

Overview of Public Health & Environmental Aspects of Recycled Water - II

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OVERVIEW

PART A Recap recycled water framework, key concepts, terminology & Bolivar system analysis

PART B Consolidation of recycled water public health aspects

PART C Recycled water environmental aspects

PART D Aquifer aspects



PART A

Recap of recycled water framework, key concepts, terminology, & Bolivar system analysis



Recap - The "framework" for management of water quality & use

Figure 1.1 Elements of the framework for management of recycled water quality and use





Recap - key concepts & terminology

- Hazard
- Hazardous event
- Pathogen Log Reduction Value (LRV)
- Preventive measure
- Critical control point (CCP)
- Multiple-barrier
- Risk management



Bolivar system analysis & management (element 2)

- 1. Define Bolivar system configuration (current)
- 2. Source of recycled water, intended uses, receiving environments & routes of exposure (current & considering MAR)
- 3. Recycled water system components (current & considering MAR)
- 4. Assessment of water quality data & available information
- 5. Hazard identification (for human health, environment)



Wednesday, 13 Jan 2016

Figure 2 Location of Bolivar ASR trial site near the Northern Adelaide Plains horticultural area (from Barry et al., 2009).



Bolivar system configuration

- **Current:** Treat sewage via the Bolivar WWTP & RWTP & it gets distributed via the VPS distribution network to growers & commercial food crops are grown.
- **Research on Managed Aquifer Recharge:** Bolivar Aquifer Storage & Recovery whereby recycled water was injected & recovered from the confined tertiary 2 limestone aquifer



Figure 3 Location of wells and piezometers at the Bolivar site. The red dot represents the T2 ASR production well (#18777), the orange dot is the T2 observation well at 4 m (#19450), the yellow dot targets the T1 aquifer well (#19179), the white dots are T2 piezometers at 50 m, and green dots are observation wells at 75 m 120 m and 300 m (from Barry *et al.* 2009)



Source of recycled water, intended uses, receiving environments & routes of exposure

Source of recycled water: sewage – Salisbury & Adelaide trunk mains *Current use: commercial food crop* irrigation in Northern Adelaide Plains

• Current treatment & supply: via Bolivar WWTP & RWTP & VPS

Future use: commercial food crop irrigation

• NAIS processes & storage options in development



Endpoints & routes of exposure to recycled water

Current human endpoint

- 1. Crop consumption
- 2. Accidental ingestion: of recycled water (as aerosol inhalation) due to irrigation via sprinklers:
 - By growers/irrigators
 - By local communities
- Accidental consumption: due to cross-connection of pipelines



Endpoints & routes of exposure to recycled water

Environmental endpoints

- 1. Irrigated crops via sprinklers/spray
- Crops currently grown in VPS area include): Broad acre, Glasshouse & Perennial (from Marks & Boon, 2005)
- 2. Soil beneath the irrigated crops
- Five soil types in the NAP: ranging from loamy sands to medium clay (from Stevens *et al.*, 2003)
- 3. Storage aquifer receiving the recycled water
- Ensuring the protection of the *beneficial uses* & *environmental values* of the aquifer is paramount.



Bolivar recycled water process





Recycled water system components





Available information to inform risk assessment

- Water quality data from routine program
- Process performance
- Research investigations
- Previous incidents & effectiveness of corrective responses



Current Bolivar water quality sampling points



Sewage SP4001 (composite sampler) for chemical





Current Bolivar water quality sampling points



Recycled water SP6373 (grab tap) for microbiological SP6374 (composite sampler) for chemical





Current Bolivar routine water quality sampling program

Table 20 Summary of routine verification monitoring activities

| Location | Parameters | Frequency |
|-----------------|--|--------------------|
| Lagoon influent | Nitrogen - Ammonia | Daily |
| (SP4004) | Biochemical Oxygen Demand | 6-daily |
| | Suspended Solids | |
| | рн | |
| | Nitrogen - TKN, Oxidised | |
| | Phosphorus | |
| | Chemical Oxygen Demand | 12-daily |
| | Alkalinity | |
| | Protozoa | 7-daily (Dec-Mar) |
| | | 14-daily (Apr-Nov) |
| Lagoon effluent | Biochemical Oxygen Demandmust & coldal | 6-daily |
| (SP4007) | pH | |
| | Conductivity | |
| | Total Dissolved Solids | |
| | Dissolved Oxygen | |
| | Nitrozen – Ammonia, TKN, Oxidised | |
| | E. coli | Weekly |
| | Phosphorus | 12-daily |
| | Alkalinity | |
| | Chemical Ovvren Demand | 24-daily |
| | Suspended Solids | 24 Guly |
| | Temperatura | |
| | Colour | |
| | Table | |
| | Cations - Ca. Mar. K. Na | |
| | Calibrate | |
| | Natala Al Sh Ar Ba B Cd Cr Ca Cu Fa Bh Li Ma Ma Ma Ma | |
| | Metals - Al, So, Ar, Be, B, Co, Cr, Co, Cu, Fe, Po, Li, Min, Hg, Mo, Ni, | |
| | Se, Ag, In, Sn, Va, Zh | 20.4-24 |
| | Chloride | 28-delly |
| | Herbicides, Pesticides, Volatile Organic Compounds, Halogenated | Yearly |
| | Phenois, Poly Aromatic Hydrocarbons, Cyanide, PCBs | |
| DAFF raw water | Algal Count | 7-daily |
| (SP6363) | | |
| DAFF recycled | E. coli | 7-daily |
| product water | Chlorine | |
| (SP6374) | Algal Count | |
| DAFF recycled | Biochemical Oxygen Demand (Total) | 6-daily |
| product water | Nitrogen- TKN, Oxidised Nitrogen | |
| (SP6373) | рн | 28-daily |
| | Phosphorus | |
| | Cations - Ca, Mg, K, Na | |
| | Anions - Cl', Fl | |
| | Alkalinity | |
| | Sodium Adsorption Ratio | |
| | Metals - Al, Sb, Ar, Be, Ba, B, Cd, Cr _(total & VI) , Co, Cu, Fe, Pb, Li, Mn, | |
| | Hg, Mo, Ni, Se, Ag, Th, Sn, Va, Zn | |
| | Herbicides, Pesticides, Volatile Organic Compounds, Halogenated | Yearly |
| | Phenols, Poly Aromatic Hydrocarbons, Cyanide, PCBs | |

APPENDIX A

Monitoring of Chemical Quality of Product Water from the DAFF Plant

| Parameter | Frequency of Testing | Criteria |
|---------------------------|----------------------|-------------------------|
| soluble BOD _o | Weekly | 20 mg/L |
| Arsenic | Monthly | 0.1 nig/L |
| Barium | Monthly | 1.0 mg/L |
| Beryllium | Monthly | 0.1 mg/l |
| Boron | Monthly | 4.0 mg/L |
| Cadmium | Monthly | 0.01 mg/L |
| Chromium | Monthly | 1.0 mg/L |
| Chromium VI | Monthly | (0.1 mg/L |
| Cobalt | Monthly | 0.05 mg/L |
| Load | Monthly | 0.2 mg/L |
| Manganese | Monthly | 2.0 mg/L |
| Mercury | Monshiy | 0.002 mg/L |
| Malybdenum | Monthly | 0.05 mg/L |
| Nickel | Monthly | 0.2 mg/L |
| Selenium | Monthly | 0.01 mg/l. |
| Total Cyanide | Yearly | 0.05 mg/L |
| Polychlorinated Biphenyls | Yearly | 0.5 μg/L |
| Total Herbicides | 3 Monthly | Limit of quantification |
| atrazino | • | 0.5 µg/L |
| ^I simazine | | 0.5 µg/L |
| Total Insecticides | Yearly | Limit of quantification |
| _r ondosulfan | _ | 0.5 μg/L |
| chlorpyrifos | | 0.5 µg/L |



Today: raw data & 5 year statistical analysis (2010-15)

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Hazard identification

- Risk assessment considers the approach outlined in the AGWR (2006)
- Need to compare water quality to the relevant public health and environmental guideline.
- Need to determine Maximal risk = risk if untreated sewage was supplied to growers directly or in the case of a MAR scheme, was injected into an aquifer & also supplied to growers
- Need to determine Residual risk assessment = risk which includes the preventive measures/ multiple barriers of the system: WWTP (primary & secondary treatment), lagoons, RWTP (media filtration, chlorine disinfection).

*for chemical parameters, compare *mean value* to the guideline for each of the different endpoints

• Need to also consider the likelihood & consequence of the risk & hazardous events.



Potential hazards in sewage

Table 2.2 Potential hazards found in sewage

| Classification | Examples of constituents | | | | | | | |
|----------------------|---|--|--|--|--|--|--|--|
| Conventional | Suspended solids | | | | | | | |
| | Biochemical oxygen demand | | | | | | | |
| | Total organic carbon | | | | | | | |
| | Ammonia, nitrate, nitrite, total nitrogen | | | | | | | |
| | Phosphorus | | | | | | | |
| | Metals | | | | | | | |
| | Surfactants | | | | | | | |
| | Organic chemicals | | | | | | | |
| | Pesticides | | | | | | | |
| | Total dissolved solids/salinity | | | | | | | |
| | Bacteria | | | | | | | |
| | Helminths | | | | | | | |
| | Protozoa | | | | | | | |
| | Viruses | | | | | | | |
| Emerging | Prescription and non-prescription drugs — antipyretic, antibiotics, antacids, anti- | | | | | | | |
| | inflammatory, etc | | | | | | | |
| | Home care products | | | | | | | |
| | Veterinary and human antibiotics | | | | | | | |
| | Industrial and household products | | | | | | | |
| | Sex and steroidal hormones | | | | | | | |
| | Other endocrine disrupters (hormonally active agents) | | | | | | | |
| | Water disinfection byproducts — N-nitrosodimethylamine (NDMA) | | | | | | | |
| Source: Adapted from | Tchobanoglous et al (2003) | | | | | | | |



PART B CONSOLIDATION OF PUBLIC HEALTH ASPECTS



Key guidelines – to assess water quality & public health





Pathogens: Commercial food crops & health based targets







anaging health risks in recycled w

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| Table 3.8 (| continued) | \frown | | | |
|---|---|---|--|---|---|
| Log reduction targets (V, P, B)* | Indicative treatment process | Log reductions achievable by treatment (V, P, P) | On-site preventive measures | Expo- sure reduct- ion ^b | Water quality objectives ⁶ |
| Landscape | irrigation — trees, shrubs, public gar | dens, etc | | | |
| 5.0 3.5 4.0 | Secondary treatment or primary treatment with lagoon detention | 0.5–2.0 0.5–2.0 1.0–3.0 | Combinations of: • microspray • drip irrigation • no mubic access | 2.0 4.0 | BOD <20 mg/L^d SS <30 mg/L^d <i>E. coli</i> <1000 cfu/100 mL (if not disinfected) |
| Commercia | al food crops consumed raw or unproc | eved | - no public access | 5.0 | |
| 6.0 5.0 5.0 | Advanced treatment to achieve total pathogen removal required (eg secondary, filtration and disinfection) | 6.0 5.0 5.0 | None required, although pathogen reduction will occur between harvesting and sale The recycled water can be used for all crop applications, including spray irrigation of salad crops | 0.5 V, B | To be determined on case-by-case basis, depending on technologies Could include turbidity criteria for filtration, disinfectant Ct or dose (UV) <i>E. coli</i> <1 per 100 mL |
| Commercia | al food crops | | | | |
| 6.0 5.0 5.0 | a root rops Secondary treatment with >25 days lagoon detention and disinfection | 3.0-4.0 2.0-4.0 >6.0 | Consumers Crops with limited or no ground contact and eaten raw (eg tomatoes, capsicums)— drip irrigation and no harvest of wet or dropped produce Crops with ground contact with skins removed before consumption (eg watermelons)— if spray irrigation, minimum 2 days between final irrigation and harvest Pathogen reduction between harvesting and sale Public in vicinity of irrigation area No access and drip or subsurface irrigation No access during irrigation and if spray | 3.0 3.0-4.0 0.5/ day V, B 6.0 4.0 | BOD <20 mg/L⁴ SS <30 mg/L⁴ Disinfectant residual (eg minimum chlorine residual) or UV dose^a <i>E. coli</i> <100 cfu/100 mL |

e Aim is to demonstrate reliability of disinfection and ability to consistently achieve microbial quality f Log reductions for public in the vicinity of commercial food crop irrigation areas should comply with total log reductions required for municipal use.



Pathogens: Bolivar – validation research on removal

- Adelaide metro WWTP (Bolivar, Glenelg, Christies): protozoa & virus removal (Keegan, 2009)
- Bolivar WWTP: protozoa & virus removal (Keegan & Wati, 2012)
- Bolivar stabilisation lagoons: virus & protozoa removal (Keegan, 2010)
- Bolivar DAFF reuse plant: challenge testing with Bakers yeast for protozoa, MS-2 for viruses (Keegan, 2009)
- Chlorination/ chloramination (*C.t*): virus inactivation
 @ different pH, turbidity (Keegan *et al.*, 2012)
- Protozoa: *Cryptosporidium* infectivity (King *et al.*, 2015)







Pathogens: Bolivar health based targets

| Barrier/ process | Virus | Protozoa | Bacteria |
|-------------------------------|-------|----------|----------|
| Primary & secondary treatment | 2.0 | 1.0 | 1.0 |
| Lagoons | 1.5 | 2.0 | 2.0 |
| DAFF: coagulation/filtration | 0.5 | 2.0 | 1.0 |
| Chlorine disinfection | 2.0 | 0.0 | 2.0 |
| Total | 6.0 | 5.0 | 6.0 |
| Consumers of produce | 6.0 | 5.0 | 5.0 |
| Public in the vicinity | 5.0 | 3.5 | 4.0 |

1 log = 90% 2 log = 99% 3 log = 99.9% 4 log = 99.99% 5 log = 99.999% 6 log = 99.999%









Bolivar-VPS DHA supply approval (e.g. filter performance)

- 7. The target turbidity of the product water from the DAFF plant in the filtered water duct should be less than 0.5 NTU and the product water turbidity must be less than 1 NTU measured as a daily arithmetic mean. If the turbidity exceeds 5 NTU for more than 60 minutes the product water is to be diverted and not supplied to the Virginia Pipeline Scheme until the turbidity is reduced below 5 NTU.
- 8. Turbidity of the product water will be monitored continuously in the filtered water duct. Turbidity of effluent produced by all individual filters will be monitored continually with the interval between turbidity measurements on any single filter unit not exceeding 45 minutes when the filter is in operation. Monitoring results will be available as direct readouts and will be recorded and stored.



