Sustainable Use of Greywater in Small-Scale Agriculture and Gardens in South Africa

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1-September-2011

Another project sponsored by www.wrc.org.za

What is greywater?

- All non-toilet domestic wastewater
  - Bath / shower / hand basin
  - Laundry
  - Kitchen
- Toilet wastewater (blackwater) NOT included
- Some definitions also exclude kitchen wastewater





Uncontrolled greywater is an environmental and health hazard

Photo credit: K. Carden

Why use greywater for irrigation?

- Water scarcity

- Pollution pressure on freshwater sources

- Potential benefit of greywater use for irrigation
  - environmental
  - water, nutrients
  - food security, informal employment

Concerns about the use of greywater for irrigation

- Human health considerations
- Plant growth and yield
- Ability of soil to support plant growth

- Surface water
- Effects on wastewater strength

Legislative Context

- Standards for wastewater discharge and irrigation
- Guidelines for wastewater reuse
- South African Water Quality Guidelines
- Sanitation policy
- National Building Regulations

- BUT greywater disposal and use are not addressed specifically
- *Legal status of greywater use needs to be clarified*

- WRC projects on greywater management/use

Regulations and Guidelines Worldwide

- Australia: Victoria
- USA: Arizona
- USA: California
- World Health Organisation





Methods: Underpinning principles

- Intended users:
  - Municipalities
  - Informed potential greywater users
- Focus:
  - *Irrigation use of greywater ONLY*, not general greywater management
- Goal:
  - Minimise risks of illness
  - Minimise risks of reduction in plant growth or yield
  - Minimise risks of reduction in the ability of soil irrigated with greywater to support plant growth





Methods: Process

- Survey of national and international literature (→ background studies)
- Consultation
- Identification of greywater constituents for quality limits
- Draft quality guidance limits, and review
- Draft of all sections of guidance: uncertainty and risk ; greywater water quality; greywater quality mitigation; greywater quantity
- Review
- Capacity building and feedback
- Finalisation of guideline





Guidance for greywater irrigation

- Guide to Managing Uncertainty and Risk
  - Category 1: No greywater analysis
  - Category 2: Minimum greywater analysis
  - Category 3: Full greywater analysis
- Greywater Quality: Guide to Greywater Constituents
  - Rationale underlying choice of constituents
  - Greywater constituents and guideline limits
- Greywater Quality: Mitigation of Greywater Quality
  - Integrated mitigation practices
  - Greywater treatment systems
- Greywater Quantity: Guide to Irrigation Volumes
  - Estimating plant water use
  - Look-up tables by season and climatic region
  - Adjusting for site-specific factors

