Abertay University

An Evaluation of Water Treatment Technologies for Sustainable Rural Communities.

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Outline

- Introduction
- Purpose of the Research
- Decision support process and actors
- Findings
- Recommendations

Challenges

- Rural communities in Scotland
  - Development and growth dependent on access to clean reliable drinking water source
    - Small Commercial activities (tourism, food and drink, whisky!)
    - Housing
- Landscape – multiple diffuse pressures on drinking water sources
    - Agriculture
    - Peatlands
    - Septic tanks

Drinking water quality in Scotland

Private water supplies:

Type A: (50+, commercial) – Monitored and failures reported

Type B: Domestic premises only – Monitoring not required

Parameter	Public supply (% compliance)	Type A – Private (% compliance)	Type B - Private (% compliance)
Overall compliance	99.89	93.97	87.86
Coliform bacteria	99.55	75.77	56.88
E. coli	99.99	[illegible]	78.37
Colour	100.00	[illegible]	83.18
pH	99.98	83.21	73.21
Iron	99.63	86.56	85.94
Manganese	99.70	92.70	87.73

Colour, peat, organic acids + Chlorine = Disinfection by-products

Table 1 Compliance with drinking water quality parameters in Scotland 2014

Are the benefits of improvement of rural small water supplies worth the costs?

Who is the decision maker?

What do they base their decision on?

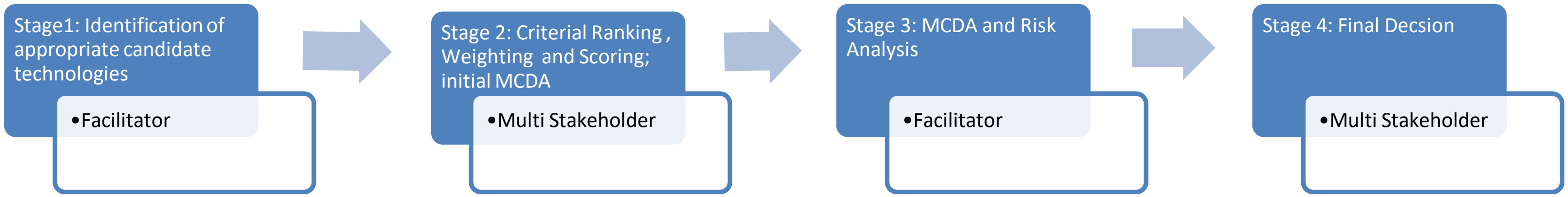
Our work

- Technology scan – what technologies are potentially suitable to provide treatment
- Consultation with experts, generation of a Technology Inventory suited to Scottish rural water treatment issues
- Identification of Criteria
- Short-list of technologies for a specific site
- Decision making workshop with key stakeholders

Deliverables

- The principle deliverables:
- An Inventory of small to medium sized water treatment technologies that are appropriate for Rural Communities (the Technology Inventory)
- A set of SRC drinking water technology selection criteria
- A decision support process and tool that utilises data from the Technology Inventory to enable stakeholders to rank potential technologies and hence to recommend the most appropriate for Sustainable Rural Communities

Stages in the decision support process and actors



Sustainability theme	Criteria	Description	Units
Economic	Capital Cost	Capital cost of equipment and install	£
	Maintenance Cost	Maintenance costs per year	£/year
	Operational Cost	Operational cost (e.g. consumables, energy)	£/year
Social	Affordability	Ability of householders to pay for services delivered	% of household budget
	Willingness to pay	Willingness to pay for attributes covering environmental , safety and health factors	£/unit of reduced risk
Technological/ performance	Complexity (user input required)	Basic, intermediate or advanced skill or low medium or high frequency of input	basic/int/adv or low/med/high
	Adaptability	Level of accommodation in design: potential and ability to accommodate future changes (qualitative)	1-5
	Reliability, ability to achieve compliance	Ability to meet drinking water quality standards (parameter specific - no treatment, good, very good, excellent/complete treatment)	0, +, ++, +++
	Durability	Design life, years expected to operate successfully	years
Environmental	Water resource use	Consumption of raw water resources	% recovery
	Energy use	Energy required in process	kWh/m^3
	Chemical use	Chemical use (qualitative or quantitative)	yes/no or kg/m^3
	Chemical transport requirement	Impact on air quality (sulphur dioxide, nitrous oxide emissions) and climate change (CO_2 emissions)	yes/no or $miles/m^3$
	Impact on water environment	Discharge of waste water from process	low/med/high
	Solid waste produced	Sludge, chemical waste streams	low/med/high or tonnes/year
	Physical footprint	Size of treatment plant	m^2
	Visual impact	Local visual impact	low/med/high

Example of a populated technology inventory with data

Activity 3A: Individual decision on technology ranking
Rank the technology against each criteria. 1 = Worst to 9 = Best