Bolivar recycled water scheme operating plan

SAWater Allwater

Allwater Do. No.: TMD-5026-OP-0088 Title: Bolivar Recycled Water Water Quality Operating Plan Document Type: RWOMS - WOOP

| Area | Critical Control | Measurement of Critical | Parameter | Sample Point | Health Limit / SPI/IM | Guideline System | Indicative value at | 9 | SCADA ala | rm set-poir | nt | Вура | is trigger | Shutdown trigger | | Incident Notification Category | Operational Response to Operational target deviation/CCP critical |
|---------------------|------------------------------|--|-----------------------|---|--|---------------------|------------------------|------|-----------|--------------------------|-----------------------------|------|---------------------|------------------|---|--|--|
| | | Control Point | | | (Critical limit) | Target | system target | LoLo | Lo | Hi | HiHi | LoLo | HiHi | LoLo | HiHi | 1 | |
| | | Effluent ammonia | Ammonia | Lagoon influent (Daily composite sample SP4004) | SPI: Annual median ≤ 1.0 mg/L; 95% of sample ≤ 2 mg/L | 0.2-1 mg/L | | | | | | | | | | SPI at risk When lagoon influent ammonia is > 1 mg/L under normal operational condition. | Check aeration system/MLSS Messure D0 at outlet of each basin Messure D0 profile of proslime masin Advise supervisor of outcome and increase D0 set points if necessary Change swing some back to seration if necessary |
| | | Effluent SS | 55 | Lagoon influent (Daily composite sample SP4004) | SPI: Annual median ≤ 30 mg/L | <30 mg/L | | | | | | | | | | SPI at risk When lagoon influent SS is > 30 mg/L under normal operational condition. | Check it carry over occurs at SSTs during high flow Check RAS pump operation normal Check and adjust SST distribution valve position if necessary Advise supervisor and adjust wasting if MLSS too high Advise supervisor it wasting is infinited by studge process |
| | Stabilisation lagoons | Total area of online lagoons | Lagoon area | Stabilisation lagoon | | > 220 ha | | | | | | | | | | Type 2 Incident When lagoon areas < 220 ha. | Ensure at least Lagoon 1,2,3 are online |
| | Flocculation /coagulation | Floc formation visual inspection | Floc size | Mixing chambers and flocculation bays | | | | | | | | | | | | | Investigate & rectify any chemical dosing faults Investigate & rectify any flocculator faults Undertake jar test & adjust chemical dosing if necessary. |
| | Floatation | Individual floated turbidity | Turbidity | Individual online floated turbidity meter | | < 5 NTU | | | | | | | | | | | Investigate & rectify any chemical dosing faults Investigate & rectify any flocculator faults Undertake jar test & adjust chemical dosing if necessary. |
| | | Individual filtered turbidity | Filtered turbidity | Individual filtered turbidity meter | SPI: 95% of time in each month must ≤ 0.5 NTU | < 0.5 NTU | | | | | | | | | | SPI at risk When individual filter turbidity is > 0.5 NTU. | Flushing turbidity meter if sample flow is low Review floated turbidity, if > 10 NTU, check and rectify blockage in poly doing line if necessary Review filter DP, initiate filter backwash, reduce filter run tim |
| St Kilda DAFF RWITP | Fitration | Combined fittrate turbidity | Turbidity | Onine FWD turbidity meter | Daily average turbidity > 1NTU or Online turbidity > 5 NTU continuously for > 60 min and production is not stopped. SPI: Daily average 60.3 NTU for 93.0% of days of a contract year | 0.3-0.3 NTU | | | | 0.5 NTU (15 min) | 0.3 NTU (30 min) | | 0.5 NTU (30 min) | | SCADA: 4.5 NTU (immedia tely) CPS: 10 NTU (immedia tely) | WQ Type 1 incident When daily average turbiolity > StrU or Online turbiolity > 3 MU continuously for > 60 min and production is not stopped. WQ Type 2 incident When production stopped due to high fibered water tuobify (other tuna Type 1 incident) SPI at risk When FWD turbidity(s > 0.3 MTU. | National and the set of the |
| | рН | Product water pH | рн | Online meter end of Contact Channel | 6-8.5 (Srice).08 any day of a Contract Year, pH must be between 6 and 8.5.) | 6-8.5 | | 6.1 | 5 | • | a.+ | | | | | When product pH is < 6 or >8.3 under normal operational condition. | Verity online analyzer reading by grab sample test, initiate calibration of meter if necessary If pit deviation is low advice supervisor and adjust chemical dosing if possible without compromising treated water turbidity |
| | TDS | Product water TDS | TDS | Online meter at end of Contact Channel | <1500 mg/L (SPI: 99.0% of any day of a Contract Year, TDS must be < 1500 mg/L) | < 1200 mg/L | | | | 1200 mg/L (60 min) | 1450 mg/L (15 min) | | | | | SPI at risk When product TDS is >1300 mg/L under normal operational condition. | Product water TDS trend should be monitored and trending u above 1200 mg/l. should be noted and advise supervisor Automatic diution should occur on SCADA alam (hi) (this currently does not work) Notify supervisor and reinstate dilution if triesered. |



DAFF filter performance - turbidity







Bolivar recycled water - E. coli (verification)



DHA approval monthly median <1 /100 mL A/C Type 1 incident: >10/100 mL A/C Type 2 incident: >4/100 mL A/C





Chemicals: Commercial food crops & Public health

Refer to AGWR (2006) section 3.5.4

Analyses of treated recycled water and associated water recycling schemes indicate that chemical quality generally complies with drinking water quality requirements for most parameters, including heavy metals, organic chemicals, pesticides and disinfection byproducts (NRC 1996, NRC 1998, USEPA 2004). This is confirmed by unpublished Australian data, which show the following:

 Average concentrations of nutrients, metals and trihalomethanes (THMs — produced as byproducts of disinfection) in filtered and chlorinated water from the Virginia Pipeline Scheme in South Australia essentially conform with ADWG values. Concentrations of pesticides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), general organics and non-THM disinfection byproducts were largely below levels of detection. Nitrogen occasionally exceeded ADWG values, but nitrogen is a nutrient for which there is a recommended upper limit but no guideline value.



Go to excel spreadsheet

| | | | | | | - | | | | | | | | 4 |
|----------------------------|--------|--------|-----|---------|---------|---------|-----------|--------------|------------|----------|---------|---------|---------------------|--------|
| Parameter | Unit | LOR | n | min | max | mean | period | source | ADWG | LTV irri | STV irr | DHA | GW ret | GW ref |
| | | | | | | | | | 110.5 | ANZECC | ANZECC | Bolivar | CSIRO | Gawler |
| Physical characteristics | - 1 | | | | | | | | | | | | | |
| Conductivity | uS/cm | 0.001 | 231 | 1540 | 2960 | 2062 | 2010-2015 | SAW routine | | 650 | 650 | | 3700 | |
| Dissolved oxygen | mg/L | 0.1 | | | | | 2010-2015 | SAW routine | | | | | 0.3 | |
| pH | | 0.1 | 245 | 6.7 | 7.5 | 7.2 | 2010-2015 | SAW routine | 6.5-8.5a | 6-8.5 | 6-8.5 | | 7 | |
| Suspended solids | mg/L | 0.1 | 260 | 34 | 860 | 405 | 2010-2015 | SAW routine | | | | | 5 | |
| Total dissolved solids | mg/L | 1 | 231 | 850 | 1600 | 1136 | 2010-2015 | SAW routine | 600a | | | | 2009 | |
| Major ions and SAR | | | | | | | | | | | | | | |
| Alkalinity as CaCO3 | | | | | | | | | | | | | | |
| Potassium | mg/L | | 1 | 28.6 | 28.6 | 28.6 | 2010-2015 | SAW routine | | | | | | |
| Sulphate | mg/L | | 24 | 95.4 | 534.0 | 132.9 | 2010-2015 | SAW routine | 250a | | | | | |
| Microbiological | | | | | | | | | | | | | | |
| Cryptosporidium | | | | | | | | SAW routine | | | | | | |
| Giardia | | | | | | | | SAW routine | | | | | | |
| Nutrients | | | | | | | | SAW routine | | | | | | |
| Ammonia | mg/L | 0.005 | 244 | 27.6 | 57.3 | 44.2 | 2010-2015 | SAW routine | 0.5a | 5 | 25-125 | | 0.06 | |
| BOD | mg/L | 2 | 182 | 134 | 740 | 326 | 2010-2015 | SAW routine | | | | 20 | | |
| COD | mg/L | 50 | 203 | 255 | 1590 | 803 | 2010-2015 | SAW routine | | | | | | |
| Phosphorous - total | mg/L | 0.005 | 117 | 1 | 29 | 11 | 2010-2015 | SAW routine | | 0.05 | 0.8-12 | | 0.024 | |
| TKN | mg/L | 0.05 | 286 | 46 | 111 | 72 | 2010-2015 | SAW routine | | | | | 0.064 | |
| TN | mg/I | | 126 | 50 | 111 | 72 | 2010-2015 | SAW routine | | | | | | |
| Nitrate | mg/I | | | | | | | SAW routine | 50 | | | | | |
| Nitrite | mg/L | | | | | | | SAW routine | 3 | | | | | |
| Metals metalloids halogens | | | | | | | | Sitt routine | , | | | | | |
| Aluminium total | ma/I | 0.005 | 50 | 0.5 | 17.6 | 7 2 | 2010-2015 | SAW routine | 0.2 | 5.0 | 20.0 | | 0.0 | |
| Antimony total | mg/L | 0.0005 | 60 | 0.0005 | 0.0022 | 0.0007 | 2010-2015 | SAW routine | 0.002 | 5.0 | 20.0 | | 0.0 | |
| | mg/L | 0.0003 | 00 | 0.0003 | 0.0022 | 0.0007 | 2010-2013 | SAW routine | 0.003 | 0.1 | 2 | 0.1 | 0.0047 | |
| Arsenic total | mg/L | 0.0005 | 60 | 0.0008 | 0.0042 | 0.0022 | 2010-2015 | SAW routine | 0.01 | 0.1 | 2 | 0.1 | 0.0047 | |
| Barium total | mg/L | 0.0005 | | | | | 2010-2015 | SAW routine | 2 | | | 1 | | |
| Beryllium soluble | mg/L | 0.0005 | 60 | 0.0002 | 0.0003 | 0.0003 | 2010-2015 | SAW routine | 0.06 | 0.1 | 0.5 | 0.1 | | |
| Beryinum totai | mg/L | 0.0005 | 60 | 0.0003 | 0.0003 | 0.0003 | 2010-2015 | SAW routine | 0.06 | 0.1 | 0.5 | 0.1 | 0.44 | |
| Boron soluble | mg/L | 0.04 | 60 | 0.16 | 1.39 | 0.35 | 2010-2015 | SAW routine | 4 | 0.5 | 0.5 | 4 | 0.11 | |
| Cadmium total | mg/L | 0.0002 | 60 | 0.00010 | 0.00100 | 0.00034 | 2010-2015 | SAW routine | 0.002 | 0.01 | 0.05 | 0.01 | <0.0002 | |
| Chromium total | mg/L | 0.003 | 60 | 0.002 | 0.082 | 0.008 | 2010-2015 | SAW routine | 0.05 | | | 1 | < 0.03 | |
| Cobalt total | mg/L | 0.0005 | 60 | 0.0005 | 0.0016 | 0.0011 | 2010-2015 | SAW routine | | 0.05 | 0.1 | 0.05 | | |
| Copper total | mg/L | 0.001 | 60 | 0.04 | 0.21 | 0.11 | 2010-2015 | SAW routine | 1 to 2 | 0.2 | 5 | | < 0.03 ⁵ | |
| Iron total | mg/L | 0.03 | 60 | 0.6 | 3.0 | 1.5 | 2010-2015 | SAW routine | 0.3a | 0.2 | 10 | | 1.3 | |
| Lead total | mg/L | 0.0005 | 60 | 0.0064 | 0.0378 | 0.0154 | 2010-2015 | SAW routine | 0.01 | 2 | 5 | 0.2 | < 0.001 | |
| Lithium total | mg/L | 0.001 | 60 | 0.0057 | 0.0429 | 0.0087 | 2010-2015 | SAW routine | | 2.5 | 2.5 | | <0.01 | |
| Manganese total | mg/L | 0.0005 | 60 | 0.08 | 0.19 | 0.11 | 2010-2015 | SAW routine | 0.1 to 0.5 | 0.2 | 10 | 2 | 0.05 | |
| Mercury total | mg/L | 0.0005 | 60 | 0.0000 | 0.0013 | 0.0002 | 2010-2015 | SAW routine | 0.001 | 0.002 | 0.002 | 0.002 | < 0.0003 | |
| Molybdeum total | mg/L | 0.0005 | 60 | 0.0023 | 0.0144 | 0.0057 | 2010-2015 | SAW routine | 0.05 | 0.01 | 0.05 | 0.05 | | |
| Nickel total | mg/L | 0.0005 | 60 | 0.0045 | 0.0198 | 0.0086 | 2010-2015 | SAW routine | 0.02 | 0.2 | 2 | 0.2 | 0.0011 | |
| Selenium total | mg/L | 0.003 | 60 | 0.0001 | 0.0096 | 0.0035 | 2010-2015 | SAW routine | 0.01 | 0.02 | 0.05 | 0.01 | | |
| Silvertotal | mg/L | 0.0002 | 60 | 0.0001 | 0.0032 | 0.0009 | 2010-2015 | SAW routine | 0.1 | | | | | |
| Thallium total | mg/L | 0.0005 | 60 | 0.0001 | 0.0004 | 0.0001 | 2010-2015 | SAW routine | | | | | | |
| Tin total | mg/L | 0.0005 | 60 | 0.0028 | 0.0096 | 0.0061 | 2010-2015 | SAW routine | | | | | | |
| Vandadium total | mg/L | 0.003 | 48 | 0.0001 | 0.0191 | 0.0064 | 2010-2015 | SAW routine | | 0.1 | 0.5 | | | |
| Zinc total | mg/L | 0.003 | 60 | 0,10 | 0,24 | 0.15 | 2010-2015 | SAW routine | 3a | 2 | 5 | | 0.042 | |
| Organic compounds | - 10 | 2.235 | | | | | | | 50 | - | | | | |
| Phenols | mg/I | 0.01 | 58 | 0.01 | 0.23 | 0.08 | 2010-2015 | SAW routine | | | | | | |
| Other | | 0.01 | 30 | 0.01 | 0.23 | 0.00 | 2010-2015 | e routine | | | | | | |
| Oranide total | ma/I | 0.05 | 58 | 0.05 | 0.05 | 0.05 | 2010-2015 | SAW routine | | | | | | |
| Greace | ma/I | 0.03 | 57 | 0.03 | 150 | 0.05 | 2010-2015 | SAW routing | | | | | | |
| MED | 1118/L | 1 | 24 | 32 | 159 | /4 | 2010-2015 | SAW routine | | | | | | |
| IVIED | | | 54 | 2.2 | 7.9 | 4.8 | 2010-2015 | SHW TOULINE | | | | | | |



Emerging chemicals

- E.g. Endocrine disrupting chemicals (Holmes *et al.,* 2010)
 - Sampled non-estrogen indicator EDCs (nonyl phenol mono- & diethoxylates, 4-t-octylphenol, 4-nonyl phenol, bisphenol (plasticizer) & estrogens (17 β-estradiol, estrone, 17-α-ethynylestradiol)
 - Bioassay (yeast screen assay)
 - Estradiol equivalence (EEq) conc provides an indication of overall estrogenic potency, Bolivar WWT reduces EEq by 97%
- E.g. Disinfection by-products
 - Chlorine from disinfection reacts with organic matter to produce DBPs such as trihalomethanes (THMs) & haloacetic acids (HAAs)
 - Bolivar ASR measured in injectant, reduction in aquifer & none in recovery, not a concern for irrigation (Barry *et al.*, 2010)