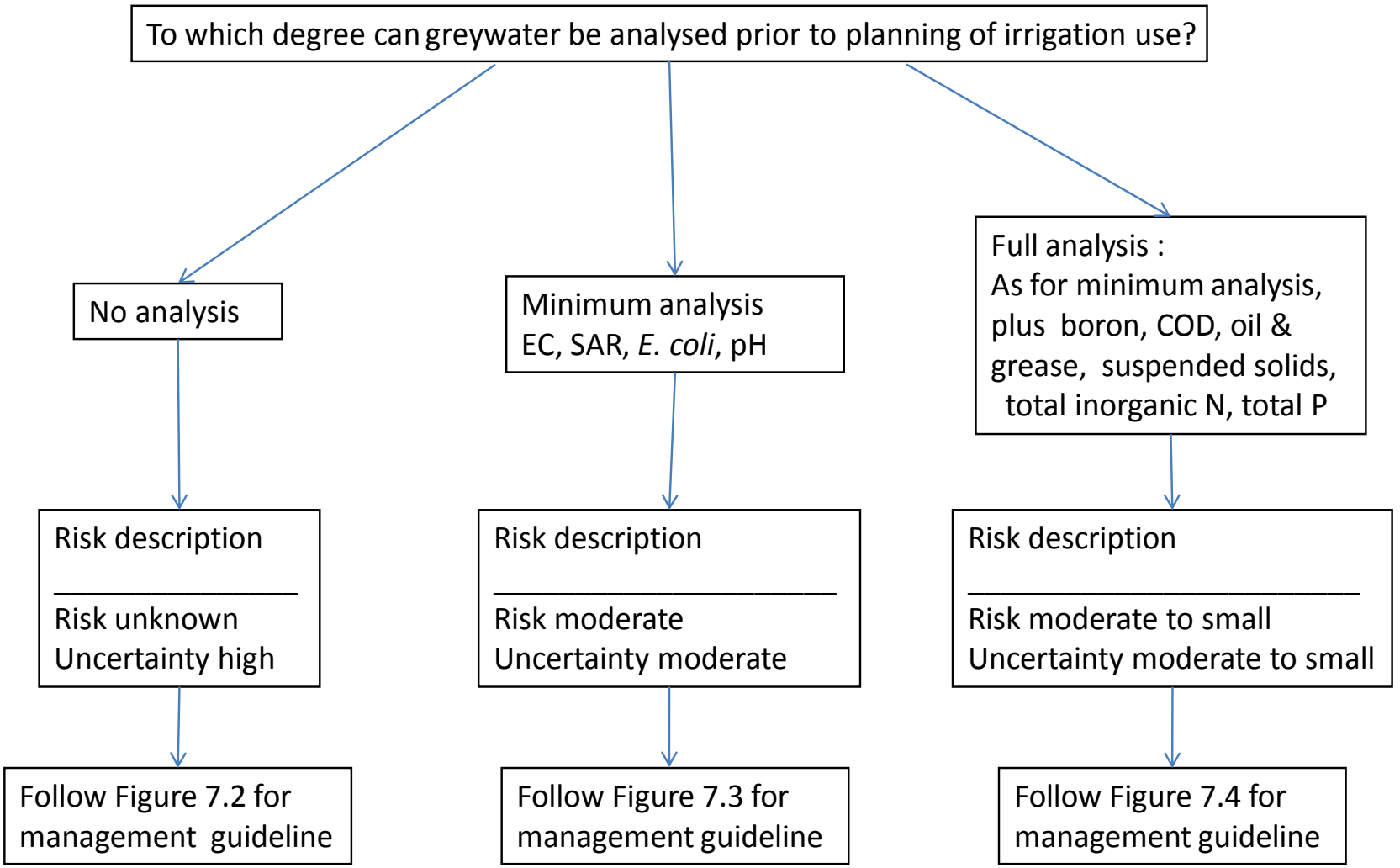


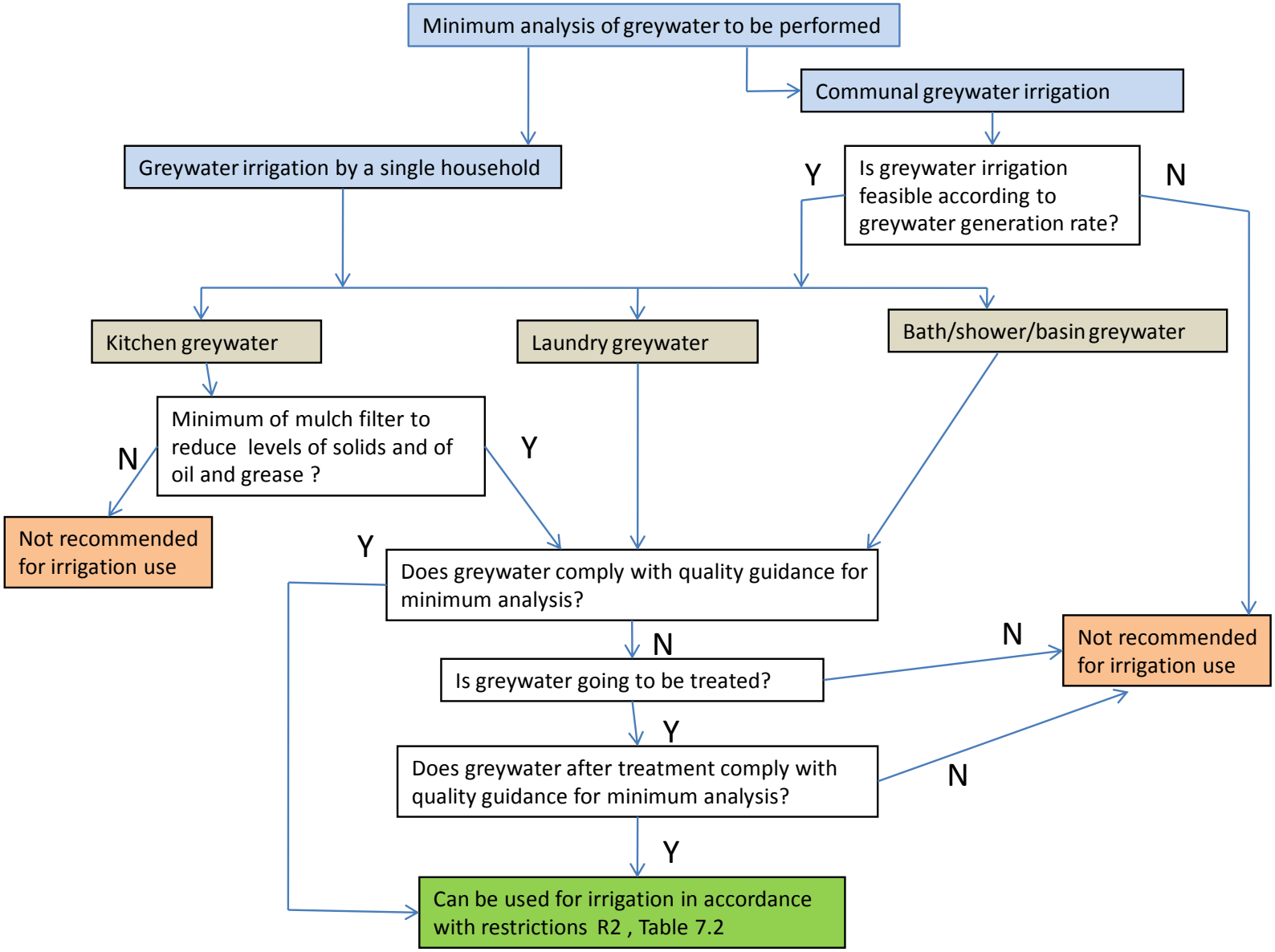


- Risk is the probability of a defined adverse effect occurring in an exposed population.
- Uncertainty refers to the degree of confidence associated with the estimate of risk.






To which degree can greywater be analysed prior to planning of irrigation use?
No analysis
Minimum analysis
EC, SAR, E. coli, pH
Full analysis :
As for minimum analysis, plus boron, COD, oil & grease, suspended solids, total inorganic N, total P
Risk description
Risk unknown
Uncertainty high
Risk description
Risk moderate
Uncertainty moderate
Risk description
Risk moderate to small
Uncertainty moderate to small
Follow Figure 7.2 for management guideline
Follow Figure 7.3 for management guideline
Follow Figure 7.4 for management guideline


Minimum analysis of greywater to be performed
Communal greywater irrigation
Greywater irrigation by a single household
Y
Is greywater irrigation feasible according to greywater generation rate?
N
Kitchen greywater
Laundry greywater
Bath/shower/basin greywater
Minimum of mulch filter to reduce levels of solids and of oil and grease ?
N
Y
Not recommended for irrigation use
Y
Does greywater comply with quality guidance for minimum analysis?
N
N
Not recommended for irrigation use
Is greywater going to be treated?
Y
Does greywater after treatment comply with quality guidance for minimum analysis?
N
Y
Can be used for irrigation in accordance with restrictions R2 , Table 7.2

Restrictions R1, applicable to greywater use in Category 1

Restrictions relating to health impact

Do:

- ✓ Wash hands and arms well with soap after handling greywater.
- ✓ Use bathwater water and laundry rinse water only.
- ✓ Use all greywater within 24 hours of collection.
- ✓

Do not:

- × Do not use greywater falling in this category of use restrictions for any form of communal gardening.
- × Do not use greywater if someone in the household has an infectious disease.

