Overview of Health Risks from Rainwater and Grey Water – an Australian Perspective

David Cunliffe, SA Health, Adelaide

Li Gao, South East Water, Melbourne

Dan Deere, Water Futures, Sydney

Rainwater and Grey Water: Regulatory Considerations

- Water availability and quality of alternative sources
- Use of water
- Private or public use
- Physical settings (e.g. large cities versus rural areas, apartment style living versus detached housing)
- Population characteristics (e.g. vulnerable populations in health care settings, aged care, child care etc)
- Magnifying features (e.g. food manufacture, restaurants)
- Management and maintenance
- Presence of public mainswater supplies (cross-connection control)

Norms

Rainwater

- If used for drinking subject to drinking water guidelines
- useful to have guidelines dealing with installation, construction and maintenance. In Australia there is a national guideline and most health agencies provide additional guidance

Greywater

- Include in recycled water guidelines dealing with uses, on-site controls (e.g. above ground irrigation, subsurface irrigation), treatment and storage
- In Australia most jurisdictions provide guidance on use of grey water and approval requirements

Case study: Rainwater (for drinking) in Sth Australia

- Background: SA arid with large open spaces. High proportion of dwellings have garden areas. Rainwater tanks are a traditional source of drinking water with tanks in 50% of all homes and 80% of rural homes.

- Government position is that rainwater tanks are low risk in most settings with consumption being a matter of individual choice. Regulation in domestic settings limited to preventing backflow into public supplies

- Focus is managing rainwater tanks in vulnerable settings including health care, childcare and food premises where provision of rainwater is subject to the Safe Drinking Water Act:
  - requirements include water safety plans with regular microbial monitoring
  - rainwater in these settings typically treated with UV disinfection

- Supply of rainwater to the public allowed as a discretionary source (allowing personal choice)

Case Study: Rainwater (non-drinking) Sth Aust

- Mandatory for all new homes or major renovations to include installation of a 1kL (or more) rainwater tank

- Rainwater tank to be fitted to one or more of:
  - washing machine
  - toilet flushing
  - hot water system

- Rainwater tank to include mainswater back-up. Cross-connection control required.

Case Study: Grey Water in Australia

- Uses can include garden irrigation in domestic settings and non-drinking uses (e.g toilet flushing) in large buildings
- Regulation varies across jurisdictions and generally increases in proportion to the type of use e.g.
    - Collection of greywater in buckets from showers/baths or temporary diversion from washing machines using hoses for use in gardens
    - Diversion systems involving installation of plumbing to divert disposal away from sewer systems. Often used in gardens without treatment. Storage generally limited to 24 hrs.
    - Collection and treatment systems with either outdoor garden use or indoor use for toilet flushing
- Approval is generally required for greywater treatment systems while diverters require approval in some jurisdictions but not others. Bucketing typically unregulated.

South East Water

Aquarevo Rainwater Case Study

- South East Water, Melbourne, Victoria, Australia
- Li Gao and Dan Deere
- Heated and disinfected for hot water uses:
    - personal washing: bathing and showering; and
    - laundry: laundry trough for handwashing and clothes washing machines.

Literature review and risk assessment

How contaminated is rainwater?

What treatment and end use combination is safe?

Literature review : how clean is rainwater?

Example of QuantiTray result from raw rural rainwater tank in Queensland, Australia

Microbial indicator data in roof-harvested rainwater from pooled Australian and NZ studies.

Indicator	Prevalence (%)	Max (orgs/100 mL)	Samples taken
Unheated roof-harvested rainwater			
E. coli	29.4	9,200	2,621
Enterococci	73.1	32,000	1,141
C. perfringens	49.4	200	86
Roof-harvested rainwater from hot water systems			
E. coli	2.1	7	902
C. perfringens	83.3	23	6

Pathogen data in roof-harvested rainwater from pooled Australian and NZ studies.

Pathogen genus or species	Prevalence (%)	Max (orgs/L)	Samples taken	Prevalence (%)	Max (orgs/L)	Samples taken
	Including DNA detection results (a gene marker without cultivation or visualisation)			Excluding DNA detection results (including only cultivation or visualisation)		
Campylobacter	3.7	43	792	1.5	43	692
Salmonella	2.7	380	768	0.6	> 1	668
Pathogenic *E. coli*	4.0	> 10	1074	4.4	> 10	974
Cryptosporidium	2.2	> 1	183	4.8	> 1	83
Giardia	8.2	3.6	183	0	0	83

Examples of outbreaks or exceedances of guideline values from Australian studies.