Algae & cyanobacteria





| nytopiankton recorded in recyc | Phylon | Dedas | T and the |
|--|-------------------|-----------------|-----------------------|
| pecies | Phylum | Order | Family |
| . yclotella | Bacillariophyceae | Centrales | Coscinodis calceae |
| Cyclotella small_spp | Bacillariophyceae | Centrales | Coscinodis ca ceae |
| Navicula | Bacillariophyceae | Pennales | Naviculaceae |
| viteschia | Bacillariophyceae | Pennales | Nitzschladeae |
| Actino stru m | Chlorophyta | Chlorococcales | Scenedes maceae |
| Ankistrodesmus | Chiorophyta | Chlorococcales | Oocystaceae |
| Ankistrodesmus sp. 2 (small cells) | Chilorophyta | Chlorococcales | Oocystaceae |
| Ankyra | Chlorophyta | Chlorococcales | Chlorococcaecea e |
| Botryococcus | Chlorophyta | Chlorococcales | Dictyosphaerium |
| chlorella | Chlorophyta | Chlorococcales | Oocystaceae |
| oela stru m | Chlorophyta | Chlorococcales | Scenedes macea e |
| nidaenia | Chlorophyta | Chlorococcales | Scenedes macea e |
| Navgena | Chlorophyta | Chlorococcales | Dictiosobaecium |
| Dictriosphoerium en 7 (small cells) | Chlorophyta | Chlorococcales | Dictuosobaerium |
| Nayaspineenan sp <u>rr</u> ama (_a.is) | Chlorophyta | Chlorococcales | Dictiosobaeriaceae |
| lakatothrix | Chlorophyta | Chlorococcales | Coccomyxaceae |
| (irdineriella | Chlorophyta | Chlorococcales | Oocystaceae |
| Jocvstis | Chlorophyta | Chlorococcales | Ocystaceae |
| Docvstis sp. 2 (la rae œlls) | Chlorophyta | Chlorococcales | Oocystaceae |
| Jocvstis sp. 1. (small cells) | Chlorophyta | Chlorococcales | Oocystaceae |
| edia strum | Chlorophyta | Chlorococcales | Scenedes maceale |
| cenedesmus | Chlorophyta | Chlorococcales | Scenedesmaceae |
| nhaerocustis | Chlorophyta | Chlorococcales | Palmellaceae |
| Tetrastrum | Chlorophyta | Chlorococcales | Scenedes macea e |
| stero m acus | Chlorophyta | Tetrasporales | Asterococcus |
| tichococcus | Chlorophyta | Ulotrichales | Ulotrichaceae |
| Jothrix | Chlorophyta | Ulotrichales | Ulotrichaceae |
| hlamvdo mon as | Chlorophyta | Volvocales | chlamydo mon adacea e |
| losterium | Chlorophyta | Zvgnematales | Desmidiaceae |
| Vallomonas | Chrysophyta | Ochromomales | Synuraceae |
| Typtomona's | Cryptophyta | | Cryptomonadaceae |
| 1ph anocap sa | Cvanophyta | Chroococcales | Chroococcaceae |
| Alaro cystis aeruain osa | Cvanophyta | Chroococcales | Chroococcaceae |
| Miaro cystis flos-aa uae | Cvanophyta | Chroococcales | Chroococcaceae |
| ivnechocystis | Cvanophyta | Chroococcales | Chroococcaceae |
| hormidium broad son | Cvanophyta | Oscillatoriales | Oscillatoriaceae |
| lanktothrix | Cvanophyta | Oscillatoriales | Phormidia ceae |
| ualena | Euglenophyta | Euglenales | Euglenaceae |
| Throomonas | Cryptophyta | Cryptomonales | Cryptomonadaceae |
| tvana dictva n | Cvanophyta | Chroococcales | Synechococcaceae |
| Didvmocvstis | Chlorophyta | Chlorococcales | Scenedes macea e |
| Seltlerinema | Cvanophyta | Oscillatoriales | Phormidia ceae |
| vlonorap hidi um | Chlorophyta | Chlorococcales | Oocystaceae |
| Monoraphidium sp. 2. (short) | Chlorophyta | Chlorococcales | Oocystaceae |
| Planctonema | Chlorophyta | Ulotrichales | Ulotrichaceae |
| Pseudod idy mocystis | Chlorophyta | Chlorococcales | Scenedes macea e |
| faurosira | Chrysophyta | Pennales | Fraglariaceae |



Outcome - public health hazards

| Hazard | Sew Maxim | age Ial risk | Recycled water Residual risk | | | |
|--------------------------|---------------------|--|---------------------------------|-------------------------------------|--|--|
| | Crop consumption | Accidental aerosol inhalation | Crop consumption | Accidental aerosol inhalation | | |
| Pathogens | | | HBT met for 6, 5 | 5 , 5, <i>E. coli</i> | | |
| Inorganic chemicals | | Al> DW Fe> Aesth Pb> DW Mn> Aesth | Cl> Aesth Na> Aesth | | | |
| Salinity & sodicity | | TDS> Aesth | | TDS> Aesth | | |
| Nutrients | | NH ₄ > Aesth | | | | |
| Organic chemicals | | | | | | |
| Turbidity & particulates | | | | | | |



PART C ENVIRONMENTAL ASPECTS



Key issues in relation to irrigation water quality

Chapter 4 — Primary industries

| | Kan laana |
|--------------------|---|
| | Key Issues |
| Soll | Root zone salinity |
| | Soli structural stability |
| | Build-up of contaminants in soil |
| | Release of contaminants from soil to crops & pastures |
| Plants | Yield |
| | Salt tolerance |
| | Specific ion tolerance |
| | Follar injury |
| | Uptake of toxicants in produce for human consumption |
| | Contamination by pathogens |
| Water resources | Deep drainage & leaching below root zone |
| | Movement of saits, nutrients & contaminants to groundwaters & surface waters |
| Important | Quantity and seasonality of rainfall |
| associated factors | Soil properties |
| | Crop and pasture species and management options |
| | Land type |
| | Groundwater depth and quality |

Table 4.2.1 Key issues concerning irrigation water quality effects on soil, plants and water resources



Recycled water – key hazards for agriculture (crops & soil)

Table 4.2 Key environmental hazards, environmental endpoints and common effects on the environment when using recycled water for agricultural, municipal, residential and fire-control purposes

| Hazard | Environmental endpoint | Effect or impact on the environment |
|-----------------------|--|--|
| Boron | Accumulation in soil | Plant toxicity |
| Cadmium | A low risk with respect to c already in soils can be made increase. Chloride can be m section below). | admium concentrations in recycled water, but cadmium e more readily available to plants if chloride concentrations easured indirectly, but reliably, as salinity (see the salinity |
| Chlorine disinfection | Plants | Direct toxicity to plants |
| residuals | Surface waters | Toxicity to aquatic biota |
| Hydraulic loading | Soil | Waterlogging of plants |
| (water) | Groundwaters | Waterlogging of plants |
| | Groundwaters | Soil salinity (secondary) |
| Nitrogen | Soils | Nutrient imbalance in plants |
| | Soils | Pest and disease in plants |
| | Soils | Eutrophication of soils and effects on terrestrial biota |
| | Surface waters | Eutrophication |
| | Groundwaters | Contamination |
| Phosphorus | Soils | Eutrophication of soils and toxic effects on phosphorus |
| | | sensitive terrestrial biota (native plants) |
| | Surface waters | Eutrophication |
| Salinity | Infrastructure | Salinity may cause rising damp or corrosion of assets; this can also arise from excessive hydraulic load (secondary salinity) |
| | Soils | Plants stressed from osmotic affects of soil salinity |
| | Soils | Contamination of soils by increasing plant availability of cadmium that is already in the soil |
| | Surface water | Increasing the salinity of fresh groundwaters |
| | Groundwater | Increasing the salinity of fresh surface waters |
| Chloride | Plants | Direct toxicity to plants when sprayed on leaves |
| | Soils | Plant toxicity via uptake through the root |
| | Surface water | Toxicity to aquatic biota |
| Sodium | Plants | Direct toxicity to plants when sprayed on leaves |
| | Soils | Plant toxicity via uptake through the root |
| lan 2016 | Soils | Soil structure decline due to sodicity |

+

others as outlined in ANZECC & ARMCANZ (2000) for irrigation



Key guidelines - to assess water quality for environment (crops, soil)



ANZECC & ARMCANZ (2000) : Chapter 4: Primary industries Chapter 9: Irrigation & general use

LTV = Long term value, max conc of contaminant which can be tolerated for 100 years STV = short term value, max conc of contaminant which can be tolerated for 20 years Wednesday, 13 Jan 2016



Bolivar sewage

| | | | | | | - | | | | | | | | 4 |
|----------------------------|--------|--------|-----|---------|---------|---------|-----------|--------------|------------|----------|---------|---------|---------------------|--------|
| Parameter | Unit | LOR | n | min | max | mean | period | source | ADWG | LTV irri | STV irr | DHA | GW ret | GW ref |
| | | | | | | | | | 110.5 | ANZECC | ANZECC | Bolivar | CSIRO | Gawler |
| Physical characteristics | - 1 | | | | | | | | | | | | | |
| Conductivity | uS/cm | 0.001 | 231 | 1540 | 2960 | 2062 | 2010-2015 | SAW routine | | 650 | 650 | | 3700 | |
| Dissolved oxygen | mg/L | 0.1 | | | | | 2010-2015 | SAW routine | | | | | 0.3 | |
| pH | | 0.1 | 245 | 6.7 | 7.5 | 7.2 | 2010-2015 | SAW routine | 6.5-8.5a | 6-8.5 | 6-8.5 | | 7 | |
| Suspended solids | mg/L | 0.1 | 260 | 34 | 860 | 405 | 2010-2015 | SAW routine | | | | | 5 | |
| Total dissolved solids | mg/L | 1 | 231 | 850 | 1600 | 1136 | 2010-2015 | SAW routine | 600a | | | | 2009 | |
| Major ions and SAR | | | | | | | | | | | | | | |
| Alkalinity as CaCO3 | | | | | | | | | | | | | | |
| Potassium | mg/L | | 1 | 28.6 | 28.6 | 28.6 | 2010-2015 | SAW routine | | | | | | |
| Sulphate | mg/L | | 24 | 95.4 | 534.0 | 132.9 | 2010-2015 | SAW routine | 250a | | | | | |
| Microbiological | | | | | | | | | | | | | | |
| Cryptosporidium | | | | | | | | SAW routine | | | | | | |
| Giardia | | | | | | | | SAW routine | | | | | | |
| Nutrients | | | | | | | | SAW routine | | | | | | |
| Ammonia | mg/L | 0.005 | 244 | 27.6 | 57.3 | 44.2 | 2010-2015 | SAW routine | 0.5a | 5 | 25-125 | | 0.06 | |
| BOD | mg/L | 2 | 182 | 134 | 740 | 326 | 2010-2015 | SAW routine | | | | 20 | | |
| COD | mg/L | 50 | 203 | 255 | 1590 | 803 | 2010-2015 | SAW routine | | | | | | |
| Phosphorous - total | mg/L | 0.005 | 117 | 1 | 29 | 11 | 2010-2015 | SAW routine | | 0.05 | 0.8-12 | | 0.024 | |
| TKN | mg/L | 0.05 | 286 | 46 | 111 | 72 | 2010-2015 | SAW routine | | | | | 0.064 | |
| TN | mg/I | | 126 | 50 | 111 | 72 | 2010-2015 | SAW routine | | | | | | |
| Nitrate | mg/I | | | | | | | SAW routine | 50 | | | | | |
| Nitrite | mg/L | | | | | | | SAW routine | 3 | | | | | |
| Metals metalloids halogens | | | | | | | | Sitt routine | , | | | | | |
| Aluminium total | ma/I | 0.005 | 50 | 0.5 | 17.6 | 7 2 | 2010-2015 | SAW routine | 0.2 | 5.0 | 20.0 | | 0.0 | |
| Antimony total | mg/L | 0.0005 | 60 | 0.0005 | 0.0022 | 0.0007 | 2010-2015 | SAW routine | 0.002 | 5.0 | 20.0 | | 0.0 | |
| | mg/L | 0.0003 | 00 | 0.0003 | 0.0022 | 0.0007 | 2010-2013 | SAW routine | 0.003 | 0.1 | 2 | 0.1 | 0.0047 | |
| Arsenic total | mg/L | 0.0005 | 60 | 0.0008 | 0.0042 | 0.0022 | 2010-2015 | SAW routine | 0.01 | 0.1 | 2 | 0.1 | 0.0047 | |
| Barium total | mg/L | 0.0005 | | | | | 2010-2015 | SAW routine | 2 | | | 1 | | |
| Beryllium soluble | mg/L | 0.0005 | 60 | 0.0002 | 0.0003 | 0.0003 | 2010-2015 | SAW routine | 0.06 | 0.1 | 0.5 | 0.1 | | |
| Beryinum totai | mg/L | 0.0005 | 60 | 0.0003 | 0.0003 | 0.0003 | 2010-2015 | SAW routine | 0.06 | 0.1 | 0.5 | 0.1 | 0.44 | |
| Boron soluble | mg/L | 0.04 | 60 | 0.16 | 1.39 | 0.35 | 2010-2015 | SAW routine | 4 | 0.5 | 0.5 | 4 | 0.11 | |
| Cadmium total | mg/L | 0.0002 | 60 | 0.00010 | 0.00100 | 0.00034 | 2010-2015 | SAW routine | 0.002 | 0.01 | 0.05 | 0.01 | <0.0002 | |
| Chromium total | mg/L | 0.003 | 60 | 0.002 | 0.082 | 0.008 | 2010-2015 | SAW routine | 0.05 | | | 1 | < 0.03 | |
| Cobalt total | mg/L | 0.0005 | 60 | 0.0005 | 0.0016 | 0.0011 | 2010-2015 | SAW routine | | 0.05 | 0.1 | 0.05 | | |
| Copper total | mg/L | 0.001 | 60 | 0.04 | 0.21 | 0.11 | 2010-2015 | SAW routine | 1 to 2 | 0.2 | 5 | | < 0.03 ⁵ | |
| Iron total | mg/L | 0.03 | 60 | 0.6 | 3.0 | 1.5 | 2010-2015 | SAW routine | 0.3a | 0.2 | 10 | | 1.3 | |
| Lead total | mg/L | 0.0005 | 60 | 0.0064 | 0.0378 | 0.0154 | 2010-2015 | SAW routine | 0.01 | 2 | 5 | 0.2 | < 0.001 | |
| Lithium total | mg/L | 0.001 | 60 | 0.0057 | 0.0429 | 0.0087 | 2010-2015 | SAW routine | | 2.5 | 2.5 | | <0.01 | |
| Manganese total | mg/L | 0.0005 | 60 | 0.08 | 0.19 | 0.11 | 2010-2015 | SAW routine | 0.1 to 0.5 | 0.2 | 10 | 2 | 0.05 | |
| Mercury total | mg/L | 0.0005 | 60 | 0.0000 | 0.0013 | 0.0002 | 2010-2015 | SAW routine | 0.001 | 0.002 | 0.002 | 0.002 | < 0.0003 | |
| Molybdeum total | mg/L | 0.0005 | 60 | 0.0023 | 0.0144 | 0.0057 | 2010-2015 | SAW routine | 0.05 | 0.01 | 0.05 | 0.05 | | |
| Nickel total | mg/L | 0.0005 | 60 | 0.0045 | 0.0198 | 0.0086 | 2010-2015 | SAW routine | 0.02 | 0.2 | 2 | 0.2 | 0.0011 | |
| Selenium total | mg/L | 0.003 | 60 | 0.0001 | 0.0096 | 0.0035 | 2010-2015 | SAW routine | 0.01 | 0.02 | 0.05 | 0.01 | | |
| Silvertotal | mg/L | 0.0002 | 60 | 0.0001 | 0.0032 | 0.0009 | 2010-2015 | SAW routine | 0.1 | | | | | |
| Thallium total | mg/L | 0.0005 | 60 | 0.0001 | 0.0004 | 0.0001 | 2010-2015 | SAW routine | | | | | | |
| Tin total | mg/L | 0.0005 | 60 | 0.0028 | 0.0096 | 0.0061 | 2010-2015 | SAW routine | | | | | | |
| Vandadium total | mg/L | 0.003 | 48 | 0.0001 | 0.0191 | 0.0064 | 2010-2015 | SAW routine | | 0.1 | 0.5 | | | |
| Zinc total | mg/L | 0.003 | 60 | 0,10 | 0.24 | 0.15 | 2010-2015 | SAW routine | 3a | 2 | 5 | | 0.042 | |
| Organic compounds | - 10 | 2.235 | | | | | | | 50 | - | | | | |
| Phenols | mg/I | 0.01 | 58 | 0.01 | 0.23 | 0.08 | 2010-2015 | SAW routine | | | | | | |
| Other | | 0.01 | 30 | 0.01 | 0.23 | 0.00 | 2010-2015 | e routine | | | | | | |
| Oranide total | ma/I | 0.05 | 58 | 0.05 | 0.05 | 0.05 | 2010-2015 | SAW routine | | | | | | |
| Greace | ma/I | 0.03 | 57 | 0.03 | 150 | 0.05 | 2010-2015 | SAW routing | | | | | | |
| MED | 1118/L | 1 | 24 | 32 | 159 | /4 | 2010-2015 | SAW routine | | | | | | |
| IVIED | | | 54 | 2.2 | 7.9 | 4.8 | 2010-2015 | SHW TOULINE | | | | | | |