Restrictions relating to impacts on plant growth and yield

Restrictions relating to soil and environmental deterioration





Greywater quality: Guide to greywater constituents

- **Minimum analysis:**
  - Electrical conductivity
  - Sodium adsorption ratio
  - Faecal coliforms/*E. coli*
  - pH
- **Full analysis:** As for minimum analysis, plus
  - Boron
  - COD
  - Oil & grease
  - Suspended solids
  - Total inorganic nitrogen
  - Total phosphorus





Greywater constituent	Greywater quality / risk ranges			
	Target water quality range	**Maximum water quality range (applicable only to well-drained, chemically stable soils)**	**Water quality suitable only for short-term use on site-specific basis.[1]**	**Water quality not recommended for irrigation use**
	Suitable for unrestricted use with minimal risk to human health, plants or soil	**Increasing risk to human health, plants or soil**	**Significant risk to human health, plants or soil; tolerable for short-term use only**	**Excessive risk to human health, plants or soil**
Physical constituents				
Electrical conductivity (mS/m)	< 40	40 – 270	270 – 540	> 540
Oil and grease (mg/ℓ)	< 10	10 – 20	> 20	> 20
pH	6.5 – 8.4			< 6.5, > 8.4
Suspended solids (mg/ℓ)	< 50	50 – 100	> 100	> 100
Chemical constituents				
Boron (mg/ℓ)	< 0.5	0.5 – 4.0	4.0 – 6.0	> 6.0
Chemical oxygen demand (COD, mg/ℓ)	< 250	250 – 5 000	> 5 000	> 5 000
Sodium adsorption ratio[2] (SAR)	< 2.0	2.0 – 5.0	5.0 – 15.0	> 15.0
Total inorganic nitrogen (mg/ℓ)	< 10	10 – 20	20 – 60	> 60
Total phosphorus (mg/ℓ)	<10	10 – 15	15 – 50	> 50
Microbiological constituent				
E. coli (colony-forming units, CFU/100 mℓ)	< 1	$1 – 10^3$ (1 – 1 000)	10^3 - 10^7 (1 000 – 10 000 000) *Note: Only with appropriate exposure restrictions – see text*	$> 10^7$ (> 10 000 000)





Greywater quality: Mitigation of greywater quality

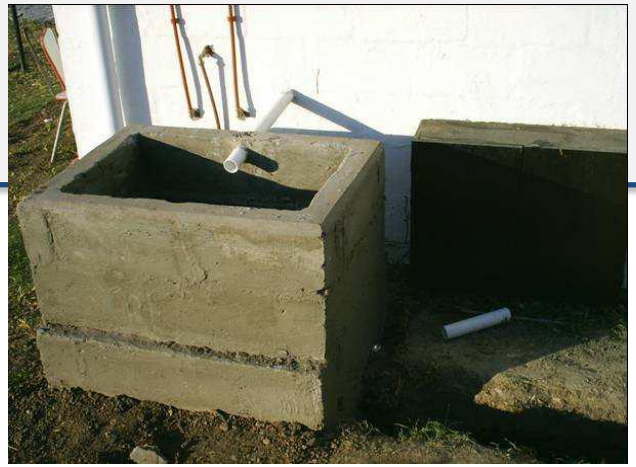
- Integrated mitigation practices
  - physico-chemical greywater constituents
  - part of plant/crop cultivation
  - Examples: sub-surface irrigation, addition of fertiliser, addition of gypsum; growing tolerant plants

- Treatment systems
  - suspended solids, oil and grease, COD and health-related bacteria
  - Examples: simple filtration; mulch tower; biological treatment; tower gardens/'agritubes'

