters can reduce the amount of fertilisers or manures required for a crop. However, if the nutrient content of recycled water is greater than the crop requirement, it could adversely affect crop growth. In addition, excessive nutrient build up in soil or discharge to ground water could have adverse environmental consequences. Excessive amounts of nutrients should be managed to ensure that these harmful effects do not occur. Refer to Section 7 ‘Fertilisation and Nutrient Management’, page 20.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up

Question/Issue	Guidance/Comment	Your Checklist
What other contaminants are present in recycled water and are these of concern?	Generally, there are three types of contaminants that could potentially be present in recycled water: heavy metals (e.g. cadmium, chromium, copper, lead and mercury); microorganisms (bacteria, viruses, protozoan parasites and nematodes); and organic contaminants like pesticides and other organic chemicals that can cause disruption of endocrine system (the system of glands in animals that are responsible for producing hormones). These contaminants are present in source waters either naturally or introduced through human actions. High levels of these contaminants can be harmful to plants, animals and the environment. Recycled water schemes should ensure through treatment, testing and monitoring, that the levels of contaminants do not exceed guidelines from human health and environmental authorities.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Are the levels of pathogens in recycled water acceptable?	All recycled water schemes in Australia comply with their state guidelines in relation to acceptable levels of pathogens. The state guidelines are based on national guidelines and are considered stringent in comparison to international standards. If the food crops grown with recycled water are to be eaten raw, the World Health Organization guidelines specify that the number of faecal coliforms should not exceed 1000 per 100 millilitres of water, and that the number of intestinal nematodes should not exceed 1 per litre. Your water supplier will be able to provide a microbiological assessment of their recycled water. Faecal coliforms are microorganisms found in the faeces of warm-blooded animals. Only a small proportion of faecal coliforms are pathogens, but they are still a useful indicator of the likely level of pathogens in recycled water. Refer to state guidelines for more information in Section 8 - Further Information, page 21.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up

5. SOIL SALINITY AND SODICITY

Soil salinity and sodicity are important considerations in any farming enterprise. Recycled water generally has a higher salinity level than drinking water. It is important to check that the salinity of the recycled water is acceptable for the crops and soils where you will be irrigating.

SOIL SALINITY

Question/Issue	Guidance/Comment	Your Checklist
Do you understand how salinity affects crop production?	Soil salinity refers to the presence of soluble salts in soils. Soil salinity mainly results from natural processes of landscape evolution. However, human activity can contribute to the development and exacerbation of soil salinity. For instance, salts can be introduced to the soil through irrigation water and fertilisers. A common misconception about salinity is that it is just caused by sodium chloride (NaCl, i.e. table salt). While sodium chloride is generally the predominant salt, salinity can be made up of many other salts (e.g. salts of calcium, magnesium, potassium) which may even come from common fertilisers and manures (e.g. ammonia, urea, ammonium sulphate, ammonium nitrate and chicken manure).	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
How is salinity assessed?	There is a range of field and laboratory analyses that can be used to assess soil salinity. Generally, electrical conductivity (EC) of a soil-water suspension is a convenient method of estimating the salt content of soil. Most Australian laboratories use a 1-part soil:5-part water suspension method to determine EC. Other methods determine the amount of total dissolved salts (TDS) directly.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up

While determining the EC of a 1:5 soil:water suspension ($EC_{1:5}$) is easier, it has many disadvantages associated with a water content that is much more dilute than field conditions. In another method, the EC of saturated-soil extract (EC_e) is measured. This method is tedious but is more representative of field conditions, and what plants might experience, as it takes into account the soil texture. Soil texture refers to the relative proportions of the various soil separates like sand, silt or clay.