A check on boron

Recycled water mean value = 0.33 mg/L

A5.3 Boron

Table A5.3 Maximum boron concentrations in irrigation or soil water tolerated by a variety of crops, without reduction in yields

| Very sensitive (threshold 0.3-0.5 mg/L) Citrus: limon Lemon Blackberry Blackberry Sensitive (threshold 0.5-0.75 mg/L) Blackberry Persea americana Avocado C. zimonis Grapefruit C. zimonis Orange Primus armeniaca Apricot P. persica Peach P. persica Peach P. avinin Cherry P. domestica Pita P. domestica Fig. kadota Pitas vinflora Grape Juliotinentis Pecan Alliun cepa Onion A. sativam Gatic Ipomea batatas Sweet potato Triticum anxitivam Wheat Helianthuz annua: Sunflower Pigna radiata Bean, mang Sesamum indicum Sesame Lupnice Strawberry Pragoria sp. Strawberry Plaaolas vulgaris Bean, sang P. lunatas Bean, linhey P. lunatas Bean, linhey P. lunatas Bean, linhey | Species name | Common name |
|--|--|---------------------------|
| Cirra: limonLemonCirra: limonBlackberrySensitive (threshold 0.5-0.75 mg/L)BlackberryPersea americanaAvocadoC. sparadisiGrapeEfuitC. sparadisiOrangePranus armeniacaApricotP. avianCherryP. avianCherryP. avianCherryP. avianCherryP. avianCherryP. avianCherryP. avianCherryP. domesticaPlumDiacayoos takiPersimmonFicus caricaFig. kadotaMits vinfigraGrapeAglans regiaOnionA sativanGatticJomao battataSweet potatoTriticum activamWheatHelianthua annua:SuflowerVigra radiataBean, mangSetamum indicumSetamueLupinus hartwegiiLupineProgaria p.StrawberryHelianthua sulgarisBean, sicheryP. VingrizBean, sicheryP. NatasiBean, innaPacabas vilgarisBean, innaPacabas vilgaris <t< th=""><th>Very sensitive (threshold 0.3-0.5 mg/L)</th><th></th></t<> | Very sensitive (threshold 0.3-0.5 mg/L) | |
| Rubu: gpBlackberrySensitive (threshold 0.5-0.75 mg/L)Persea moricanaPersea moricanaAvocadoC. smoritaGrapefruitC. smoritaOrangePrimus armeniacaApricotP. persicaPeachP. aviumCherryP. domesticaPiumDiotypyos kakiPersimmonaFicu: corricaFig. kadotaWith withforeGrapeAylant regiaWalautCarya IlinoinentisPecanJaglans: regiaWalautCarya IlinoinentisPecanJaglans: regiaWalautLargen attatasSweet potatoTriticum activumWheatHeilanthu: annuusSunflowerVigner aduataBean, mungSearmum indicumSearmeLupinue hortwegiiLupineProgravia gp.StrawberryHeilanthu: tuberocusArtichoke, JerusalemPhazeohu: vulgerisBean, sangP. hunatisPeantPoncus carotaBean, limaPastice oleracea botrytisBean, limaPastice oleracea botrytisBean, limaPastice oleracea torytasRadishSolamu tuberosusRadishSolamu tuberosusCuruberLattica sativaCuruberLattica sativasCuruberBargaCarotAghamis sativasCuruberJattica sativasCuruberLattica sativasCuruberJattica sativasCuruberJattica sativasCuruber | Citrus limon | Lemon |
| Sensitive (threshold 0.5-0.75 mg/L) Persea americana Avocado C. z paradili Grapeffuit C. Simusiti Orange Prinus amenicaca Apricot P. prinus amenicaca Apricot P. prinus amenicaca Apricot P. prinus amenicaca Persita P. aviam Cherry P. domestica Pium Diotsprost khi Persimmon Ficus carica Fig. kadota Jugians regia Walaut Carya illinomenis Pecan Allium cepa Onion A. sativam Gatic Ipomea batatas Sweet potato Triticum actrivum Weat Helianthus annuas Suflower Fregaria gr. Strawberry Helianthus unburosus Suflower Fregaria gr. Strawberry Helianthus ulgaris Bean, inna Pragoria gr. Strawberry Helianthus ulgaris Bean, inna Pragoria gr. Bean, inna Program agr. Bean, inna Program agr. Bean, inna <td>Rubus sp</td> <td>Blackberry</td> | Rubus sp | Blackberry |
| Parsea amoricanaAvocadoC: x paraditiGrapefruitC: stanatisOrangePrinuts armeniacaApricotP. persicaPeachP. persicaPeachP. viunnCherryP. domesticaPlumDiotopyros kakiPersimmonFicus caricaFig. kadotaVinis vinfleraGrapeJuliantOrangeAllium capaOnionAllium capaOnionAllium capaOnionAllium capaSamonJotaparaSufformPrintium ostivumWheetHelianthuz annuuzSufformYens rolatataBean, sufformPortea batataBean, sufformPrintium ostivumWheetHelianthuz intuberozuAtrichoke, JerusalemPhasobus vulgarisBean, sumpP. vulgarisBean, sumpP. vulgarisBean, sumpP. lunatusBean, sumpP. lunatusBean, sumpP. lunatusBean, SumaJourus carotaCarotoRaphanus sativusRadishSolamun tuberosumPotatoCapticum annuumPeatureParaditaDeationSolamun tuberosumPotatoCucumis strivusCarotoAgahamus sativusRadishSolamun tuberosumPotatoCucumis strivusCarotoAgahamus sativusBarleyPirgen rodicataCarotoAgahamus sativusBarleyPortea carotaCarot | Sensitive (threshold 0.5-0.75 mg/L) | |
| C. z paradizi C. zimeniaca Grapefinit C. zimeniaca Apricot P. persica Peach P. avium P. domestica Peach P. avium P. avium C. zariva Jilium cepa Alizin regia Jinglans regia C. zariva Alizin cepa Alizin cepa Alizin Alizin cepa Alizin Alizin cepa Alizin Ali | Persea americana | Avocado |
| C. sineutia Orange Pranus armenica Apticot P. prixia Peach P. aviam Charry P. domestica Pum P. domestica Pum Disagoyos kaki Pesimmon Picas carica Fig. kadota Pitas carica Fig. kadota Pitas carica Pis, kadota Pitas carica Pis, kadota Pitas vinflera Grape Jugians regia Walant Carya illinoinenis Pecan Allium cega Onion A. sativum Gartic Jomea batatas Sweet polato Driticum activum Wheat Helianthua annua Satino Seamun indicum Sesame Lupinus hartwegii Lupine Progeria ap. Strawberry Helianthua tuberocuu Artichoke, Jerusalem Phazolus vulgaris Bean, snap P. lunatus Bean, ikiney P. kungaris Bean, ikiney Daccuu sativa Potat | C. x paradisi | Grapefruit |
| Promus armeniacaApricotP. perticaPechP. perticaPechP. oriumCherryP. domesticaPlumDisapyros kakiPersimmonFicus caricaFig, kadotaVitis vinferaGrapeJuginos regiaWalnutCarya illinoinenisPecanJilimoinenisDecanJulimo regiaOnionJ. artivamGarticIpomea batatasSweet potatoTriticum activamWalnutHelianthuz annuusSunflowerFigna radiataBean, mungSuramum indicumSustantowerPragaria q.StrawberryHelianthuz tuberosusAttichoke, JerusalemPragaria q.StrawberryHelianthuz tuberosusBean, sanpP. LunatusBean, SanpPasolus sativasBadishSolamu tuberosumPotatoCapticum arativaCarotPapartensica oleracea topitataCabageaSolamu tuberosumCarotaJata SativasBaleySolamu tuberosumCabageaB | C. sinensis | Orange |
| P. percica Pech P. arxium Cherry P. domestica Plum Diagayros kaki Persimanon Fitz strike Pristic strike Pittic vinflera Grape Vittis vinflera Grape Using and the strike Vittis vinflera Carya illinoinentis Pecan Allium copa Onion A sativum Gartic Jonnea Ostatas Sweet potato Triticum austivum Wheat Helianthus annus Sunflower Searnum indicum Seasame Lupinus hartwegii Lupine Progeria ap. Stratkowery Helianthus tuberosus Artichoke, Jerusalem Phazoslus vulgeris Bean, strape Pulgaris Bean, strape Pasoslus vulgaris <td>Prunus armeniaca</td> <td>Apricot</td> | Prunus armeniaca | Apricot |
| P. avium Cherry P. domestica Plum Diagryros kaki Persimmoon Ficas carica Fig. kadota Vitis vinifera Grape Jugins regia Walnut Carya illinoinenis Pecan Allium cepa Onion A cativam Gariic Ipomea batatas Sweet potato Triticum activam Wheat Helianthuz annuuz Sunflower Vigna radiata Bean, mung Sesamue inductur Bean, mung Sesamue inductur Bean, sang P. Lunatas Bean, sang P. Lunatas Bean, sidney P. Lunatas Bean, sidney P. Lunatas Bean, lima Pascolus vulgaris Bean, lima Pascolus vulgaris Bean, lima Prasta olus vulgaris Bean, lima P. lunatas Bean P. lunatas Carrot Aghamus zativas Radish Solamu tuberosum Potato Cucumis strivas Cucumber Lattaca striva Carrot Raphamus zativas Radish Solamu tuberosum Otato Solamu tuberosum Otato Parateusica oleracea capitata <td>P. persica</td> <td>Peach</td> | P. persica | Peach |
| P. domestica Plumi P. docayros kaki Persimmon Ficu: carica Fig. kadota Fini: vinifiva Grape Augians regia Walmat Carya ilinoinenis Pecan Alitam copa Onion A sativam Grape Jopmea Datatas: Sweet potato Jorne adatas: Sweet potato Triticum activam Wheat Helianthus annus: Sunflower Vigra radiata Bean, mung Searmun indicum Seama Lupinus hartwegii Lupine Fregoria ag. Stratwberry Helianthus tuberosus: Artichoke, Jerusalem Phazolito xulgeris: Bean, sanp P. Vingaris: Bean, sichery P. Vingaris: Bean, sichery P. Vingaris: Bean, sichery P. Vingaris: Bean, sichery P. Junatas Bean, inna Parasolito xulgeris: Bean, sichery P. Linatas Bean, inna Parasolito xulgeris: Bean, Sichery P. Junatas Bean, inna Parasolito xulgeris: Bean, Sichery Plassitio colerace aborytis: Brococli Capticum annuim Pota Datascica ol | P. avium | Cherry |
| Diogynot kaki Persimmon Ficus carica Fig. kadota Vints winffera Grape Vints winffera Grape Jutant Carya illinoinenis Pecaa Carya illinoinenis Pecaa Onion Latarium Garkit Sweet potato Ipomea batatas Sweet potato Triticum activum Helianthus annuus Sunflower Vigna radiata Seamum indicum Seasame Lupine Fragorarda p. Strawberry Helianthus tuberocus Artichoke, Jerusalem Phazoolus vulgaris Bean, saup P Nugaris Bean, saup P. hunatus Bean, saup P Nugaris Bean, saup P. lunatus Bean, saup P P P P. lunatus Bean, saup P P P P. lunatus Bean, saup P P P P. lunatus Bean, saup P P P P P P P P P P | P. domestica | Plum |
| Ficus carcia Fig. kadota Fins vinjibra Grape Juglans regia Walanat Carya tilinoinenis Pecan Alliam cepa Onion A sativam Gatic Jpomea batatas Sweet potato Jrinis vinjibra Sundiover Jrinis vanjibra Sundiover Jrinis matus Sundiover Jrinis hartwegii Lupine Pregaria gr. Strawberry Helianthus tuberosus Bean, sange P. Vingoris Bean, sinher P. Junatis Bean, inna Pacasolas vulgeris Bean, inna Arachis lopogoaa Peanut Moder ately exestitive (threshold 1.0-2.0 mg/L) Brassica oleracea botrytis Brassica oleracea botrytis Bean, inna Solarum stuba Cauno Solarum tuberosum Potato Solarum tuberosum Potato Solarum tuberosum Cabage Solarum tuberosum </td <td>Diospyros kaki</td> <td>Persimmon</td> | Diospyros kaki | Persimmon |
| Fini: winifera Grape Juglans regia Walanut Carya dilinoineniz Pecan Allium copa Onion A. sativum Gatic Jomana batata: Sweet potato Triticum activum Wheat Hellanthuz annuu: Sunflower Frigna radiata Bean, mung Seamun indicum Seamun Jomana batata: Bean, mung Seamun indicum Seamun Lupine hartwegii Lupine Fragara data Bean, sung Phaceolus vulgariz Bean, kichney Phacolus vulgariz Bean, sung P. hardus Bean, sung P. vulgariz Bean, sung P. hardus Bean, sung P. vulgariz Bean, sung P. hardus Bean, sung P. vulgariz Bean, sung P. vulgariz Bean, sung P. hardus Bean, sung P. apartatis Bean, sung Dancus carota Carot Raphanus sativa Cauumber Lactuca sativa Cauum | Ficus carica | Fig, kadota |
| Juglans regia Walnut Cargu illinoinenis Pecan Allium cepa Onion A sativum Gartic Ipomea batatas Sweet potato Triticum acsivum Wheat Helianthus annuus Sunflower Vigna radiata Bean, mung Sacamum indicum Seame Lupinus hartwegii Lupine Progaria gr. Strawberry Helianthus tuberosus Atrichoke, Jerusalem Phaseolus vulgeris Bean, snap P. Vulgeris Bean, snap P. lunants Bean, inna Arachis lopogaea Peanut Moder setey sensitive (Intershold 1.0-2.0 mg/L) Intershold Second Capsticum annuum Peper, red Pisam sativas Radish Solamum tuberosum Potato Cucumis strivas Cucumber Lactica sativa Cucumber Lactica sativa Beage Solamum tuberosum Potato Moder setey tolerant (Intershold 2.0-4.0 mg/L) Parapretensit Bluegrass, Kennucky Hordenatey tolerant (Intershold 2.0-4.0 mg/L) Programing Gabage Argen auris Cobage Argen auris Corn Korthans tub | Vitis vinifera | Grape |
| Carya illinoinenis Pecan Allium capa Onion A. sativum Gartic Jopome bataas Sweet potato Triticum aastivum Wheat Helianthus annuus Sunfower Yigna radiata Bean, mung Saturum indicum Seamu Lupinus hartwegi Lupine Fragarai ap. Strawberry Helianthus unbursout Artichoke, Jerusalem Phazeolus vulgaris Bean, kidney P. vulgaris Bean, juina Phazeolus vulgaris Bean, juina P. vulgaris Bean, juina Phazeolus vulgaris Bean, juina P. vulgaris Bean, juina Arachis hypogoaa Peanut Moderately sensitive (threshold 1.0-2.0 mg/L) Brascia oleracea borynis Brascia oleracea borynis Brascia oleracea capitata Solamum tuberosum Poitato Cucumis strivus Cucumber Lattuce Lattuce Moderately tolerant (threshold 2.0-4.0 mg/L) Brascia oleracea capitata Cabbage S. rapa Curunis Poratensi: Bluegrass, Kentucky Horden vulgare Gabage S. rapa Curu Ventan stathoa Cartuce </td <td>Juglans regia</td> <td>Walnut</td> | Juglans regia | Walnut |
| Alliam cepa Onion A sarivam Gartic Ipomea batatas Sweet potato Triticum activam Wheat Helianthuz annuux Sunflower Figna radiata Bean, mung Summun indicum Sesama Lupinus hartwegii Lupinus Fraggrai ag Strawberry Helianthux tuberosus Artichoke, Jerusalem Phaseolis vulgeris Bean, stap P. lunatus Bean Dacusc carota Carot Rapharus sativas Radish Solamun tuberosum Potato Cucumis strivas Custoper Lactuca sativa Carot Moder ately tolerant (threshold 2.0-4.0 mg/L) Prague atagra Carot Brapa Carot <td>Carya illinoinenis</td> <td>Pecan</td> | Carya illinoinenis | Pecan |
| A sativam Garlic Jonnea Datatas Sweet polato Jriticum oactivam Wheat Helianthua annua: Sunflower Vigna radiata Bean, mmg Seamum indicum Seame Lupinus harivegii Lupine Prograf ag. Strawberry Helianthua tuberosu: Artichoke, Jerusalem Phascolus vulgaris Bean, kichey P. vulgari: Bean, sanp P. nutatus Bean, inna Arachic hypogna Pesanut Moderately sensitive (threshold 1.0-2.0 mg/L) Brasciac oloracca borynis Brasciac oloracca borynis Beacoli Capticum annuam Pepper, red Pianus activa Carot Raphanus activas Radish Solarum tuberosum Potato Cucumis striva: Caroto Lactice of accea capitata Cabbage B. rapa Surajo Brascia coloracca capitata Cabbage B. rapa Corna Portensi: Bluegrass, Kentucky Pirana sativa Carot Rapparatensi: Bluegrass, Kentucky Portensi: Bluegrass, Kentucky Pirana sativa Corna Avena sativa Corna <t< td=""><td>Allium cepa</td><td>Onion</td></t<> | Allium cepa | Onion |