- 2007: 27 cases of salmonellosis among 55 attendees at a school camp due to *Salmonella* Typhimurium definitive phage type 9.
- 2005: eight cases of salmonellosis caused by a contaminated rainwater tank due to *Salmonella* Muenchen, Chester, and Subspecies 3b.
- 1997: three hospital admissions led to finding that contamination of a tank water supply led to outbreak of *Campylobacter* causing 23 suspected cases of gastroenteritis at a tourist facility.
- 1999: GP notifications led to finding that contamination of tank water supply with *Salmonella* Saintpaul caused 28 cases of gastroenteritis amongst 200 workers.
- 2007: testing of rainwater tanks showed many had levels of lead and nickel exceeding drinking water guidelines due to pollution of the airshed.
- 2005: testing rainwater tank revealed several hundred office employees, including 20 pregnant women, consumed water with elevated levels of lead and copper with lead 16 times guideline
- Various: Testing rainwater tanks in schools revealed after school holiday periods, the rainwater had created elevated copper and lead levels in first draw water samples above guidelines. Schools were required to connect to the town water supply or install a filter (for metal removal) and a UV disinfection system (for microbial inactivation).
- Testing of rainwater supplied to persons in a new multi-occupancy building revealed mercury at levels above the drinking water guidelines leading to the rainwater supply being decommissioned. Investigations and legal actions followed.