The international unit of EC is deci Siemen per metre (dS/m). Other common EC-based units and their inter-relationships are:

µS/cm – micro Siemen per centimetre

EC units – numerically same as µS/cm (=1 µS/cm)

µmho/cm – micro mho per cm (= µS/cm)

mmho/cm – milli mho per cm (= dS/m)

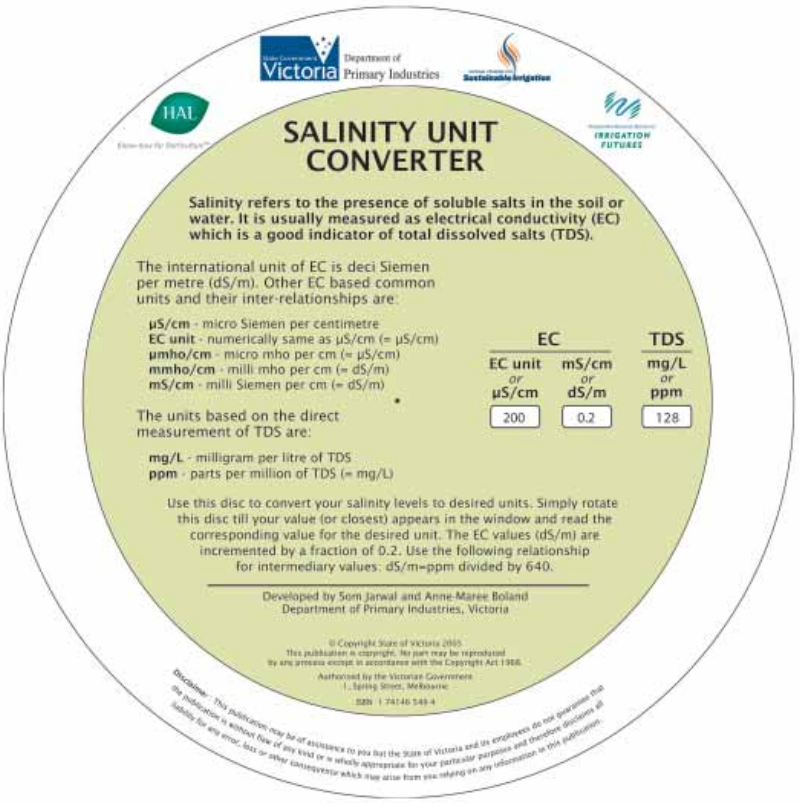
mS/cm – milli Siemen per cm (= dS/m)

The units based on the direct measurement of TDS are:

mg/L – milligram per litre of (TDS)

ppm – parts per million of TDS, same as mg/L

A converter (see below) has been provided with this guide (back cover pocket). It can be used to convert other units to dS/m.



Soil salinity and sodicity continued

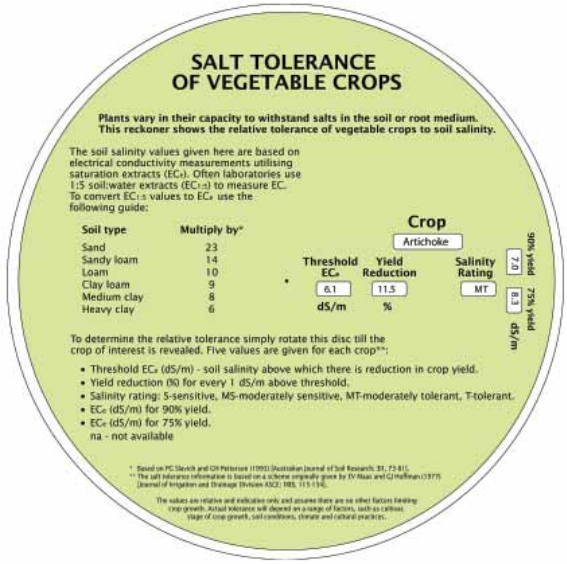
A large amount of information on soil salinity is available that refers to EC_e (i.e. electrical conductivity of a saturation paste extract from soil). To use that information, the salinity values expressed in $EC_{1:5}$ must be converted to EC_e. The following guide may be used for conversion from $EC_{1:5}$ to EC_e for different types of soil:

Soil type	Multiply $EC_{1:5}$ by the number below to get EC_e*
Sand	23
Sandy loam	14
Loam	10
Clay loam	9
Medium clay	8
Heavy clay	6

The above conversions are intended as an approximate guide only; in practice, a range of site-specific conditions will influence these values. Soils can be rated based on salinity, e.g. low, moderate, high, extreme. These ratings are relative therefore it is the underlying salinity level that counts. See further discussion on salinity under 'Salt tolerance of crops', page 13.