| Ipomea batatas Sweet potato Iprincum activum Wheat Helianthuz annuus Sunflower Vigna radiata Bean, mung Sesamum indicum Sesame Lupinus harvesgii Lupina Fragaratas Artichoke, Jerusalem Phasolus vulgaris Bean, sidney P. lunatas Bean, inma P. lungaris Bean, imma P. lungaris Bean, imma P. lunatas Bean, imma Artachis hypogaea Peanut Moder refsy sensitive (threshold 1.0-2.0 mg/L) Brasciac oloracea botrytis Brasciac oloracea botrytis Broccoli Capticum amuum Peper, red Pium sativa Radish Solamm tuborosum Potato Cucumis strivas Cucumber Lattuce sativa Cucumber Barley Solamu tuborosum Potato Courale Arder set polerant (threshold 2.0-4.0 mg/L) Buegrass, Kentucky Hordaum vulgare Batley Hordaum vulgare Batley | A. sativum | Garlic |
| Triticum aastrivum Wheat First annuus Sunflower First annuus Sunflower First annuus Sunflower First annuus Sesame Lupinus hartwegii Lupinus Fragoria ga, Strawberry Helianthus tuberosus Artichoke, Jerusalem Prazolaus vulgaris Bean, students P. vulgaris Bean, students P. kunatus Bean, students Arachis hypogoaa Peanut Moderately sensitive (threshold 1.0-2.0 mg/L) Broscoli Parassica oleracea borysis Broscoli Capticum annuam Pepper, red Pizam sativa Radish Solamun tuberosum Potato Cucumis strivus Cucumber Lactuca sativa Banega Braga Turnip Poo pratensis Blaegrass, Kentucky Hordamu vulgare Graley Hordamu vulgare Compea Avena sativa Oats Zear mays Con Cyconia statoacu Oats Zear mays Con Molerately statoacu Tobacco Prostica juncea Mistard | Ipomea batatas | Sweet potato |
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| Secamm indicum Sesame Lupins harvegii Lupine Fragaria g. Strawberty Fredianthui tuberocus Artichoke, Jensalem Phaceolus vulgaris Bean, kichey P. vulgaris Bean, snap P. nutatus Bean, ima Arachis hypogaea Peanut Moderately sensitive (threshold 1.0–2.0 mg/L) Brassica oleracea botry fis Brassica oleracea botry fis Broccoli Capticum armunam Peper, red Piann sativa Radish Solanum tuberosum Potato Cucumis strivus Cacumber Lattuce Lattuce Moderately tolerant (threshold 2.0–4.0 mg/L) Brassica oleracea capitata Cabbage B. rapa Paratentis Bluegrass, Kentucky Horden ately tolerant (threshold 2.0–4.0 mg/L) Gradum stativa Paratentis Bluegrass, Kentucky Portanous cativa Compea Avena sativa Cotto Quanta sativa Cotto Corna sativa Cotto Corna sativa Cotto Cycotara sativa Cotto Motorately Attichoke Vicotiana tubacum Tobacco Paratesatip maine Mustard | Vigna radiata | Bean, mung |
| Luptines: hartwegti Luptine Fregarria q.; Strawberry Helianthus tuberosus Artichoke, Jensulem Phazeolas vulgeris Bean, stanp P. vulgeris Bean, stanp P. lunatus Bean, inma Arackis hypogaea Peanut Moder ately exestitive (threshold 1.0-2.0 mg/L) Brassica oleracea botrytis Brassica oleracea botrytis Broccoli Capcicum annuum Pepper, red Pisam sativas Radish Solamus tuberosum Potato Cucumis strivus Cucumber Lactuca sativa Lettace Moder ately tolerant (threshold 2.0-4.0 mg/L) Brage Pragaria quicata Cabage Solamus tuberosum Potato Cucumis strivus Cucumber Lactuce astriva Cabage B rapa Turnip Pa pratensiti Bluegrass, Kentucky Hordann vulgare Garley Vigna unguiculata Compea Avena sativa Oats Car mays Com Krotima tubeucum Tobacco Prostici giuncea Mustard | Sesamum indicum | Sesame |
| Program ap. Strawberry Program ap. Strawberry Helianthu: tuberosu: Artichoke, Jerusalem Phazobla: vulgaris Bean, kichey P. vulgaris Bean, ima P. hundau: Bean, ima Artachis hypogoa Peanut Moderately sensitive (threshold 1.0-2.0 mg/L) Brassica oleracea botry fit: Brassica oleracea botry fit: Capticum armum Pizum sativa Pea Dancus: carota Carot Raphanus: antivas Radish Solamu: tuberosum Potato Cucumits strivas Cucumber Lattuce Lattuce Moderately tolerant (threshold 2.0-4.0 mg/L) Brassica oleracea capitata B. rapa Turnip Poartensi: Bluegrass, Kentucky Hordenn vulgare Barley Viena sativa Compea Avena sativa Oats Cara mays Com Cycotara scolymus Artichoke Micotania tubacum Tobacco Brassica juncea Muistard | Lupinus hartwegii | Lupine |
| Heliatritus tuberosus Artchoke, Jerusalem Phaseolas vulgeris Bean, stap P. Nunatus Bean, linna P. Iunatus Bean, linna Arachis hypogaea Peanut Moderately sensitive (Intershold 1.0-2.0 mg/L) Image and the sensitive (Intershold 1.0-2.0 mg/L) Brassica oleracea botrytis Broccoli Capsicum annuum Peper, red Pisam sativa Radish Solamum tuberosum Potato Cucumis strivas Cucumber Lattnce Moderately colorant (Intershold 2.0-4.0 mg/L) Brassica oleracea capitata Cabbage B. rapa Turnip Poa pratensti: Bluegrass, Kentucky Hordandur Mugare Barley Tigran unguiculata Compea Avena sativa Catico Moterately atabacum Tobacco Paratenstic juncea Mustard Melionus indica Clover, sweet <td>Fragaria sp.</td> <td>Strawberry</td> | Fragaria sp. | Strawberry |
| Practicolius vingeris Deali, stainely P. vulgeris Bean, ima P. untartas: Bean, ima Arachis hypogaa Peanut Moderately sensitive (threshold 1.0-2.0 mg/L) Brassica oleracea botrytis Brassica oleracea botrytis Broccoli Capcicum annuam Pepper, red Pisum sativa Radish Solamun tubercum Potato Cucumber Lattuce Moderately tolerant (threshold 2.0-4.0 mg/L) Brassica oleracea capitata Braga Cabage B. rapa Turaip Portensiti Bluegrass, Kentucky Horden wulgare Barley Viena sativa Corn Zea mays Corn Cynard scolymus Artichoke Micotiana tabacum Tobacco Brassica juncea Mustard | Helianthus tuberosus | Artichoke, Jerusalem |
| P. Nardnik Bean, inap P. Inardnik Bean, imap P. Inardnik Bean, imap P. Inardnik Bean, imap Penatt Bean, imap Paratriki ippogaea Peanut Peanut Brassice oleracea botynic Broccoli Capticum amuman Pepper, red Pinum sativa Radish Solamm tuberosum Potato Cucumis strivas Cucumber Lactuca sativa Cucumber Brassice oleracea capitata Cabbage B. rapa Turnip Poratensti: Bluegrass, Kentucky Hordeaunt vulgare Batley Vigna unguiculata Cowpea Avena sativa Com Cynara scolymus Totas Nicotinan tubacum Tobacco Brassica juncea Muistard | Phaseonus vulgaris | Bean, kidney |
| Printing Deal, illing Arachis hypogasa Peanut Moderately sensitive (threshold 1.0-2.0 mg/L) Peanut Brassica obsences botynis Broccoli Capsicum annuam Pepper, red Pisum sativa Pea Dancus carota Carot Raphanus sativas Radish Solamun tubercum Potato Cucumber Lattuca sativa Solamun tubercum Dotato Cucumber sativa Lettuce Moderately tolerant (threshold 2.0-4.0 mg/L) Brassica oleracea capitata Brassica oleracea capitata Cabbage B. rapa Turaip Pon partensis Bluegrass, Kentucky Hordeam vulgare Barley Viena sativa Compea Avena sativa Corn Zea mays Corn Cynard scolymus Attichoke Micotiana tabacum Tobacco Brassica juncea Mustard | P. Vulgaris | Bean, snap Dean, lines |
| Articinis njožgava Peratili Brazsica oleracea botynis Broccoli Gapticum muum Pepper, red Piamusativa Pea Dancus carota Radish Solamum tuberosum Potato Cucumic strivus Cauticum Lactuca sativa Cautober Lactuca sativa Lettuce Moder ately tolerant (threshold 2.0-4.0 mg/L) Brasica oleracea capitata Cabbage B. rapa Portenscia Bluegrass, Kentucky Horden ately tolerant Cowpea Avena sativa Oats Zea mays Com Nicotinan tubacum Tobacco Brazica juncea Mustard Melionus indica Clover, sweet | F. tunanus | Beau, Iuna Dromot |
| Autoer stery sensitive (ultression 1.5–2.0 mg).) Brassica (obrancea botrynis) Broccoli Capsicum annuum Pepper, red Pixam sativa Pea Daucus carota Carrot Raphamus sativas Radish Solamun tuborosum Potato Cucumber Lattaca sativa Solamun tuborosum Lettace Moderately tolerant (threshold 2.0–4.0 mg/L) Brassica oleracea capitata Ponarientis Bluegrass, Kentucky Hordeann vulgare Barley Virgna unguiculata Cowpea Avena sativa Attichoke Nicotiana tubacum Tobacco Brassica juncea Mustard | Arachis hypogaea | Peanur |
| Daratica obratca obrytit Bioccoli Captician mumium Pepper, red Piam. sativa Pea Dancus corota Carot Raphanus sativas Radish Solamun tubercusm Potato Cucumis strivus Cucumber Lactuce sativa Cucumber Brassica oleracea capitata Cubege B. rapa Turnip Poarotensis Bluegrass, Kentucky Hordean vulgare Barley Viena unguiculata Cowpea Avena sativa Oats Cara mays Com Cyconar scolymus Artichoke Nicotiana tubacum Tobacco Brassica juncea Muistard | Moderately sensitive (threshold 1.0-2.0 mg/L) | D V |
| Capizetim annum Pegper, red Pitam sativa Pea Dancus carota Carot Raphamis sativus Radish Solamun tuberozum Potato Cucumis strivus Cucumber Lactuca sativa Lettnce Moderately tolerant (threshold 2.0–4.0 mg/L) Posasica oleracea capitata Cabbage Brago Poa pratenzis Bluegrass, Kentucky Hordsam vulgare Barley Virgna unguluata Compea Avena sativa Oats Cyara scolymus Artichoke Nicotima tubacum Tobacco Brazica juncea Mustard | Brassica oleracea botryns | Broccoll |
| Plancus: carota Pea Dancus: carota Carot Raphanus: sativus Radish Solamun: tuberosum Potato Cucumber Lettuce Moderately tolerant (threshold 2.0-4.0 mg/L) Barbage Brassica oleratea capitata Cabage B. rapa Turaip Por paratensis Bluegrass, Kentucky Hordeam vulgare Barley Virgen unguiculata Cowpes Avena sativa Cara Quanta sativa Cora Quanta sativa Cora Quanta sativa Cora Motorian tabacum Tobacco Brazica juncea Mustard | Capsicum annuum | Pepper, rea |
| Daticus carota Carrot Raphamus starivus Radish Solamum tuberosum Potato Cucumis strivus Cucumber Lactuce a strivus Lettuce Moderately tolerant (threshold 2.0–4.0 mg/L) Brassica oleracea capitata Brassica oleracea capitata Cabbage Brapa Turnip Poa pratemsti: Bluegrass, Kentucky Hordanum vulgare Barley Vigna unguiculata Compea Avena sativa Oats Cara mays Com Cynara scolymus Artichoke Prototina tubacum Tobacco Brassica juncea Mustard | Pisum sativa | Pea |
| Raphanus sativus Radish Solamun tuberscum Potato Cucumber Lettuce Moderately tolerant (threshold 2.0–4.0 mg/L) Brassica oleracea capitata Strapa Cabbage B. rapa Turaip Pon pratenzis Bluegrass, Kentucky Hordeam vulgare Barley Vigna unguiculata Cowpea Avena sativa Oats Zea mays Corn Qynara scolymus Artichoke Micotiana tabacum TobaccO Brassica juncea Mustard | Daucus carota | Carrot |
| Solation tuberozium potato Cucumis trivus Cucumber Lactuce atativa Lettuce Moderately tolerant (threshold 2.0–4.0 mg/L) Brassice oleracea capitata Cabbage B. rapa Turnip Poa pratensti: Bluegrass, Kentucky Hordeum vulgare Batley Hordeum vulgare Batley Vigna unguiculata Cowpea Avena cativa Oats Zear mays Com Cynara scolymus Artichoke Nicotiana tubacum Tobacco Brassica juncea Mustard Melionus indica Clover, sweet | Raphanus sativus | Radish |
| Cucumber Lactuca starius Cucumber Lactuca starius Lettucce Moderately tolerant (threshold 2.0–4.0 mg/L) Brassica oleracea capitata Cabbage B. rapa Turnip Poa pratonsis Barley Hordeam vulgare Barley Vigna unguiculata Cowpea Avona sativa Oats Zea mays Corn Cymara scolymus Artichoke Nicotiana tabacum Tobacco Brassica juncea Mustard Meilonus indica Clover, sweet | Solanum tuberosum | Potato |
| Lacture Julie Leuron Moderately tolerant (threshold 2.0-4.0 mg/L) Brassica oleracea capitata Cabbage B. rapa Turnip Poa pratensi: Bluegrass, Kentucky Hordean vulgare Barley Vigna unguiculata Cowpea Avena sativa Oats Com ago Com Cynara scolymus Artichoke Nicotiana tabacum Tobacco Brassica juncea Mustard Melionus indica Clover, sweet | Cucumus strvus | Cucumber |
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| Drastic owneed capitalia Caboage Brapa Turaip Pod pratenziz Bluegrass, Kentucky Hordeam vulgare Barley Virgna unguiculata Cowpea Avena zativa Oats Zea mays Corn Cynara szołymus Artichoke Nicotiam tabacum Tobacco Brasica juncea Mustard Meilonus indica Clover, sweet | Moder atery toler and (inreshold 2.0-4.0 mg/L) | Cabhara |
| Drapa Tamp Do prateristi Bluegrass, Kentucky Hordaum vulgare Barley Vigna unguiculata Cowpea Avena sativa Oats Zear mays Corn Cynara scohmus Artichoke Nicotiana tabacum Tobacco Brassica juncea Mustard Meilonus indica Clover, sweet | Brassica Overacea capitala | Turnin |
| Food privation Diarguistics, Kennink Ky Hordeam vulgare Barley Vigna unguiculata Cowpea Avena sativa Oats Zea mays Corn Cynara scolymus Artichoke Nicotiana itabacum Tobacco Brassica juncea Mustard Meilonus indica Clover, sweet | D. rupu Rea matancia | Discourses Fontucing |
| Horadum vugare Bartey Figna ungukulata Compea Avena sativa Oats Zea mays Com Cynara scolymus Artichoke Nicotiana tabacum Tobacco Brassica juncea Mustard Melionus indica Clover, sweet | Pou pratensis | Bidegrass, Kentucky |
| Fight unguiculatia Competitiva Avena sativa Oats Zea mays Corn Cymara scohmus Artichoke Nicotiana tabacum Tobacco Brassica juncea Mustard Meilonus indica Clover, sweet | Horaeum vulgare | Barley |
| Aventa saliva Zee mayo Com acobymus Com Cynara scolymus Artichoke Nicotiana tabacum Tobac.co Brassica juncea Mustard Meliotus indica Clover, sweet | Vigna unguiculata | Cowpea |
| Zear mays Colu Cynara scolymus Artichoke Nicoliana tabacum Tobacco Brassica juncea Mustard Melilonus indica Clover, sweet | | Com |
| Nicotiana tabacum Tobacco Brassica juncea Mustard Melilotus indica Clover, sweet | One and scohous | Artichoka |
| Brassica juncea Mustard Melilotus indica Clover, sweet | Nicotiana tabacum | Tobacco |
| Melilotus indica Clover, sweet | Reassing juncon | Mustard |
| Civita, Meet | Melilotus indica | Clover sweet |
| Cucurbita pepo Squash | Cucurbita pepo | Souash |

Table A5.3 (continued)

| Species name | Common name |
|--------------------------------------|---------------|
| Cucumis melo | Muskmelon |
| B. oleracea botrytis | Cauliflower |
| Tolerant (threshold 4.0-6.0 mg/L) | |
| Medicago sativa | Alfalfa |
| Vicia benghalensis | Vetch, purple |
| Petroselinum crispum | Parsley |
| Beta vulgaris | Beet, red |
| B. vulgaris | Sugar beet |
| Lycopersicum | Tomato |
| Very tolerant (threshold 6.0-15.0 mg | g/L) |
| Sorghum bicolor | Sorghum |
| Gossypium hirsutum | Cotton |
| Apium graveolens | Celery |
| Asparagus officinalis | Asparagus |

Note: Boron tolerance may vary, depending upon climate, soil conditions and crop variety. Source: Maas (1986, 1990b); Keren and Bingham (1985).