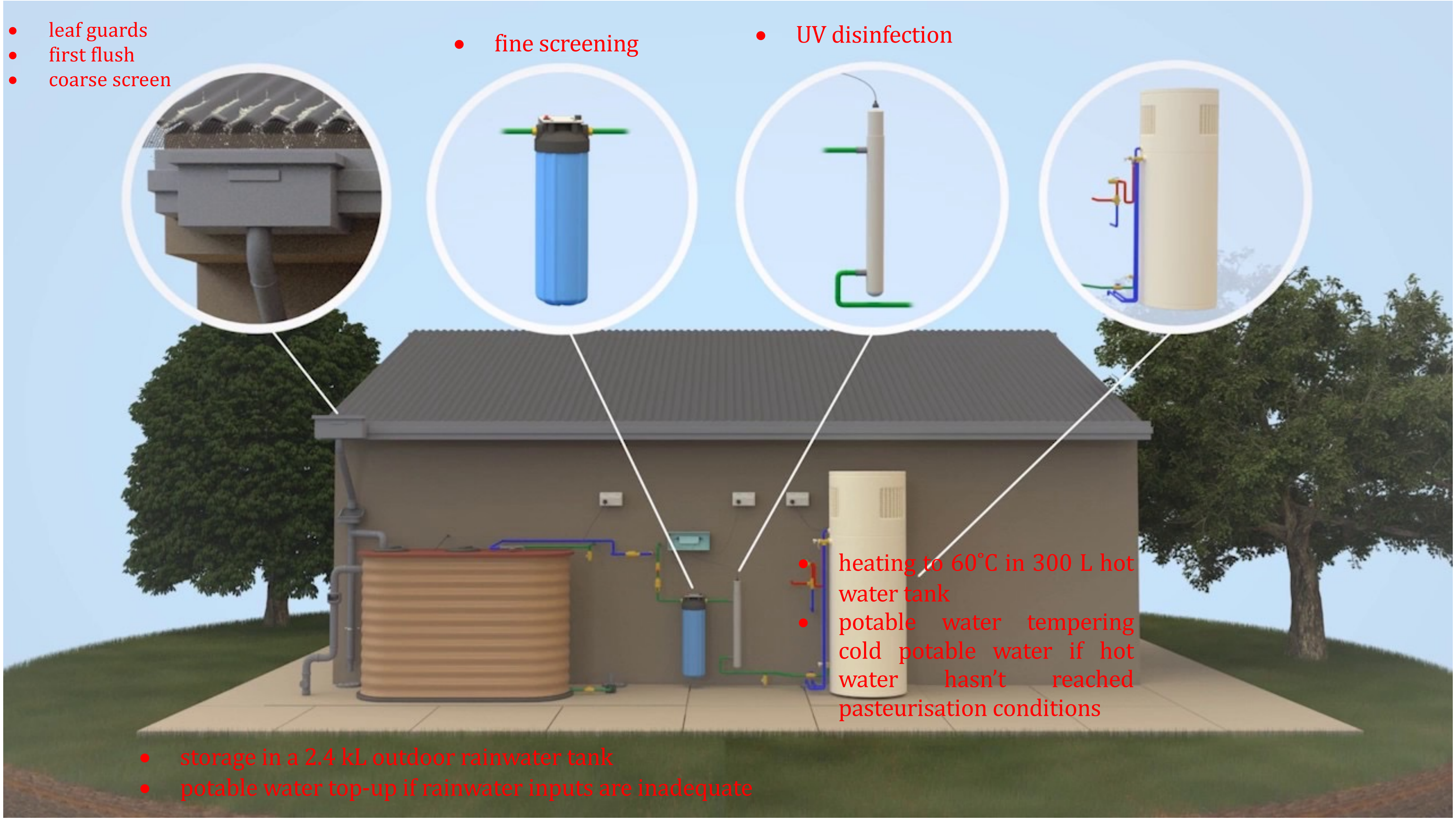
Conclusions on rain water

Raw rainwater is contaminated with bacteria

- Contamination is not extreme
- Treatment on site can reduce pathogens to safe levels
- End uses can be limited to low exposure

Rainwater can be corrosive

- Plumbing systems may leach to above guideline values
- Treatment on site can stabilise water and/or remove metals
- End uses can be limited to low exposure



leaf guards
first flush
coarse screen
fine screening
UV disinfection
heating to 60˚C in 300 L hot water tank
potable water tempering cold potable water if hot water hasn't reached pasteurisation conditions
storage in a 2.4 kL outdoor rainwater tank
potable water top-up if rainwater inputs are inadequate

Summary statistics for microorganisms in raw urban rainwater (26-Sept-2018 to 16-Dec-2021 from research by South East Water, Melbourne, Australia)

Parameter	**Count**	**% <1**	**Average**	**95%ile**	**Max**
E. coli MPN/100 mL	510	55%	84	381	> 2400
Enterococci MPN/100 mL	188	14%	298	> 2400	> 2400
Clostridium perfringens spore CFU per 100 mL	188	44%	34	61	2000
Campylobacter spp. cultivable presence/absence per 2 L	188	95%	N/A	N/A	Detect
Salmonella spp. cultivable presence/absence per 2 L	188	98%	N/A	N/A	Detect
Cryptosporidium spp. oocysts per 10 L	184	99%	< 1	< 1	1
Giardia spp. cysts per 10 L	184	100%	< 1	< 1	< 1
Legionella spp. MPN per 100 mL	188	100%	< 1	< 1	< 1
Helminth ova per 10 L	185	100%	< 1	< 1	< 1

Summary statistics for microorganisms in treated urban rainwater (26-Sept-2018 to 16-Dec-2021 from research by South East Water, Melbourne, Australia)

Parameter	**Count**	**% <1**	**Average**	**95%ile**	**Max**
E. coli MPN/100 mL	511	99.6%	< 1	< 1	1
Enterococci MPN/100 mL	187	100.0%	< 1	< 1	< 1
Clostridium perfringens spore CFU per 100 mL	187	99.5%	< 1	< 1	1
Campylobacter spp. cultivable presence/absence per 2 L	187	100.0%	< 1	< 1	< 1
Salmonella spp. cultivable presence/absence per 2 L	187	100.0%	< 1	< 1	< 1
Legionella spp. MPN per 100 mL	187	100%	< 1	< 1	< 1
Plate count CFU/mL (20˚C)	187	94%	< 1	1	7

Summary statistics for lead and nickel for hot water taps (26-Sept-2018 to 16-Dec-2021 from research by South East Water, Melbourne, Australia)

Parameter	Health-based ADWG guideline value	2019 95%ile	2020 95%ile	2021 95%ile
Lead	0.01	0.06	0.02	0.01
Nickel	0.02	0.01	0.01	0.01