* Based on PG Slavich and GH Petterson (1993) Australian Journal of Soil Research: 31, 73-81.

Question/Issue	Guidance/Comment	Your Checklist
How does salinity affect horticultural production?	Soil salinity generally affects plant growth by increasing osmotic tension in the soil making it more difficult for the plants to absorb water from the soil. Excessive uptake of salts by plants from the soil may also have a direct toxic effect on plant cells. Saline water, depending on the concentration of salts, applied through sprinkler irrigation can also cause direct damage to the leaves.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
What is the right recycled water salinity for the crop that I want to grow?	The salinity of irrigation water is not the only factor that influences the salinity of the soil irrigated. Other factors than can influence soil salinity are the leaching fraction (see also Section 6, page 18) of irrigation water applied, frequency of irrigation, soil type, rainfall and climate. Usually the salinity of the soil irrigated (EC_e) will be higher than the salinity of the water irrigated. For your specific situation this can be calculated more accurately by your agronomic advisor.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
What can you do to deal with the effects of salinity?	Salinity can be effectively managed by reducing salt input. This can be achieved by shandying (mixing) saline water with low salinity water, as well as appropriate crop selection, leaching salt from the root zone and irrigation management. For a discussion on leaching and irrigation see Section 6, 'Irrigation Management', page 18. There is huge variation in the tolerance of different crops to salinity. For example, turnip and carrots are among the most sensitive crops and can only tolerate soil salinities of about 1 dS/m before a yield decline may be experienced. Zucchini on the other hand, can tolerate soil salinity of up to 4.7 dS/m before a reduction in yield is recorded. Most vegetable crops and fruits fall into the sensitive to moderately sensitive range. Table 1 (pages 14 & 15) illustrates relative tolerance of some vegetable and fruit crops to soil salinity. The information given in Table 1 has been transformed into easy-to-use decision support tools (included with this guide) to help you compare the tolerance of horticultural crops to soil salinity.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up