A check on cadmium

Recycled water mean Cd = 0.0003 mg/L, Cl⁻ = 406 mg/L, TDS = 1,1,35 mg/L

A5.4 Cadmium

| Limit | Value |
|---|-----------|
| Long-term trigger value in irrigation water | 0.01 mg/L |
| Short-term trigger value in irrigation water (short-term use) | 0.05 mg/L |
| Cumulative contaminant loading in soil receiving irrigation water | 2 kg/ha |

Table A5.5 Guidelines values for cadmium in recycled water

Table A5.6 Relationship between irrigation water chloride concentration or salinity, and risk of increasing crop uptake of cadmium

| | Likelihood of increasing | | |
|----------|--------------------------|-------------------------|----------------|
| Chloride | Total dissolved solids | Electrical conductivity | crop cadmium |
| (mg/L) | (mg/L) | (dS/m) | concentrations |
| <350 | <1100 | <1.9 | Low |
| 350-750 | 1100-1650 | 1.9-2.8 | Moderate |
| >750 | >1650 | >2.8 | High |

Source: Modified from ANZECC and ARMCANZ (2000a); electrical conductivity and chloride data from Australian sewage treatment plants



A check on chlorine residual



- Need chlorine for disinfection & unrestricted use
- Improved ammonia removal & greater control on chlorine dosing
- Online continuous monitoring & chlorine C.t calculation
- Storage lagoon/ distribution system, decreases residual

• AGWR (2006) – A4.2, target criteria 1-5 mg/L depending on plants Wednesday, 13 Jan 2016



Salinity & sodicity

- Sewage TDS: 850-1,600 mg/L, EC: 1.5-2.9 dS/m
- Recycled water TDS: 850-1,310 mg/L
- Strong seasonality
- Irrigation salinity rating: Medium
- Key factors: soil characteristics, climate, plant species, irrigation management
- 5 soil types, most common is loamy sands ~>20% LF



Table 9.2.5 Irrigation water salinity ratings based on electrical conductivity*

| | EC (d\$/m) ⁶ | Water salinity rating | Plant suitability |
|---|-------------------------|-----------------------|----------------------------|
| | <0.65 | Very low | Sensitive crops |
| | 0.65-1.3 | Low | Moderately sensitive crops |
| (| 1.3-2.9 | Medium | Moderately tolerant crops |
| | 2.9-5.2 | High | Tolerant crops |
| 1 | 5.2-8.1 | Very high | Very tolerant crops |
| | >8.1 | Extreme | Generally too saline |

a Adapted from DNR (1997); b 1d8/m = 1000 µ8/cm



Salinity







Table A5.15 Approximate salinity tolerance of fruit, vegetable, grain and pasture crops

Salinity (EC) & crop tolerance as a function of leaching fraction

| | | | | ECi* | | | |
|----------------------------------|------------------------|-----------|----------|--------|----------------|-------|---------------|
| Scientific name | Common name | Salinity | Source | | | | 12% |
| | | tolerance | | | 20% LF | 17% | LF |
| | | threshold | | 25% | (eg | LF | (eg |
| | | (ECe | | LF (eg | sandy loom) | (eg | hght clar) |
| Fruit crops | | usanj | | sanna) | юашу | Ioam) | ciajj |
| Prumus dulcis | Almond | 15-4 | tu | 2.8 | 24 | 2.0 | 15 |
| Malus sylvestris | Apple | 1 | , u t | 10 | 0.9 | 07 | 0.6 |
| Prunus armoniaca | Apricot | 16 | | 16 | 14 | 12 | 0.0 |
| Persea americana | Avocado | 13 | ť | 1.3 | 11 | 1.0 | 0.7 |
| Rubus spp | Blackberry. | 15 | 0 | 1.5 | 1.3 | 1.1 | 0.8 |
| | boysenberry, etc | | - | | | | |
| Vitis spp | Grape | 1.5-8 | t, u, r | 4.8 | 4.1 | 3.5 | 2.7 |
| Citrus paradisi | Grapefruit | 1.8-6 | t, u | 3.9 | 3.4 | 2.9 | 2.2 |
| Citrus limonea | Lemon | 1-6 | t, u | 3.5 | 3.0 | 2.6 | 2.0 |
| Olea europaea | Olive | 4 | t | 4.0 | 3.4 | 2.9 | 2.2 |
| Citrus sinensis | Orange | 1.7-6 | t, u | 3.9 | 3.3 | 2.8 | 2.2 |
| Prunus persica | Peach | 3.2 | t | 3.2 | 2.8 | 2.4 | 1.8 |
| Pyrus spp | Pear | 1 | t | 1.0 | 0.9 | 0.7 | 0.6 |
| Cucurbita pepo pepo | Pumpkin | 1.5-3* | 0 | 2.3 | 1.9 | 1.7 | 1.3 |
| Capsicum annuum | Pepper | 1.5 | 0 | 1.5 | 1.3 | 1.1 | 0.8 |
| Prunus domestica | Plum | 1.5 | 0 | 1.5 | 1.3 | 1.1 | 0.8 |
| Cucumis melo | Rockmelon | 2.2 | t | 2.2 | 1.9 | 1.6 | 1.2 |
| Fragaria spp | Strawberry | 1 | 0 | 1.0 | 0.9 | 0.7 | 0.6 |
| Lycopersicon esculentum | Tomato | 2.3-2.5 | t,o | 2.4 | 2.1 | 1.8 | 1.3 |
| Cucurbita pepo | Zucchini | 4.7 | 0 | 4.7 | 4.1 | 3.5 | 2.6 |
| melopepo | | | | | | | |
| Hondown ywlaana | Barlay | 0 | - | 80 | 60 | 5.0 | 4.5 |
| Provision valgare | Canola (oileand | 2.4 | | 3.0 | 26 | 2.5 | 17 |
| Brassica napus | rape) | 2-4 | 1 | 5.0 | 2.0 | 2.2 | 1./ |
| Vicia faba | Faba bean | 2-4 | r | 3.0 | 2.6 | 2.2 | 1.7 |
| Lupinus | Narrow-leaf | 2-4 | r | 3.0 | 2.6 | 2.2 | 1.7 |
| angustifolium | lupin | | | | | | |
| Avena sativa | Oats | | t | 5.0 | 4.5 | 3.7 | 2.8 |
| Zea mays | Corn, grain, sweet | 1.7 | t | 1.7 | 1.5 | 1.3 | 1.0 |
| Gossypium hirsutum | Cotton | 7.7 | t | 7.7 | 6.6 | 5.7 | 4.3 |
| Vigna unguiculata | Cowpea (seed) | 1.6 | t | 1.6 | 1.4 | 1.2 | 0.9 |
| Vigna unguiculata var Caloona | Cowpea, Caloona | 2.0 | t | 2.0 | 1.7 | 1.5 | 1.1 |
| Vinum usitatissimum | Flax/Linseed | 1.7 | t | 1.7 | 1.5 | 1.3 | 1.0 |
| Sorghum | Peanut | 3.2 | t | 3.2 | 2.8 | 2.4 | 1.8 |
| Sorghum, crooble | Phasey bean, Murray | 0.8 | t | 0.8 | 0.7 | 0.6 | 0.4 |
| Soybean | Rice, paddy | 3 | t | 3.0 | 2.6 | 2.2 | 1.7 |
| Carthamus tinctorius | Safflower | 6.5 | t | 6.5 | 5.6 | 4.8 | 3.7 |
| Sorghum bicolor | Sorghum | 6.8 | t | 6.8 | 5.9 | 5.0 | 3.8 |



Chloride & Sodium



| Sensitive | Moderately sensitive | Moderately tolerant | Tolerant |
|-----------------|----------------------|---------------------|-------------|
| Sodium (mg/L) | | | |
| <115 | 115-230 | 230-460 | >460 |
| Chloride (mg/L) | | | |
| <175 | 175-350 | 350-700 | >700 |
| Almond | Pepper | Barley | Cauliflower |
| Apricot | Potato | Maize | Cotton |
| Citrus | Tomato | Cucumber | Sugar beet |
| Plum | | Luceme | Sunflower |
| Grape | | Safflower | |
| - | | Sesame | |
| | | Sorghum | |

Note: Degree of injury is affected by site-specific environmental and agricultural conditions Source: ANZECC and ARMCANZ (2000a) and Maas (1990a)



Sodium & soil structure (sodicicity)



4.3 Relationship between sodium adsorption ratio (SAR) and electrical conductivity (EC) of irrigation water and likelihood of soil structure breakdown (source: ANZECC and ARMCANZ 2000a)

Sewage mean conductivity = 2,062 μ S/cm = 2.0 dS/m, SAR = 8.0





Findings – environmental hazards

| Hazard | Sew Maxim | age al risk | Recycled water Residual risk | | |
|--------------------------|-----------------------|--------------------|---------------------------------|-------|--|
| | Crops | Soils | Crops | Soils | |
| Pathogens | | | | | |
| Inorganic chemicals | | Al> LTV Fe> LTV | | | |
| Salinity & sodicity | TDS/ EC > LTV,STV | | TDS/ EC > LTV,STV | | |
| Nutrients | NH ₃ > LTV | | | | |
| Organic chemicals | | | | | |
| Turbidity & particulates | | | | | |



Environmental residual risk with preventive measures

Recycled water supply

- Trade waste management in Bolivar catchment
- Bolivar WWTP (primary & secondary treatment)
- Bolivar WWTP lagoons
- Bolivar RWTP (DAFF process coagulation, media filtration)
- Bolivar RWTP (chlorine disinfection)

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Agricultural sector

- Soil properties
- Plant types
- Climate
- Landscape
- Irrigation management practices (e.g. leaching fraction, method, soil applicants)



PART D MANAGED AQUIFER RECHARGE ASPECTS



Background - what is MAR?

2.1 Definition, purposes and types of managed aquifer recharge

2.1.1 Definition and purposes of managed aquifer recharge

Managed aquifer recharge is the intentional recharge of water to aquifers for subsequen recovery or environmental benefit; the managed process assures adequate protection of human health and the environment. Aquifers may be recharged by diversion of water in wells or infiltration of water through the floor of basins, galleries or rivers.



ASR = aquifer storage and recovery; ASTR = aquifer storage, transport and recovery.



Generic components of an ASR scheme



The storage zone contains water that is fit for its intended use when recovered. Beyond the attenuation zone, the environmental values of the ambient groundwater are always preserved. Beyond the water-quality impact zone, there is no measurable change in groundwater quality. Beyond the hydraulic impact zone, there is no attributable change in hydraulic head (this zone is typically many times larger than the water-quality impact zone, especially for confined aquifers). The dotted line represents the maximum separation distance between the managed aquifer recharge structure and the observation well's for verification monitoring, to ensure that the ambient groundwater is protected.

Figure 7.1 Schematic showing zones of influence of a managed aquifer recharge operation



Must consider aquifer environmental values – SA EPA

Environment Protection (Water Quality) Policy 2015-1.1.2016 Schedule 1-Environmental values of waters (clause 6)

| Waters | Aquatic ecosystem | Recreation and aesthetics | Drinking water for human consumption | Primary industries— irrigation and general water uses | Primary industries— livestock drinking water | Primary industries— aquaculture and human consumption of aquatic foods | ANZECC & ARMCANZ (2000) |
|---|----------------------|---------------------------------|---|---|--|--|-------------------------|
| Public stormwater systems | x | x | | | | | |
| Surface waters in a water protection area (within the meaning of section 61 of the Act) | x | x | x | x | x | x | Chapter 9 LTV, STV |
| Underground waters as follows: | † | <u>⊢</u> · | + | | | | |
| (a) underground water with a background TDS level of less than 1 200 mg/L | 5 | | x | x | x | x | |
| (b) underground water with a background TDS level of 1 200 mg/L or more, but less than 3 000 mg/L | 5 | | | x | x | x | |
| (c) underground water with a background TDS level of 3 000 mg/L or more, but less than ednesday3190 mg/L2016 | 5 | | | | x | x | |



Must consider the end use of the water - agriculture

Table 4.2 Key environmental hazards, environmental endpoints and common effects on the environment when using recycled water for agricultural, municipal, residential and fire-control purposes

| Hazard | Environmental endpoint | Effect or impact on the environment | | | | |
|-----------------------|--|---|--|--|--|--|
| Boron | Accumulation in soil | Plant toxicity | | | | |
| Cadmium | A low risk with respect to c already in soils can be made increase. Chloride can be m section below). | admium concentrations in recycled water, but cadmium e more readily available to plants if chloride concentrations seasured indirectly, but reliably, as salinity (see the salinity | | | | |
| Chlorine disinfection | Plants | Direct toxicity to plants | | | | |
| residuals | Surface waters | Toxicity to aquatic biota | | | | |
| Hydraulic loading | Soil | Waterlogging of plants | | | | |
| (water) | Groundwaters | Waterlogging of plants | | | | |
| | Groundwaters | Soil salinity (secondary) | | | | |
| Nitrogen | Soils | Nutrient imbalance in plants | | | | |
| | Soils | Pest and disease in plants | | | | |
| | Soils | Eutrophication of soils and effects on terrestrial biota | | | | |
| | Surface waters | Eutrophication | | | | |
| | Groundwaters | Contamination | | | | |
| Phosphorus | Soils | Eutrophication of soils and toxic effects on phosphorus sensitive terrestrial biota (native plants) | | | | |
| | Surface waters | Eutrophication | | | | |
| Salinity | Infrastructure | Salinity may cause rising damp or corrosion of assets; this can also arise from excessive hydraulic load (secondary salinity) | | | | |
| | Soils | Plants stressed from osmotic affects of soil salinity | | | | |
| | Soils | Contamination of soils by increasing plant availability of cadmium that is already in the soil | | | | |
| | Surface water | Increasing the salinity of fresh groundwaters | | | | |
| | Groundwater | Increasing the salinity of fresh surface waters | | | | |
| Chloride | Plants | Direct toxicity to plants when sprayed on leaves | | | | |
| | Soils | Plant toxicity via uptake through the root | | | | |
| | Surface water | Toxicity to aquatic biota | | | | |
| Sodium | Plants | Direct toxicity to plants when sprayed on leaves | | | | |
| | Soils | Plant toxicity via uptake through the root | | | | |
| | Soils | Soil structure decline due to sodicity | | | | |