Inkerman Greywater Case Study

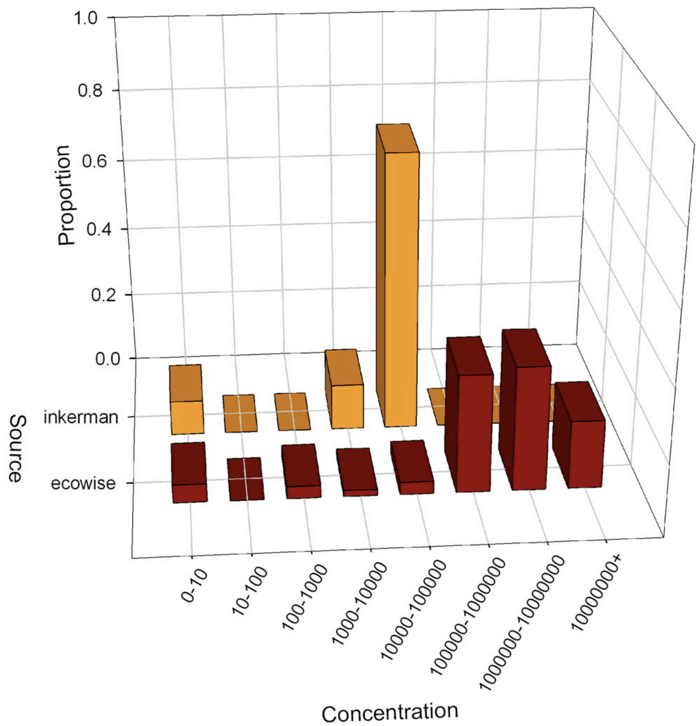
- South East Water, Melbourne, Victoria, Australia
- Li Gao, Hamish Reid, Christobel Ferguson, Peter White, Martin Krogh and Dan Deere
- Recycled greywater (MBR and UV) from bathrooms:
    - Toilet flushing; and
    - Irrigation

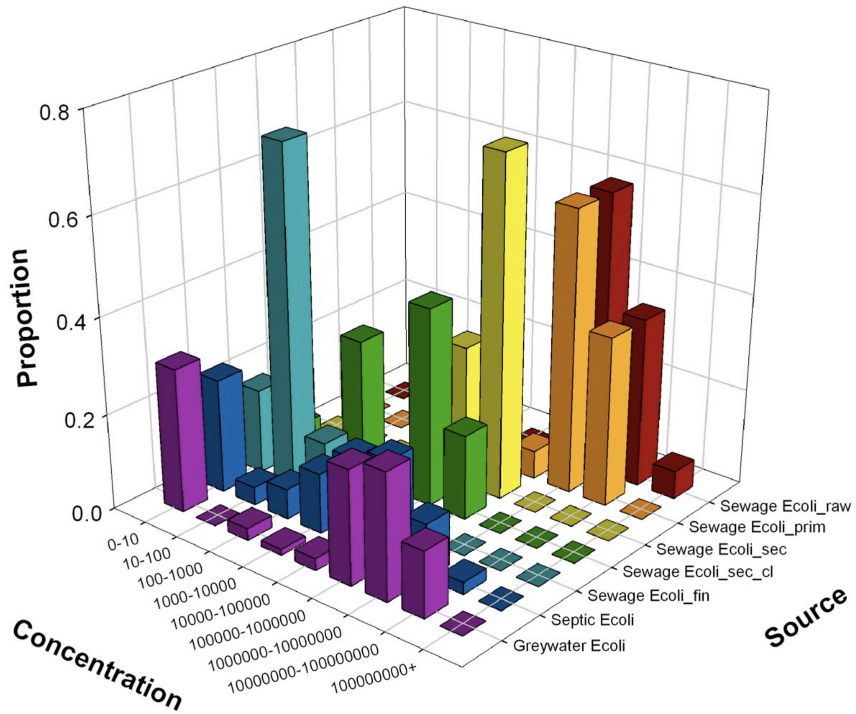
Literature review and risk assessment

How contaminated is greywater?