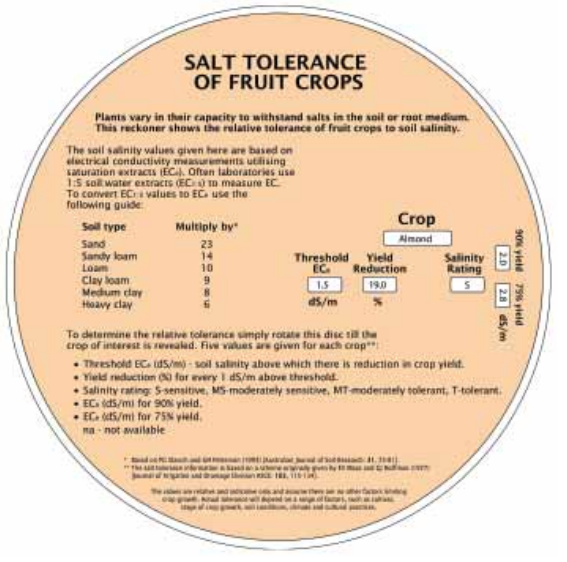


Table 1: Soil salt tolerance of horticultural crops

Vegetables

Common name	Scientific name	Soil salinity (EC_e) threshold[a]	Yield reduction[b] % per dS/m above threshold	Soil salinity (EC_e), dS/m for			Salinity rating[d]
		dS/m		90% yield[c]	75% yield[c]	50% yield[c]	
Artichoke	*Cynara scolymus*	6.1	11.5	7.0	8.3	10.4	MT
Asparagus	*Asparagus officinalis*	4.1	2.0	9.1	16.6	29.1	T
Bean	*Phaseolus vulgaris*	1.0	18.9	1.5	2.3	3.6	S
Broccoli	*Brassica oleracea*	2.8	9.1	3.9	5.5	8.3	MS
Cabbage	*Brassica oleracea capitata*	1.8	9.7	2.8	4.4	7.0	MS
Carrot	*Daucus carota*	1.0	14.1	1.7	2.8	4.5	S
Cauliflower	*Brassica oleracea botrytis*	2.5	na	na	na	na	MS
Celery	*Apium graveolens*	1.8	6.2	3.4	5.8	9.9	MS
Cucumber	*Cucumis sativus*	2.5	13.0	3.3	4.4	6.3	MS
Eggplant	*Solanum melongena*	1.1	6.9	2.5	4.7	8.3	MS
Garden beet	*Beta vulgaris*	4.0	9.0	5.1	6.8	9.6	MT
Garlic	*Allium sativum*	3.9	14.3	4.6	5.6	7.4	MS
Lettuce	*Lactuca sativa*	1.3	13.0	2.1	3.2	5.1	MS
Onion	*Allium cepa*	1.2	16.1	1.8	2.8	4.3	MS
Pea	*Pisum sativum*	3.4	10.6	4.3	5.8	8.1	MS
Pepper	*Capsicum annum*	1.5	14.1	2.2	3.3	5.0	MS
Potato	*Solanum tuberosum*	1.7	12.0	2.5	3.8	5.9	MS
Pumpkin	*Cucurbita pepo pepo*	3.2	16.0	3.8	4.8	6.3	MS
Radish	*Raphanus sativus*	1.2	13.0	2.0	3.1	5.0	MS
Rockmelon	*Cucumis melo*	1.0	8.4	2.2	4.0	7.0	MS
Spinach	*Spinacia oleracea*	2.0	7.6	3.3	5.3	8.6	MS
Sweet corn	*Zea mays*	1.7	12.0	2.5	3.8	5.9	MS
Sweet potato	*Ipomoea batatas*	1.5	11.0	2.4	3.8	6.0	MS
Tomato	*Lycopersicon esculentum*	2.3	18.9	2.8	3.6	4.9	MS
Turnip	*Brassica rapa*	0.9	9.0	2.0	3.7	6.5	MS
Zucchini	*Cucurbita pepo melopepo*	4.7	9.4	5.8	7.4	10.0	MT

The data in this table serve only as a guideline to relative tolerances among crops. Actual tolerance will vary depending upon climate, soil conditions, cultivar/rootstock, stage of crop growth and cultural practices. The data is taken from published literature based on the plant salt tolerance scheme originally given by E.V. Maas and G.J. Hoffman (1977) [Crop salt tolerance – current assessment. Journal of the Irrigation and Drainage Division, American Society of Civil Engineers 103,115-130].
Also see footnotes on page 15.