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others as outlined in ANZECC & ARMCANZ (2000) for irrigation



Bolivar ASR research (led by CSIRO)



Figure 3 Location of wells and piezometers at the Bolivar site. The red dot represents the T2 ASR production well (#18777), the orange dot is the T2 observation well at 4 m (#19450), the yellow dot targets the T1 aquifer well (#19179), the white dots are T2 piezometers at 50 m, and oreen dots are observation wells at 75 m 120 m and 300 m (from Barry *et al.* 2009)







Bolivar Reclaimed Water Aquifer Storage and Recovery Project: Assessment of the Third and Fourth ASR Cycles Karen Barry, Joanne Vanderzalm, Paul Pavelic¹, Rudi Regel², Robert May², Peter Dilon, Jatinder Stidhu and Kerry Levet





Operational residual risk assessment for the Bolivar ASR recycled water project

Neus Ayuso Gabella, Declan Page, Peter Dillon, Rudi Regel, Joanne Vanderzalm, Karen Barry, and Kerry Levett

ctober 2010



Bolivar ASR research - overview

- 4 cycles of aquifer injection & recovery, into a single bore
- Numerous observations bores (4 m, T2, T1)
- Change in Bolivar WWT over the cycles
- Investigations:
 - Performance (injection rates, specific capacity, purge water management)
 - Hydraulic impacts
 - Salinity & recovery efficiency
 - Water quality in/ out & relative to agricultural requirements
 - Hydrogeological reactions (e.g. As, limestone dissolution)
 - Aquifer characterisation & capability (pump testing, storage volumes)
 - Column studies, mineralogy
 - Aquitard & bore stability
 - Targeted studies
- Research fed into drafting the national AGWR MAR (2009)

Wednesday, 13 Jan 2012 0 risk assessment as per AGWR undertaken for Bolivar



Bolivar ASR research – water quality results

Sewage – maximal risk

| | Unit | LOR | n | min | mean | median | max | 95th p. | Period | ADWG | GW ref. | LTV Irrig. | STV Irrig. | WHO DW | Mean <gl< th=""></gl<> |
|---------------------------------|-----------|--------|-----|--|--|--|--|---|---------|---------|---------|---------------|-------------------------|-----------|---------------------------|
| Physical characteristics | | | | | | | | | | | | | | | _ |
| Electrical Conductivity | dS/am | 0.001 | 188 | 0.022 | 2.0 | 2.0 | 2.6 | 2.3 | 05-2008 | | 3.7 | 0.65 1 | 0.651 | | |
| Dissolved Oxygen | mg/L | 0.1 | 405 | <lor< td=""><td>0.66</td><td>0.33</td><td>25</td><td>1.6</td><td>05-2008</td><td></td><td>0.3</td><td></td><td></td><td></td><td></td></lor<> | 0.66 | 0.33 | 25 | 1.6 | 05-2008 | | 0.3 | | | | |
| рн | pH units | 0.1 | 191 | 6.8 | 7.3 | 7.3 | 7.8 | 7.6 | 05-2008 | 6.5-8.5 | 7.0 | 6-8.5 | 6-8.5 | | |
| Suspended Solids | mg/L | 0.1 | 187 | 104 | 415 | 424 | 764 | 552 | 05-2008 | | 5.0 | | | | |
| Total Dissolved Solids | mg/L | 1 | 188 | 12 | 1103 | 1110 | 1420 | 1260 | 05-2008 | 500 | 2009 | | | | |
| Microbiological | | | | | | | | | | | | | | | |
| Cryptosporialium | oocysts/L | 1 | 24 | <lor< td=""><td>326</td><td>28</td><td>5000</td><td>747</td><td>99-2000</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<> | 326 | 28 | 5000 | 747 | 99-2000 | | | | | | |
| Giardia | cysts/L | 1 | 24 | -LOR | 2720 | 345 | 26000 | 8355 | 99-2000 | | | | | | |
| Nutrients | | | | | | | | | | | | | | | |
| Ammonia as N | mgt. | 0.005 | 186 | 22 | 44 | 45 | 54 | 51 | 05-2008 | 0.50 | 0.06 | 52 | 25- 125 ² | | |
| Biological Oxygen Demand | mg/L | 2 | 192 | 170 | 397 | 410 | 575 | 495 | 05-2008 | | | | | | |
| Chemical Oxygen Demand | mgt | 50 | 106 | 299 | 819 | 803 | 1390 | 1180 | 03-2008 | | | | | | |
| Phosphorus - Total | mg/L | 0.005 | 72 | 8 | 12 | 12 | 17 | 14 | 03-2008 | | 0.024 | 0.05 3 | 0.8-12 | | |
| Total Kjeldahl Nitrogen as N | mg/L | 0.05 | 72 | 48 | 66 | 66 | 87 | 77 | 03-2008 | | 0.064 | | | | |
| Metals, metalloids and halogens | | | | | | | | | | | | | | | |
| Aluminium Total | mgL | 0.005 | 92 | 0.010 | 5.2 | 4.7 | 15 | 11 | 03-2008 | 0.2 | 0.028 | 5 | 20 | 0.2 | |
| Antimony Total | mg/L | 0.0005 | 89 | <lor< td=""><td>0.0010</td><td>0.00090</td><td>0.0023</td><td>0.0016</td><td>03-2008</td><td>0.003</td><td></td><td></td><td></td><td>0.02</td><td>_</td></lor<> | 0.0010 | 0.00090 | 0.0023 | 0.0016 | 03-2008 | 0.003 | | | | 0.02 | _ |
| Arsenic Total | mg/L | | 92 | 0.0005 | 0.0015 | 0.0010 | 0.0050 | 0.0040 | 03-2008 | 0 | | | | | |
| Barlum Total | mg/L | 0.0005 | 17 | 0.0070 | 0.26 | 0.069 | 1.4 | 1.3 | 05-2007 | 1.1 | | | | | |
| Beryllum Soluble | mgt_ | 0.0005 | 47 | <lor< td=""><td><lor< td=""><td><lor< td=""><td>0.0025</td><td><lor< td=""><td>05-2008</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<></td></lor<></td></lor<></td></lor<> | <lor< td=""><td><lor< td=""><td>0.0025</td><td><lor< td=""><td>05-2008</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<></td></lor<></td></lor<> | <lor< td=""><td>0.0025</td><td><lor< td=""><td>05-2008</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<></td></lor<> | 0.0025 | <lor< td=""><td>05-2008</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<> | 05-2008 | | | | | | |
| Beryllum Total | mg/L | 0.0005 | 7 | <lor< td=""><td><lor.< td=""><td><lor< td=""><td><lor< td=""><td><lor< td=""><td>2006</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<></td></lor<></td></lor<></td></lor.<></td></lor<> | <lor.< td=""><td><lor< td=""><td><lor< td=""><td><lor< td=""><td>2006</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<></td></lor<></td></lor<></td></lor.<> | <lor< td=""><td><lor< td=""><td><lor< td=""><td>2006</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<></td></lor<></td></lor<> | <lor< td=""><td><lor< td=""><td>2006</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<></td></lor<> | <lor< td=""><td>2006</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<> | 2006 | | | | | | |
| Boron Soluble | mg/L | 0.04 | 74 | 0.23 | 0.39 | 0.35 | 1.4 | 0.55 | 03-2008 | | | | | | |
| Cadmium Total | mg/L | 0.0002 | 92 | 0.00025 | 0.00042 | 0.00025 | 0.0036 | 0.00095 | 03-2008 | 0 | | | | | |
| Chromium Total | mg/L | 0.003 | 92 | <lor< td=""><td>0.06</td><td>0.03</td><td>2.3</td><td>0.09</td><td>03-2008</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<> | 0.06 | 0.03 | 2.3 | 0.09 | 03-2008 | | | | | | |
| Cobalt Total | mg/L | 0.0005 | 92 | <lor< td=""><td>0.0014</td><td>0.0013</td><td>0.0031</td><td>0.0025</td><td>03-2008</td><td></td><td>Table</td><td>A-4 Rec</td><td>overed</td><td>water q</td><td>uality s</td></lor<> | 0.0014 | 0.0013 | 0.0031 | 0.0025 | 03-2008 | | Table | A-4 Rec | overed | water q | uality s |
| Copper Total | mal | 0.001 | 92 | 0.023 | 0.17 | 0.15 | 0.42 | 0.36 | 03-2008 | | | | | | |

• Drinking water: *ADWG (2004)*

- Environmental value: ANZECC & ARMCANZ (2000)
 LTV, STV
- Groundwater reference

Recycled water/ injectant

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¹ For sensitive crops; moderately sensitive 0.65-1.3, moderately tolerant 1.3-2.9. See ANZECC-ARMCANZ guidelines for ² Values given for the sum of all the inorganic nitrogen (ammonia + ammonium + nitrite + nitrate)

³ To avoid bloclogging in irrigation equipment, ⁴ For very sensitive crops: sensitive 0.5-1, moderately sensitive 1-2. See ANZECC-ARMCANZ guidelines for a detailed tolerance of different crops to avoid the sensitive crops and the sensitive 1-2. See ANZECC-ARMCANZ guidelines for a detailed tolerance of different crops to avoid the sensitive crops and the sensitive 1-2. See ANZECC-ARMCANZ guidelines for a detailed tolerance of different crops to avoid the sensitive crops and the sensitive 1-2. See ANZECC-ARMCANZ guidelines for a detailed tolerance of different crops to avoid the sensitive crops and the sensitive 1-2. See ANZECC-ARMCANZ guidelines for a detailed tolerance of different crops to avoid the sensitive crops and the sensitive 1-2. See ANZECC-ARMCANZ guidelines for a detailed tolerance of different crops to avoid the sensitive crops and the sensitive 1-2. See ANZECC-ARMCANZ guidelines for a detailed tolerance of different crops to avoid the sensitive crops are avoid to avoid to avoid the sensitive 1-2. See ANZECC-ARMCANZ guidelines for a detailed tolerance of different crops to avoid the sensitive crops avoid to avoid the sensitive 1-2. See ANZECC-ARMCANZ guidelines for a detailed tolerance of different crops to avoid the sensitive crops avoid to avoid the sensitive 1-2. See ANZECC-ARMCANZ guidelines for a detailed tolerance of different crops to avoid the sensitive crops avoid to avoid the sensitive 1-2. See ANZECC-ARMCANZ guidelines for a detailed tolerance of different crops to avoid to avoi

| | Unit | LON | | | 11741 | median | IIIdA | Jaur p. | Pellou | ADITO | Unitel. | Irrig. | Irrig. |
|---------------------------------|-----------|-------|----|---|---|---|---|---|---------|---------|---------|------------------|--------|
| Physical characteristics | | | | | | | | | | | | | |
| Electrical Conductivity | dS/cm | 0.001 | 25 | 1.9 | 2.2 | 2.3 | 2.6 | 2.5 | 02-2005 | | 3.7 | 0.65 1 | 0.651 |
| Dissolved Oxygen | mg/L | 0.1 | 6 | <lor< td=""><td><lor< td=""><td><lor< td=""><td><lor< td=""><td><lor< td=""><td>02-2005</td><td></td><td>0.30</td><td></td><td></td></lor<></td></lor<></td></lor<></td></lor<></td></lor<> | <lor< td=""><td><lor< td=""><td><lor< td=""><td><lor< td=""><td>02-2005</td><td></td><td>0.30</td><td></td><td></td></lor<></td></lor<></td></lor<></td></lor<> | <lor< td=""><td><lor< td=""><td><lor< td=""><td>02-2005</td><td></td><td>0.30</td><td></td><td></td></lor<></td></lor<></td></lor<> | <lor< td=""><td><lor< td=""><td>02-2005</td><td></td><td>0.30</td><td></td><td></td></lor<></td></lor<> | <lor< td=""><td>02-2005</td><td></td><td>0.30</td><td></td><td></td></lor<> | 02-2005 | | 0.30 | | |
| Eh | mV SHE | | 6 | -11 | 56 | 77 | 94 | 93 | 02-2005 | | 65 | | |
| pH | units | 0.1 | 17 | 7.3 | 7.8 | 7.9 | 8.2 | 8.2 | 02-2005 | 6.5-8.5 | 7.0 | 6-8.5 | 6-8.5 |
| Total dissolved solids | mg/L | 1 | 25 | 1027 | 1230 | 1238 | 1403 | 1383 | 02-2005 | 500 | 2009 | | |
| Temperature | °C | - | 6 | 12 | 18 | 18 | 23 | 22 | 02-2005 | | 25 | | |
| Turbidity | NTU | 0.1 | 25 | 0.76 | 2.7 | 1.8 | 7.9 | 7.2 | 02-2005 | 5.00 | 12 | | |
| Major ions and SAR | | | | | | | | | | | | | |
| Alkalinity as Calcium Carbonale | mg/L | 4 | 2 | 193 | | | 211 | | 02-2005 | | 305 | | |
| Bicarbonate | mg/L | 4 | 25 | 235 | 275 | 272 | 350 | 317 | 02-2005 | | 325 | | |
| Caldum | mg/L | 0.1 | 25 | 53 | 69 | 66 | 86 | 83 | 02-2005 | | 150 | | |
| Chloride | mg/L | 4 | 25 | 364 | 467 | 458 | 611 | 584 | 02-2005 | 250 | 976 | 175 ² | |
| Cyanide as CN - Total | mg/L | 0.05 | 2 | <lor< td=""><td></td><td></td><td><lor< td=""><td></td><td>2005</td><td>0.08</td><td></td><td></td><td></td></lor<></td></lor<> | | | <lor< td=""><td></td><td>2005</td><td>0.08</td><td></td><td></td><td></td></lor<> | | 2005 | 0.08 | | | |
| Magnesium | mg/L | 0.3 | 25 | 34 | 41 | 41 | 50 | 50 | 02-2005 | | 85 | | |
| Potassium | mg/L | 1 | 25 | 33 | 43 | 44 | 48 | 48 | 02-2005 | | 13 | | |
| SAR | SAR | - | 25 | 6.5 | 7.4 | 7.4 | 8.3 | 8.3 | 02-2005 | | 8 | 22 | |
| Sodium | mg/L | 0.5 | 25 | 263 | 313 | 312 | 370 | 358 | 02-2005 | 180 | 503 | 115 2 | |
| Sulphate | mg/L | 1.5 | 25 | 166 | 196 | 195 | 233 | 220 | 02-2005 | 500 | 297 | | |
| Nutrients | | | | | | | | | | | | | |
| Ammonia as N | mg/L | 0.005 | 19 | 0.0060 | 1.7 | 1.6 | 7,4 | 3.2 | 02-2005 | 0.50 | 0.060 | 53 | 2 |
| DOC | mg/L | | 14 | 6.6 | 13 | 12 | 38 | 22 | 02-2005 | | 2.9 | | |
| Nitrate + Nitrite as N | mg/L | 0.005 | 21 | 0.0090 | 0.67 | 0.64 | 2.1 | 1.9 | 2002 | | 0.0034 | 5° | 2 |
| Nitrate as N | mg/L | 0.005 | 12 | <lor< td=""><td>0.32</td><td>0.032</td><td>1.9</td><td>1.5</td><td>2002</td><td>11</td><td>0.00050</td><td>53</td><td>2</td></lor<> | 0.32 | 0.032 | 1.9 | 1.5 | 2002 | 11 | 0.00050 | 53 | 2 |
| Nitrite as N | mg/L | 0.005 | 9 | 0.0070 | 0.26 | 0.021 | 1.5 | 1.1 | 2002 | 0.91 | <0.005 | 5° | 2 |
| Phosphorus - Dissolved | mg/L | 0.005 | 14 | 0.34 | 0.90 | 0.80 | 1.6 | 1.6 | 02-2005 | | | | |
| Phosphorus - Total | mg/L | 0.005 | 25 | 0.37 | 0.86 | 0.76 | 1.9 | 1.6 | 02-2005 | | 0.024 | 0.05* | |