Examples of greywater quality mitigation

Low technology sub-surface irrigation system

Photo credits (clockwise): L. Salukazana; C. Buckley; S. Jackson

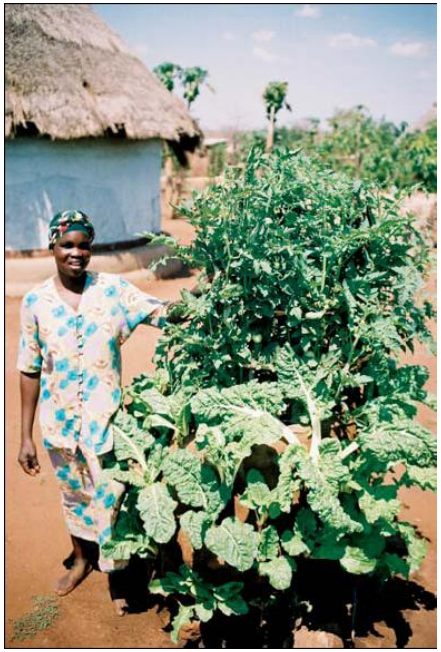


Mulch tower for treatment of greywater

Mulch tower and resorption bed

Photo credits:
K. Whittington-Jones (top);
P. Naicker (left)

Another project sponsored by www.wrc.org.za



Tower garden

"Agritube"

Photo credits: S. Crosby (above left); N. Alcock (above)

Greywater quantity: Guide to irrigation volumes

- Broad guidance on the amount of greywater that can be applied. Should be seen in the context of existing knowledge of good irrigation and plant cultivation practices.

- Basic estimate of volume

$$EWU = E_0 \times CF \times HA$$

EWU is estimated water use
E_0 is reference evapotranspiration (mm/day)
CF is crop factor (high crop factor → high water use)
HA is area irrigated (m^2)





Clustering of climatic zones by mean rainfall and temperature to determine E_0

Climatic Region	Province	Weather Station	E_0 Summer mm/day	E_0 Winter mm/day
Hot and arid	Northern Cape	Upington	12.7	5.0
		Okiep	10.7	5.3
		Calvinia	6.2	2.0
	North West	Mafikeng	9.4	6.0
Hot and semi-arid	Limpopo	Pietersburg (Polokwane)	8.0	5.5
Temperate and semi-arid	Western Cape	Elgin	5.8	3.0
		Oudtshoorn	8.1	3.4
		Vredendal	7.9	3.6
	Free State	Bloemfontein	8.2	3.1
	Mpumalanga	Loskopdam-Groblersdal	7.9	4.0
Temperate and non-arid	Gauteng	Jan Smuts (OR Thambo) Airport	7.1	4.9
	Eastern Cape	Dohne	6.1	4.9
	KwaZulu-Natal	Mount Edgecombe	5.3	3.0
		Vryheid	6.6	4.9

Estimated water use (EWU) based on climatic factors only

			Litres Per Day – Summer		
			Land area (sq. m)		
Representative weather station	**Summer E0**	**CF**	**5**	**10**	**20**
Upington	12.7	0.3	19	38	76
	12.7	0.5	32	64	127
	12.7	0.8	51	102	203

Numerical factors and / or precautions provided to adjust EWU for site-specific factors: soil type, crop coverage and recent rainfall

$EWU_{adjusted}$ =

(EWU x CC) – (mm rainfall in preceding 24 hours x HA)