Table 1 continued

Fruits

Common name	Scientific name	Soil salinity (EC_e) threshold[a]	Yield reduction[b] % per dS/m above threshold	Soil salinity (EC_e), dS/m for			Salinity rating[d]
		dS/m		90% yield[c]	75% yield[c]	50% yield[c]	
Almond	*Prunus dulcis*	1.5	19.0	2.0	2.8	4.1	S
Apple	*Malus sylvestris*	1.0	18.0	1.6	2.4	3.8	S
Apricot	*Prunus armeniaca*	1.6	24.0	2.0	2.6	3.7	S
Avocado	*Persea americana*	1.3	21.0	1.8	2.5	3.7	S
Banana	*Musa acuminata*	na	na	na	na	na	S
Blackberry	*Rubus fruticosus*	1.5	22.0	2.0	2.6	3.8	S
Boysenberry	*Rubus ursinus*	1.5	22.0	2.0	2.6	3.8	S
Coconut	*Cocos nucifera*	na	na	na	na	na	MT
Date palm	*Phoenix dactylifera*	4.0	3.6	6.8	10.9	17.9	T
Grape[e]	*Vitis spp.*	1.5	9.5	2.6	4.1	6.8	MS
Grapefruit	*Citrus paradisi*	1.8	16.1	2.4	3.4	4.9	S
Guava	*Psidium guajava*	4.7	9.8	5.7	7.3	9.8	MT
Lemon	*Citrus limon*	1.5	12.8	2.3	3.5	5.4	S
Macadamia	*Macadamia integrifolia*	3.6	na	na	na	na	MS
Olive	*Olea europaea*	4.0	na	na	na	na	MT
Orange	*Citrus sinensis*	1.7	15.9	2.3	3.3	4.8	S
Peach	*Prunus persica*	1.7	21.0	2.2	2.9	4.1	S
Pear	*Pyrus spp.*	1.0	na	na	na	na	S
Pineapple	*Ananas comosus*	na	na	na	na	na	MT
Plum	*Prunus domestica*	2.6	31.0	2.9	3.4	4.2	MS
Prune	*Prunus domestica*	2.6	31.0	2.9	3.4	4.2	MS
Rockmelon	*Cucumis melo*	1.0	8.4	2.2	4.0	7.0	MS
Strawberry	*Fragaria x ananassa*	1.0	33.3	1.3	1.8	2.5	S

The data in this table serve only as a guideline to relative tolerances among crops. Actual tolerance will vary depending upon climate, soil conditions, cultivar/rootstock, stage of crop growth and cultural practices. The data is taken from published literature based on the plant salt tolerance scheme originally given by E.V. Maas and G.J. Hoffman (1977) [Crop salt tolerance – current assessment. Journal of the Irrigation and Drainage Division, American Society of Civil Engineers 103,115-130].

na - not available

[a]Level of soil salinity above which there is reduction in crop yield. All the soil salinity data is in EC_e.

[b]Yield reduction (%) for every 1 dS/m above threshold.

[c]Level of soil salinity up to which 90%, 75% or 50% yield can be achieved.

[d]Salinity rating as given by relevant researchers (generally based on the level of yield reduction for every 1 dS/m of soil salinity above threshold); S - sensitive, MS – moderately sensitive, MT - moderately tolerant, T – tolerant.

[e]Crop cultivars show some variation in their ability to tolerate soil salinity, however, grape varieties and rootstocks show huge variation in their ability to tolerate soil salinity. For example, while most commercial varieties in Australia can only tolerate soil salinity up to 1.8 dS/m there are rootstocks that can tolerate up to 5.6 dS/m.

SODICITY

Question/Issue	Guidance/Comment	Your Checklist
What is sodicity? 	Sodicity refers to a condition where too much exchangeable sodium is present in the soil compared with other cations. This has a negative impact on soil structural behaviour. Cation is an atom or group of atoms that have a positive electric charge. Exchangeable sodium is different from sodium in the soil solution. It is held on the negatively charged clay particles in the soil by a bond. Sodium forms a weaker bond with clay than calcium, magnesium or potassium. When such soils are wet, the sodium bond is easily broken and the clay particles disperse, giving the soil a cloudy appearance (left jar in picture).	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
How is sodicity measured? The relationships between ESP and SAR commonly used in Australia are: For saturation extract ESP ≈ SAR_e For 1:5 suspension ESP ≈ $2SAR_{1:5}$	Australian soils are defined as sodic if the exchangeable sodium percentage (ESP) is greater than six. In other words, ESP is the extent of exchangeable sodium as compared with all the cations taken together. Another commonly used measure of sodicity is sodium adsorption ratio (SAR). This measure is also used for water. Like salinity, SAR for soils can be measured using either saturation extracts or 1:5 soil:water suspension. While ESP and SAR can only be determined through laboratory analysis, there are some surrogate methods that can be used by farmers to obtain first-hand assessment of soils in relation to sodicity. One such method involves observing the behaviour of air dry soil aggregates in rain/distilled water. To do this assessment, drop about 8-10 small soil aggregates in a glass jar containing rain/distilled water and leave undisturbed for about two hours. If the water becomes cloudy (clay dispersed) then this is an indication of sodicity. Most laboratories providing soil and plant analysis services will undertake soil sodicity tests.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
How does sodicity affect horticultural production?	In contrast to salinity, the effect of sodicity is via its adverse influence on soil structure. Sodic soils are hard setting with restricted infiltration of water, prone to water logging and difficult to work with. Crops grown under such conditions suffer from poor root development and restricted nutrient and water uptake. Soil structure is the combination or arrangement of primary soil particles into aggregates or clumps. Sodicity affects the structural stability or the ability of the soil to resist adverse changes to the structural arrangement.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up