	Economic			Social			Performance			Environmental							
Technology	Capital cost (£)	Maintenance Cost (£/yr.)	Operational Cost (£/yr.)	Affordability cost per year per household	Willingness to pay	User input required (complexity)	Adaptability	Reliability (ability to achieve compliance) (--, -, +, ++, +++)	Durability	Resource utilisation (Water % recovery)	Energy use (kWh/m^3)	Chemical use (kg/m^3)	Chemical transport requirement	Impact on water environment	Waste	Physical footprint (m^2)	Visual impact (Low, med, high)
Ceramic membrane filter	£11000-£21000 (About 16% higher than MF)	£ 150.00	£ 300.00	£4.50	Very willing Willing Neutral Unwilling Very unwilling	Safe handling of membranes, periodic monitoring and inspection	Can accommodate higher flux than polymer membrane, therefore can achieve more per m^2 surface area, however they are more expensive.	Fe/Mn +/+ Heavy metals - Organics - Bacteria +++ Viruses - Protozoa +++ Taste/Odour -/- Turbidity +++	Able to accommodate higher flux, membrane life time up to 20 years	97-99.9%	0.1-0.2 kWh/m^3	Low (may be used in cleaning e.g. citric acid, NaOCl)	minimal, cleaning chemicals	about 1% wastewater	Low	Small	Low
Microfiltration	£5000-£18500	£ 150.00	£ 400.00	£6.50	Very willing Willing Neutral Unwilling Very unwilling	Periodic monitoring and inspection, replacement of filter (cartridges or modules)	Suitable for small community; can be modular; Scalable by addition of modules	Fe/Mn +/+ Heavy metals -- Organics -- Bacteria +++ Viruses- Protozoa +++ Taste/Odour -/- Turbidity +++	Membrane life 7 to 8 years or less depending on source water. Membrane integrity testing required periodically to check for wear or damage.	92 to 95% average	0.22-0.9 kWh/m^3	Low (some may be used in cleaning)	minimal, cleaning chemicals	about 5-8% wastewater	Low	Small to med (larger than ceramic)	Low
Sand filtration	£27000-£31000	£ 100-2545	£438	£ 5-30	Very willing Willing Neutral Unwilling Very unwilling	Skimming top layer of sand, once per year, and washing for reuse	Once installed may not be easy to expand capacity, May require to add additional system (or have sufficient redundancy built into design)	Fe/Mn ++/++ Heavy metals - Organics - Bacteria ++ Viruses ++ Protozoa ++ Taste/Odour ++/++ Turbidity +++	Very durable, low tech system. Periodic skimming and renewal of sand may necessitate two filters. Requires start up period for biofilm layer to form.	>99.5	minimal	nil (non chemical method)	None	minimal	Low	Med-large ($9m^2$)	Med

Note: Estimates based on Average Scottish consumption (150 litres per person per day) and small community system (up to 100 homes, 200 pe) = 200 x 150 x 365 = 10,950,000 litres or 10950 m^3 per year. Data provided are not absolute, and provided for comparison purposes only.

Stakeholder MSDA workshop

- Technology expert, local residents, enterprise agency, water company representative
- Stakeholders determined the weighting of each category and each criteria
- Stakeholders discussed and ranked each technology against criteria (0-100)

Normalised Criteria weights

Group A			Group B		
Criteria	Weights	Normalised	Criteria	Weights	Normalised
Capital Cost	12.5	0.125	Capital Cost	10	0.1
Maintenance Cost	7.5	0.075	Maintenance Cost	6.25	0.0625
Operational Cost	5	0.05	Operational Cost	8.75	0.0875
Affordability	12.5	0.125	Affordability	8.75	0.0875
Wiliness to pay	7.5	0.075	Wiliness to pay	10	0.1
User input required	5	0.05	User input required	6.25	0.0625
Adaptability	4.5	0.045	Adaptability	7	0.07
Reliability	16.5	0.165	Reliability	15.75	0.1575
Durability	9	0.09	Durability	12.25	0.1225
Resource utilisation	4	0.04	Water resources	1.5	0.015
Energy requirement	2	0.02	Energy requirement	0.75	0.0075
Chemical use	3	0.03	Chemical use	3	0.03
Chemical transport	1.4	0.014	Chemical transport	3	0.03
Impact of water	4	0.04	Impact of water	0.75	0.0075
Waste	2	0.02	Waste	1.5	0.015
Physical footprint	1.6	0.016	Physical footprint	2.25	0.0225
Visual impact	2	0.02	Visual impact	2.25	0.0225
	100	1		100	1

Outcomes

- Decision was the same for two separate groups
- Stakeholders found exercise surprising – technology experts had not considered local needs/priorities; Community members did not have much prior knowledge of the technology
- Investment cost was important, but other features much more important locally.