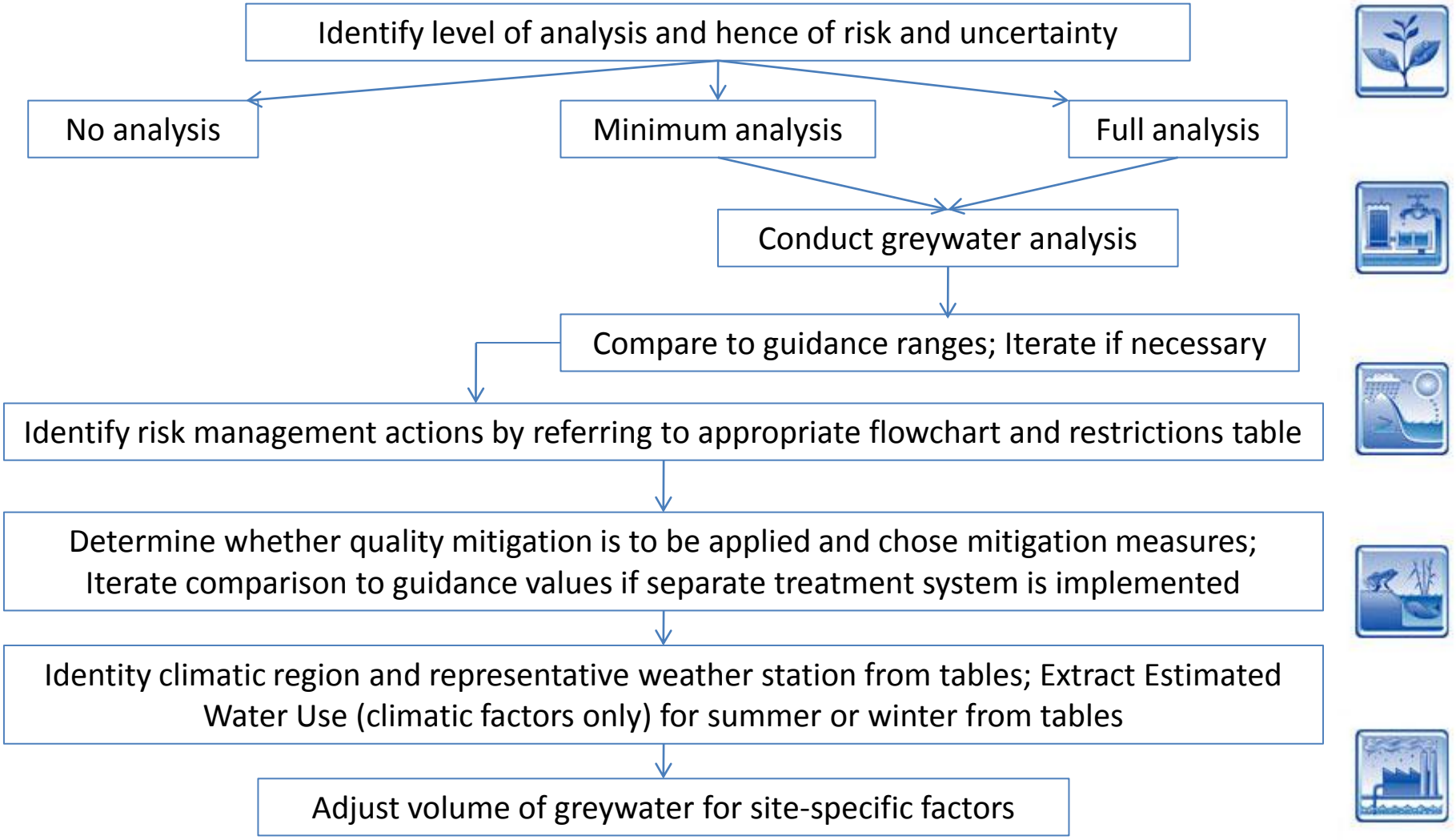
EWU is estimated water use as per look-up tables

CC is crop coverage factor (from a table)

HA is area to be irrigated (measured in m^2)

Greywater application rate and frequency are adjusted for soil type

Summary


Identify level of analysis and hence of risk and uncertainty
No analysis
Minimum analysis
Full analysis
Conduct greywater analysis
Compare to guidance ranges; Iterate if necessary
Identify risk management actions by referring to appropriate flowchart and restrictions table
Determine whether quality mitigation is to be applied and chose mitigation measures; Iterate comparison to guidance values if separate treatment system is implemented
Identity climatic region and representative weather station from tables; Extract Estimated Water Use (climatic factors only) for summer or winter from tables
Adjust volume of greywater for site-specific factors

Challenges

- National level
- Municipal level
- Settlement level
  (informal settlements)





Acknowledgements

- Water Research Commission
- Students of School of Biological and Conservation Sciences, UKZN
- Background studies co-funded by research partners
  - eThekwini Municipality
  - National Research Foundation
  - Stockholm Environment Institute