Question/Issue	Guidance/Comment	Your Checklist
What can you do to deal with the effects of sodicity? 	Gypsum is the most commonly used material to improve sodic soils. The amount of gypsum to be applied will depend on the level of sodicity and the quality (purity) of gypsum. Gypsum contains calcium in the form of calcium sulphate. When gypsum is applied to the soil calcium displaces sodium. Calcium forms stronger bonds between clay particles resulting in reduced clay dispersion. The more calcium the better in the long-term. Gypsum is available as mined gypsum and as an industrial by-product commonly known as phospho-gypsum which is sold as powder or in liquid form. Phospho-gypsum is generally of high purity but can be contaminated with cadmium (which could be a potential health risk to users). On the other hand, there is huge variation in the purity (quality) of the material sold as mined gypsum. The amount of gypsum to be applied may need to be adjusted upward depending on its purity. Information on the quality of gypsum is available from the suppliers. Lime (calcium carbonate) is another material that can be used in acidic soils. Lime supplies calcium and also reduces the acidity. Consult with your local adviser, government agencies or fertiliser suppliers to decide the amount of gypsum or lime that should be applied based on the level of sodicity and gypsum purity. Another way to manage soil sodicity is to improve the organic matter content of soils. Organic matter helps maintain good soil structure as well as supplying essential plant nutrients as it breaks down in the soil. Soil organic matter content can be improved by retaining and incorporating crop residues, by growing and ploughing in green manure crops or through application of manures and other organic amendments. Users need to be aware of high salt content of some manures.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up

6. IRRIGATION MANAGEMENT

The switch to recycled water may provide an opportune time to review your irrigation practices (including irrigation method and salinity management), to improve water use efficiency.

Question/Issue	Guidance/Comment	Your Checklist
Have you identified the best method for application of recycled water?	Ideally, the use of recycled water should not require you to alter your current irrigation practices. However, you should be aiming to optimise water use efficiency and minimise run-off and seepage to ground water and to creeks or rivers. Consider irrigation scheduling, along with methods like drip irrigation, to minimise water loss and improve water use efficiency. If nutrients in recycled water promote algal growth in your storage facility, you may need to install better filtration systems if using drip irrigation. Irrigation scheduling is the matching of crop demand for water with supply, i.e. applying the right amount of water at the right time. Water use efficiency is a measure of dry matter or harvested portion of the crop produced per unit of water consumed.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
How can you effectively irrigate with recycled water without increasing soil salinity?	To prevent salt from accumulating in the soil, excess water can be applied to deliberately cause a fraction of the water to flow through the root zone and flush away excess salts. This excess water used for leaching is called 'leaching requirement'. This practice has been used effectively in containing salt build-up under saline water irrigation. However, unless the water table is very deep, or the lateral groundwater drainage is sufficiently rapid, the extra irrigation can cause a progressive rise of water the table. Therefore, the amount of water applied must be optimised to allow leaching without a water table rise. Your agronomic advisor can estimate irrigation rates and leaching requirements.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up