Range of consensus scores for Economic, Social and Technical Performance Criteria

Technology	Criteria								
	Economic			Social			Performance		
	Capital Cost	Maintenance Cost	Operational Cost	Affordability	Willingness to Pay	User Input Required	Adaptability	Reliability	Durability
Ceramic membrane filter	7	1	1	1	3	4	3	5	9
	9	1	6	5	9	5	6	6	8
	7	9	9	9	3	4	7	9	9
	2	7	8	7	7	6	8	8	7
	7	9	9	9	7	1	6	9	9
Ceramic membrane filter Consensus	7	9	9	9	9	1	6	9	9
Microfiltration	9	2	3	3	3	9	9	1	4
	9	1	7	4	9	5	8	4	6
	8	9	4	4	3	1	9	7	5
	8	7	3	5	7	6	9	7	5
	9	9	2	1	5	4	9	5	1
Microfiltration Consensus	9	9	2	1	7	4	9	5	1
Sand filtration	1	9	9	9	1	1	1	9	1
	1	9	8	2	9	8	2	5	7
	1	1	1	1	1	9	1	4	5
	2	1	2	3	3	8	7	9	9
	1	1	1	4	3	9	1	1	8
Sand filtration Consensus	1	1	1	4	1	9	1	1	8

Scoring of Alternatives

	Economic			Social			Technical/Performance			Environmental								
	0.13	0.08	0.05	0.13	0.08	0.05	0.05	0.17	0.09	0.04	0.02	0.03	0.01	0.04	0.02	0.02	0.02	Weight
	capital	maint.	oper.	afford	willing	U/I	adapt.	reliab.	durab.	resource	energy	chem	chem tran	impac t	waste	physical	visual	Av.
tech stage 1	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	
Ceramic	5	9	9	9	9	8	2	4	7	6	1	1	1	6	9	9	9	
Micro	9	9	5	5	6	9	9	1	1	1	3	1	1	1	9	5	9	
Sand	1	1	1	1	1	1	1	9	9	9	9	9	9	9	9	1	1	
Ceramic	0.63	0.68	0.45	1.13	0.68	0.40	0.09	0.66	0.63	0.24	0.02	0.03	0.01	0.24	0.18	0.14	0.18	6.38(1)
Micro	1.13	0.68	0.25	0.63	0.45	0.45	0.41	0.17	0.09	0.04	0.06	0.03	0.01	0.04	0.18	0.08	0.18	4.86(2)
Sand	0.13	0.08	0.05	0.13	0.08	0.05	0.05	1.49	0.81	0.36	0.18	0.27	0.13	0.36	0.18	0.02	0.02	4.35(3)
tech stage 2																		
chemical	1	1	1	1	1	1	9	1	1	9	9	1	1	1	9	1	1	
UV	8	9	6	9	7	7	1	8	9	9	1	9	9	9	1	9	9	
UVC-LED	9	9	9	8	9	9	1	9	7	9	5	9	9	9	5	9	9	
chemical	0.13	0.08	0.05	0.13	0.08	0.05	0.41	0.17	0.09	0.36	0.18	0.03	0.01	0.04	0.18	0.02	0.02	2.00(3)
UV	1.00	0.68	0.30	1.13	0.53	0.35	0.05	1.32	0.81	0.36	0.02	0.27	0.13	0.36	0.02	0.14	0.18	7.63(2)
UVC-LED	1.13	0.68	0.45	1.00	0.68	0.45	0.05	1.49	0.63	0.36	0.10	0.27	0.13	0.36	0.10	0.14	0.18	8.18(1)
tech stage 3																		
pH - lime	1	9	1	1	1	1	9	9	9	9	9	1	1	1	9	9	9	
pH - chem	9	1	9	9	9	9	1	1	1	9	1	9	9	9	9	9	9	
pH - lime	0.13	0.68	0.05	0.13	0.08	0.05	0.41	1.49	0.81	0.36	0.18	0.03	0.01	0.04	0.18	0.14	0.18	4.93(2)
pH - chem	1.13	0.08	0.45	1.13	0.68	0.45	0.05	0.17	0.09	0.36	0.02	0.27	0.13	0.36	0.18	0.14	0.18	5.84(1)

Workshop findings

- The process of reaching consensus amongst delegates at the decision making workshop identified the range of priorities and values different stakeholders place on different criteria with relation to drinking water criteria.
- All delegates found that discussion of the technologies assisted in enhancing knowledge about technologies application, but also in recognising issues that they may previously have discounted as unimportant

Conclusions

- Technology landscape is complex, multiple options for treatment
- MCDA is useful tool for water treatment decision making on best treatment for a specific location
- No one-size fits all system – must take into account local treatment needs, technology suitability and local concerns


Thank you for listening!