³ Values given for the sum of all the inorganic nitrogen (ammonia + ammonium + nitrite + nitrate).

dual Risk Assessment for the Bolivar ASR recycled water project

ASR recovered water

| | Unit | LOR | n | min | mean | median | max | 95th p. | Period | ADWG | GW ref. | LTV Irrig. | STV Irrig. | DW | Mean <gl.< th=""></gl.<> |
|----------------------------------|---------------|-------|--------|---|---|---|--------|---|---------|-------|--|---------------|-------------------------|------|-----------------------------|
| Microbiological | | | | | | | | | | | | | | | |
| Bacteria | | | | | | | | | | | | | | | |
| Enterococci * | utc/100mL | 1 | 1 | | <lor< td=""><td></td><td></td><td></td><td>2008</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<> | | | | 2008 | | | | | | |
| Ent/F.Strep - Presumptive * | utc/100mL | 1 | 1 | | <lor< td=""><td></td><td></td><td></td><td>2008</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<> | | | | 2008 | | | | | | |
| E. coll - Presumptive | cful100 mL | 1 | 244 | <lor< td=""><td>0.20</td><td><lor< td=""><td>19</td><td><lor< td=""><td>05-2008</td><td>0</td><td>0</td><td></td><td></td><td></td><td></td></lor<></td></lor<></td></lor<> | 0.20 | <lor< td=""><td>19</td><td><lor< td=""><td>05-2008</td><td>0</td><td>0</td><td></td><td></td><td></td><td></td></lor<></td></lor<> | 19 | <lor< td=""><td>05-2008</td><td>0</td><td>0</td><td></td><td></td><td></td><td></td></lor<> | 05-2008 | 0 | 0 | | | | |
| Faecal coliforms * | ufc/100mL | 1 | 2 | 6 | | | 20 | | 04-2008 | | | | | | |
| Faecal Streptococci * | uto/100mL | 1 | 1 | | <lor< td=""><td></td><td></td><td></td><td>2008</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<> | | | | 2008 | | | | | | |
| Total Coliforms * | ufc/100mL | 1 | 1 | | 110 | | | | 2004 | | | | | | |
| Protozoa | | | | | | | | | | | | | | | |
| Cryptosporialum - confirmed # | /50 L | | 13/255 | 1 | 4.42 | 4 | 12.25 | 9.8 | 05-2009 | | | | | | |
| Glardla - confirmed ## | /50 L | | 2/255 | 3 | 7.75 | 7.75 | 12.25 | 12.025 | 05-2009 | | | | | | |
| Cryptosportdlum - Presumptive ** | cysts/L | 0.02 | 72 | <lor< td=""><td>0.047</td><td>0.040</td><td>0.16</td><td>0.089</td><td>07-2008</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<> | 0.047 | 0.040 | 0.16 | 0.089 | 07-2008 | | | | | | |
| Glardia - Presumptive ** | cysts/L | 0.02 | 72 | <lor< td=""><td>0.069</td><td>0.060</td><td>0.20</td><td>0.16</td><td>07-2008</td><td></td><td></td><td></td><td></td><td></td><td></td></lor<> | 0.069 | 0.060 | 0.20 | 0.16 | 07-2008 | | | | | | |
| Disinfection | | | | | | | | | | | | | | | |
| Chlorine - Free | mg/L | 0.1 | 436 | <lor< td=""><td>1.6</td><td>1.5</td><td>5.8</td><td>3.0</td><td>05-2008</td><td>5</td><td></td><td></td><td></td><td></td><td></td></lor<> | 1.6 | 1.5 | 5.8 | 3.0 | 05-2008 | 5 | | | | | |
| Chlorine - Total | mg/L | 0.1 | 436 | 0.10 | 2.5 | 2.0 | 7.0 | 4.0 | 05-2008 | | | | | 5 | |
| Nutrients | | | | | | | | | | | | | | | |
| Ammonia as N * | mg/L | 0.005 | 34 | 0.017 | 1.1 | 0.32 | 5.5 | 3.7 | 02-2008 | | 0.06 | 53 | 25- 125 ³ | | |
| DOC. | mg/L | | 22 | 9.6 | 17 | 18 | 24 | 21 | 02-2008 | | 2.9 | | | | |
| Nitrate + Nfrite as N | mg/L | 0.005 | 55 | 0.29 | 7.9 | 6.3 | 14 | 14 | 07-2008 | | 0.0034 | 5 * | 25- 125 3 | | |
| Nitrate as N | mg/L | 0.005 | 76 | 0.28 | 8.6 | 8.1 | 14 | 14 | 07-2008 | 11 | 0.00050 | 53 | 25- 125 * | 11 | |
| Nitrite as N | mg/L | 0.005 | 59 | <lor< td=""><td><lor< td=""><td><lor< td=""><td>0.009</td><td><lor< td=""><td>07-2008</td><td>0.91</td><td><lor< td=""><td>5°</td><td>25- 125 *</td><td>0.91</td><td></td></lor<></td></lor<></td></lor<></td></lor<></td></lor<> | <lor< td=""><td><lor< td=""><td>0.009</td><td><lor< td=""><td>07-2008</td><td>0.91</td><td><lor< td=""><td>5°</td><td>25- 125 *</td><td>0.91</td><td></td></lor<></td></lor<></td></lor<></td></lor<> | <lor< td=""><td>0.009</td><td><lor< td=""><td>07-2008</td><td>0.91</td><td><lor< td=""><td>5°</td><td>25- 125 *</td><td>0.91</td><td></td></lor<></td></lor<></td></lor<> | 0.009 | <lor< td=""><td>07-2008</td><td>0.91</td><td><lor< td=""><td>5°</td><td>25- 125 *</td><td>0.91</td><td></td></lor<></td></lor<> | 07-2008 | 0.91 | <lor< td=""><td>5°</td><td>25- 125 *</td><td>0.91</td><td></td></lor<> | 5° | 25- 125 * | 0.91 | |
| Phosphorus - Dissolved * | mg/L | 0.005 | 22 | 0.016 | 2.2 | 2.0 | 5.9 | 3.8 | 02-2008 | | | | | | |
| Phosphorus - Total | mg/L | 0.005 | 10 | 0.69 | 2.2 | 2.3 | 3.5 | 3.4 | 07-2008 | | 0.02 | 0.05 * | 0.8-12 | | |
| TKN as N | mg/L | 0.05 | 11 | 2.0 | 3.0 | 2.6 | 5,3 | 4.7 | 07-2008 | | 0.06 | | | | |
| TOC * | mg/L | | 34 | 10 | 16 | 14 | 26 | 21 | 02-2008 | | 0.48 | | | | |
| Metals, metalloids and halogens | | | | | | | | | | | | | | | |
| Aluminium Totai | mg/L | 0.005 | 17 | 0.010 | 0.11 | 0.044 | 0.68 | 0.44 | 07-2008 | 0.2 | 0.028 | 5 | 20 | 0.2 | |
| Arsenic Soluble * | mg/L | - | 3 | 0.0020 | 0.0023 | 0.0020 | 0.0030 | 0.0029 | 2008 | | 0.0043 | | | | |
| Arsenic Total | mg/L | - | 17 | 0.0010 | 0.0017 | 0.0010 | 0.0040 | 0.0032 | 07-2008 | 0.007 | 0.0047 | 0.1 | 2 | 0.01 | |

Wednesday, 13 Jan 2016

Operational Residual Risk Assessment for the Bolivar ASR recycled water project

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Bolivar ASR CSIRO research – targeted studies

- Arsenic speciation/ mobilisation
- Disinfection by-products
- Trace organics
- Pathogens

APPENDIX D: HYDROCHEMISTRY CALCULATIONS

The aquifer sediments are a potential source for a number of elements that are considered in the irrigation guidelines (ANZECC & ARMCANZ, 2000). While some of these species are present at higher concentrations in the injectant than in the ambient groundwater, the soluble concentration present in the injectant is negligible when compared to the insoluble component within the aquifer sediments (Table D-1).

Aquifer storage can also lead to release of species from the sediments to the aqueous phase through hydrogeochemical processes such as calcite dissolution, pyrite oxidation and reductive iron(III) oxide dissolution. The overall impact on the concentration of metals/metalloids in the recovered water quality can be evaluated by examining the quality of recovered water in comparison to guideline values and quantifying the dominant reaction processes within the system.

Based on 11 core samples taken from the T2 aquifer, calcite constitutes 74%, quartz 18%, ankerite 5%, with traces of hematite, microcline and albite (Vanderzalm et al., 2006). Organic carbon, iron and manganese constitute low percentages.

Assuming a porosity of 0.45 and a bulk density of 1.5 g/cm³, 1 L of water occupies 2.17 L of aquifer, and 3.3 Kg of aquifer material. Using aluminium as an example, 1L of water is in contact with 4,290 mg of aluminium (3.3 Kg aquifer material x 1,300 mg/Kg Al) which is far greater that than added through injection of reclaimed wastewater during ASR injectantion. Then calculating e.g. Aluminium, the average aluminium concentration in the sediments is; if 1 L of water occupies 3.3 Kg of aquifer material, then it can be potentially released from the sediments. So, the water injected in the aquifer introduces a very low amount of aluminium compared to what it can be dissolved from the aquifer. However, the aquifer immediately surrounding the ASR well could be at risk of metal accumulation if all of the injected metal accumulate around the point of injection and are not effectively removed through backwashing procedures.

Calculating for the other metals cited in Section 4.2, the results are summarized in Table D-1.

Table D-1 Potential release of metals from the aquifer

| Metal | Injectant (mg metal/L injected water) | Ambient groundwater (mg metal /L ambient groundwater | Aquifer sediments (mg metal /Kg sediment) | Estimated concentration in contact with 1L of injectant (mg) |
|-----------|---|--|---|--|
| Aluminium | 0.11 | 0.028 | 1300 | 4290 |
| Cadmium | 0.00058 | < 0.0002 | 1 | 3.3 |
| Chromium | 0.0031 | < 0.003 | 33 | 109 |
| Copper | 0.011 | < 0.001 | 1 | 3.3 |
| Nickel We | ednesedav | .13.Jem 2016 | 7 | 23 |



Figure 27 Arsenic behaviour over duration of the third and fourth ASR cycles at Bolivar



Figure 22 Total dissolved solids (TDS) increases during the three recovery phases in relation to volume recovered



Bolivar ASR research – hazard risk assessment

Table 3 Maximal risk assessment regarding the hazards identified in the MAR guidelines

| | Human en | idpoints – | Envi | ronment endpoi | nts – |
|---|---------------------|------------------------|-----------------------|----------------------|---------|
| MAR Hazards | Crop consumption | Ingestion of sprays | Irrigation – crops | Irrigation – soil | Aquifer |
| 1. Pathogens | н | н | н | н | н |
| 2. Inorganic chemicals | н | н | н | н | н |
| 3. Salinity and sodicity | L | L | н | н | L |
| 4. Nutrients: nitrogen, phosphorous and organic carbon | L | L | н | н | н |
| 5. Organic chemicals | L | н | | н | н |
| 6. Turbidity and particulates | L | L | | н | н |
| 7. Radionuclides | U | U | | | U |
| 8. Pressure, flow rates, volumes and groundwater levels | | | | | н |
| 9. Contaminant migration in fractured rock and karstic aquifers | | | | | U |
| 10. Aquifer dissolution and stability of well and aquitard | | | | | н |
| 11. Aquifer and groundwater-dependent ecosystems | | | | | н |
| 12. Energy and greenhouse gas considerations | | | | | U |
| | | | | | |

Preventive measures:

Recycled water supply +**ASR** management +Agricultural sector

H: high risk, one or more of the parameters related to the hazard have a mean value higher than the guideline value for the end point.

U: uncertain risk - further investigations required.

L: low risk, all parameters related to the hazard have a mean value lower than the guideline value for the end point.

White: the hazard does not apply to the end point.

Table 4 Residual risk assessment regarding the hazards identified in the MAR guidelines

| | Human en | dpoints – | Envi | ronment endpoi | nts – |
|---|---------------------|------------------------|-----------------------|----------------------|---------|
| MAR Hazard | Crop consumption | Ingestion of sprays | Irrigation – crops | Irrigation – soil | Aquifer |
| 1. Pathogens | L | L | L | L | L |
| 2. Inorganic chemicals | L | L | L | L | L |
| 3. Salinity and sodicity | L | L | L | L | L |
| 4. Nutrients: nitrogen, phosphorous and organic carbon | L | L | L | L | L |
| 5. Organic chemicals | L | L | | L | L |
| 6. Turbidity and particulates | L | L | | L | L |
| 7. Radionuclides | L | L | | | L |
| 8. Pressure, flow rates, volumes and groundwater levels | | | | | L |
| 9. Contaminant migration in fractured rock and karstic aquifers | | | | | L |
| 10. Aquifer dissolution and stability of well and aquitard | | | | | L |
| 11. Aquifer and groundwater-dependent ecosystems | | | | | L |
| 12. Energy and greenhouse gas considerations | | | | | L |

H: high risk, one or more of the parameters related to the hazard have a mean value higher than the guideline value for the end point.

U: uncertain risk - further investigations required.

L: low risk, all parameters related to the hazard have a mean value lower than the guideline value for the end point.

White: the hazard does not apply to the end point.



Future presentations related to MAR

Table 5.1 Summary of key hazards in source water, groundwater and aquifer materials for managed aquifer recharge projects, with examples of specific hazards and preventive methods

| Hazard | Origin* | Examples | Preventive measures | Relevant section of document ^d |
|--|-----------|------------------------------------|--|---|
| Pathogens | S, (G) | Viruses | Adequate aquifer residence time | 5.1 |
| Inorganic chemicals | G, A, S | Arsenic | Control Eh during recharge (avoid mobilisation) ^b | 5.2 |
| Salinity and sodicity | G, (S) | Salinity | Increase volume of freshwater recharged | 5.3 |
| Nutrients | S, (G) | Nitrogen | Pretreat water (eg activated sludge) | 5.4 |
| Organic chemicals | S, (G) | Pesticides | Exclude prone subcatchments | 5.5 |
| Turbidity and particulates | S, (G) | Suspended solids | Pretreat water (eg wetland) | 5.6 |
| Radionuclides | G, A, (S) | Alpha radiation | Aquifer selection (avoidance) | 5.7 |
| Pressure, flow rates, volumes and levels | S | Waterlogging | Reduce injection pressure | 5.8 |
| Contaminant migration in fractured rock and karstic aquifers | S, (G) | PAHs⁰ | Pretreat or extend attenuation zone (exclusion) | 5.9 |
| Aquifer dissolution and aquitard and well stability | S, A | Excess sand recovery | Control pH of source water (avoid dissolution) | 5.10 |
| Impacts on groundwater-dependent ecosystems | S, A | Levels outside historical range | Avoid proximity to groundwater-dependent ecosystems | 5.11 |
| Greenhouse gases | S | Excessive energy use | Substitute passive treatments for active | 5.12 |

a A = aquifer minerals; G = groundwater; S = source water for recharge; Brackets show possible secondary source.
b Eh = a measure of redox potential — the propensity for oxidation and reduction reactions.

c PAHs = polycyclic aromatic hydrocarbons.

d See also the Phase 1 guidelines, the augmentation guidelines (NRMMC-EPHC-NHMRC 2008) and the fresh and marine water quality guidelines (ANZECC-ARMCANZ 2000a). Wednesday, 13 Jan 2016 • CSIRO (27/1/16)

- Bolivar ASR research
- Glen Harrington (10/2/16)
 - Principles of hydrogeology
 - Types of aquifers
 - Bore construction
 - Pump testing & aquifer characterisation
 - Hydrogeological modelling (pressure, solute transport)
 - MAR
 - NAP