Question/Issue	Guidance/Comment	Your Checklist
If you are using a sprinkler irrigation system, have you identified the best practice to minimise spray drift?	As a minimum requirement when using recycled water, no overhead spray should be directed towards a neighbouring property, public land or public roadway. Sprinklers at the boundary of properties should have adjustable spray heads or shields so that irrigation can be directed within farm boundaries. Good irrigation practice would include avoiding irrigation during strong winds and using spray heads and pressures that prevent fine mist generation.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Do you have appropriate drainage and run-off controls?	If nitrogen and phosphorus are in high concentrations (relative to that in receiving water bodies), or large amounts of fertilisers are being used, the run-off caused from irrigation can present a risk to neighbouring land and environmentally sensitive waterways by increased nutrient loads. To minimise run-off, avoid irrigating prior to a storm event, postpone irrigation if heavy rainfall is experienced and avoid excessive irrigation that results in pooling of water on the soil surface. Reduced run-off can be achieved by irrigation scheduling and improving drainage characteristics such as maintaining good soil structure through adding organic matter or calcium based soil amendments.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Are you aware of any withholding periods needed after irrigating with recycled water?	Generally, the higher the treatment level of recycled water the lesser the requirement for withholding periods. Your water supplier should specify if there are any withholding period requirements between the irrigation application and marketing of the produce.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up

7. FERTILISATION AND NUTRIENT MANAGEMENT

It is important to get the nutrient balance right. This will ensure crop productivity is not affected by under-supply (deficiency) or oversupply (toxicity) of essential nutrients. A sound nutrient management plan can provide significant advantages in crop yield and quality. The use of recycled water adds another dimension to crop nutrient management plans as most recycled waters contain nutrients – in some cases, more than plant or fertilisation requirement. A comprehensive nutrient plan will consider soil fertility, crop requirement and removal, nutrient content of recycled water, crop rotation and potential losses through volatilisation, leaching or run-off.

Question/Issue	Guidance/Comment	Your Checklist
Do you have access to information on the nutrient content of recycled water?	Your supplier can provide you with the water analysis results including the concentration of plant nutrients. Some schemes could be shandying recycled water with other water sources (e.g. river, potable) to lower the salinity levels. Shandying would also affect the nutrient content, so use caution when interpreting water analysis results.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Will the use of recycled water result in over-fertilisation?	Using recycled water during a crop growth cycle may lead to an excessive supply of nutrients and subsequently affect the crop and soil. As plant requirements change the application of nutrients also needs to change. When using recycled water it is possible to dilute nutrient content by mixing with other sources of water with low or no nutrients during periods when there is a demand for water but not for additional nutrients.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up
Have you developed a nutrient plan for your crops?	A nutrient plan contains information on when, how and what nutrients need to be applied. Application rates will depend on soil fertility status and crop requirements. Soil analysis is a valuable technical tool that provides information on the ability of the soil to supply nutrients to the crop and is invaluable in planning and assessing fertilisation programs. The analysis will also provide information required for crop selection. Setting realistic yield targets is also important as it helps to define the total nutrient requirement of a crop. This is done in conjunction with gross margin analysis to identify highest profitability. While it is possible to achieve high yield, it may come at significant costs. A nutrient plan will consider current soil nutrient status, all the inputs (e.g. fertilisers, soil amendments, recycled water), removal (e.g. crop uptake, losses through leaching and erosion) and the balance (remaining in the soil). Your agronomic advisor will be able to assist you in developing a crop nutrient plan.	☐ Not applicable ☐ Strategy in place ☐ Need to follow up

8. FURTHER INFORMATION

NATIONAL RECYCLED WATER GUIDELINES

ANZECC & ARMCANZ, NHMRC (2000) Guidelines for sewerage systems: Use of reclaimed water. NWQMS.