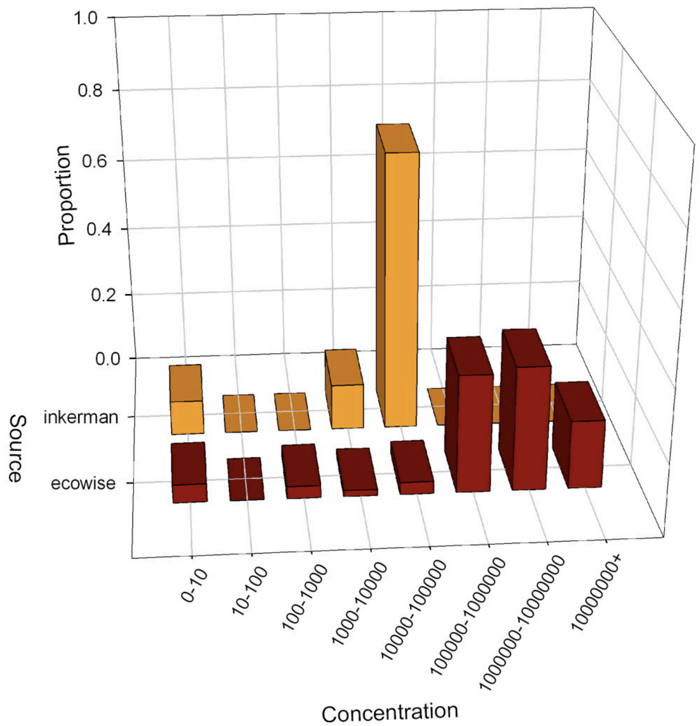
What treatment and end use combination is safe?

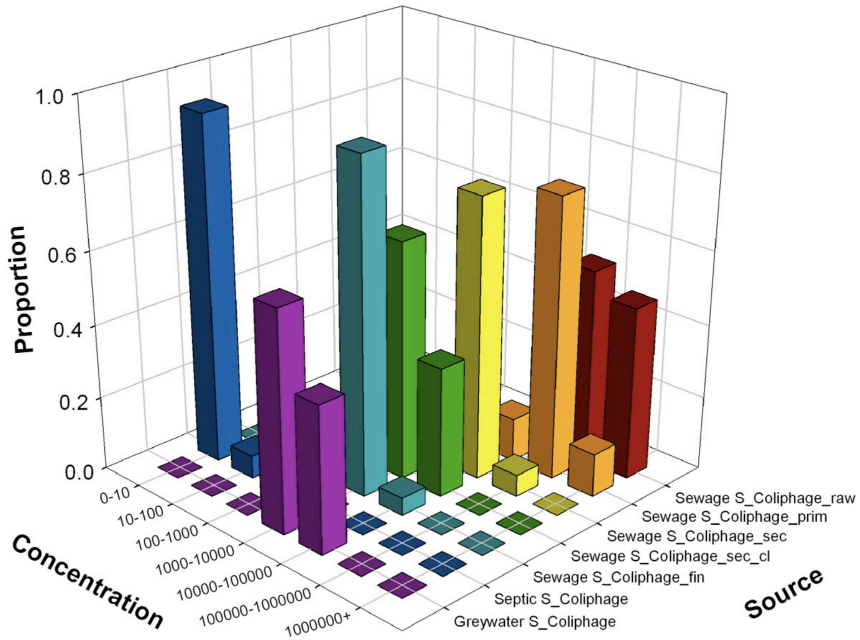
Greywater – similar to secondary sewage





Greywater – similar to secondary sewage





Shades of grey…

- Problem
  - Highly variable
  - More so than sewage or septics
- Solution
  - Identify source of variation
  - Classify grey water

Conclusions on grey water

- Grey water is contaminated
  - Contamination is highly variable
  - Raw sewage is around 100 (±100) times more contaminated
  - Grey water is more like secondary sewage but can be sporadically highly contaminated
  - Treatment on site can reduce pathogens to safe levels
  - End uses can be limited to low exposure

Reference pathogen concentrations

Class of grey water	*Escherichia coli*/100 ml	Rotavirus/L	*Crypto-sporidium* spp/L	*Campylobacter jejuni*/L	*Salmonella* spp/L
Median or 95%ile		0	0	0	0
1. Washing machine	10^3	0.92	0.02	5.0	2.0
2. +Adults	10^4	9.2	0.20	50	20
3. +Children	10^5	92.4	2.00	500	200
4. +Kitchen	10^6	92.4	2.00	1500	1200
5. +Storage	10^7	92.4	2.00	1500	2200
Max	10^8	10^8	10^6	10^7	10^7
Sewage 95%ile	10^8	8,000	2,000	7,000	

Inkerman system assumptions and treatment requirements

Pathogen	Tolerable dose ppy (pathogen)	Exposure ppy (ml)	Target pathogen /L	Source pathogen /L (Class 3)	Log_{10} reduction
Cryptosporidium hominis	1.6×10^{-2}	11	1.45	2	0.2
Rotavirus	5.5×10^{-3}	11	0.5	95	2.3
Campylobacter jejuni	4.0×10^{-2}	11	3.6	501	2.1

Final conclusions