www.deh.gov.au/water/quality/nwqms/index.html

NRMMC, EPHC (2005) National Guidelines for Water Recycling. Managing Health and Environmental Risks. Draft for public consultation.

www.ephc.gov.au/ephc/water_recycling.html

Guidelines for developing recycled water schemes in horticulture 2005

www.daff.gov.au/corporate_docs/publications/pdf/nrm/water/water_use_recycling_hort_guidelines_june_05.pdf

STATE RECYCLED/RECLAIMED WATER USE GUIDELINES

NSW	www.environment.nsw.gov.au/water/effluent.htm
Qld	www.epa.qld.gov.au/environmental_management/water/queensland_water_recycling_guidelines
SA	www.environment.sa.gov.au/epa/pdfs/recycled.pdf
Tas	www.dpiwe.tas.gov.au/inter.nsf/WebPages/CDAT-5JV3TW?open
Vic	http://epanote2.epa.vic.gov.au/EPA/Publications.nsf/PubDocsLU/464.2?OpenDocument
ACT	No guidelines available
WA	No guidelines available
NT	No guidelines available

WEBSITES FOR MORE INFORMATION ON RECYCLED WATER

Coordinator Recycled Water Development in Horticulture	www.recycledwater.com.au
CRC for Water Quality and Treatment	www.waterquality.crc.org.au
Department of Environment and Heritage	www.deh.gov.au
Australian Heritage Commission	www.ahc.gov.au
Murray Darling Basin Commission	www.mdbc.gov.au
Department of Agriculture, Fisheries and Forestry	www.daff.gov.au
Environmental Protection and Heritage Council	www.ephc.gov.au
ATSE Water Recycling Report	www.atse.org.au/index.php?sectionid=597
National Program for Sustainable Irrigation	www.npsi.gov.au

Further information continued

QUALITY ASSURANCE SCHEMES AND GUIDELINES

Freshcare Code of Practice - www.freshcare.com.au/directory/shop.asp?site=303

Australian Certified Organic, Organic Standard - www.australianorganic.com.au

NASAA Organic Standard
www.nasaa.com.au/data/pdfs/AAA%20NASAA%20Organic%20Standard%20Dec%202004.pdf

National Standard for Organic and Bio-dynamic Produce
www.affa.gov.au/corporate_docs/publications/pdf/quarantine/national_standards.pdf

AS/NZS ISO 9001:2000 Quality Management Systems – Requirements
www.saiglobal.com/shop/Script/Details.asp?DocN=AS093043904986

AS/NZS ISO 14001:1996 Environmental Management Systems – General Guidelines on principles, systems and supporting techniques
www.saiglobal.com/shop/Script/Details.asp?DocN=AS0733764061AT

British Retail Consortium Global Standard Food - www.brc.org.uk/standards/about_food.htm

EurepGAP - www.eurepgap.org/Languages/English/index_html

SQF 2000 Code - www.sqfi.com/documentation/SQF2000_Code.pdf

SQF 1000 Code - www.sqfi.com/documentation/SQF1000_Code.pdf

Guidelines for On-Farm Food Safety for Fresh Produce 2004
www.horticulture.com.au/docs/publications/Guidelines_for_On_Farm_Food_Safety_for_Fresh_Produce_Second_Edition.pdf

Guidelines for the Management of Microbial Food Safety in Fruit Packing Houses
www.agric.wa.gov.au/pls/portal30/docs/FOLDER/IKMP/HORT/FN/PW/BULL4567.PDF

EnviroVeg Program - www.enviroveg.org

NIASA Best Practice Guidelines - www.ngia.com.au/publication_resources/overview.asp

Guidelines for Environmental Assurance in Australian Horticulture 2006, Horticulture Australia Limited
www.horticulturefortomorrow.com.au

ISO 22000:2005 Food Safety Management System
www.iso.org/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=35466&ICS1=67&ICS2=20&ICS3=&scopelist=