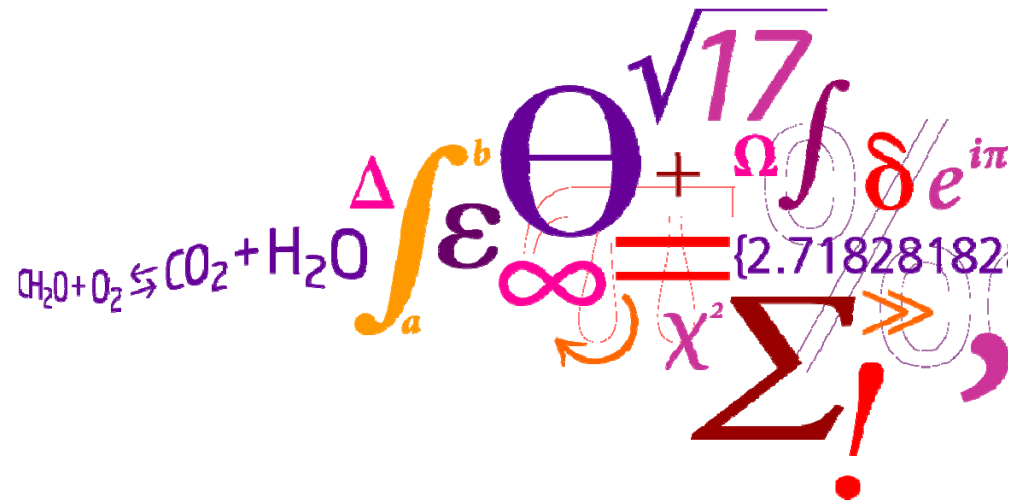




Economic assessment of water quality & Copenhagen's water future

Martin Rygaard, Hans-Jørgen Albrechtsen, Erik Arvin & Philip Binning
Technical University of Denmark



Five roads to increased self-sufficiency

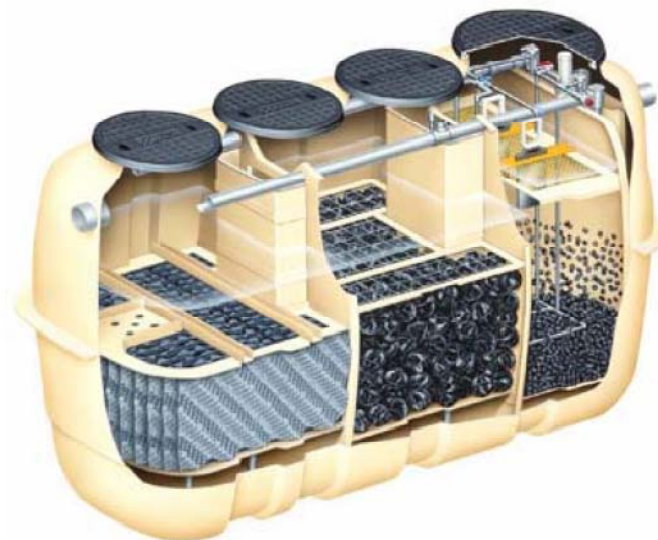


113 cases

- A. Water savings
- B. Recirculation of used water
- C. Use of polluted/remediated GW
- D. Desalination of local saline waters
- E. Rainwater collection



Amagerværket, København

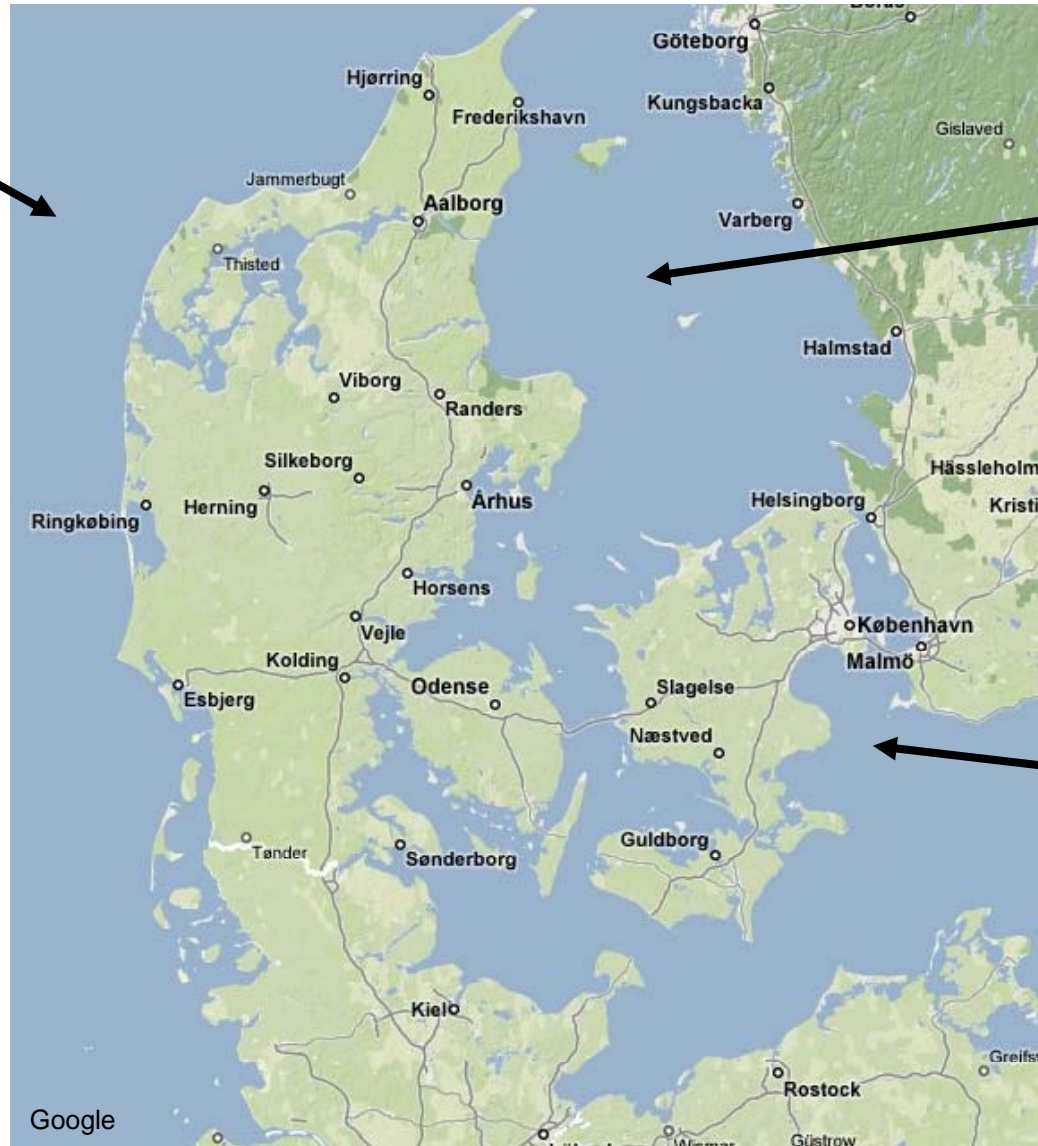


Fujiclean CRX, Japan



Salinity (ppm)

~30,000



~20,000

~10,000

Novelty & objective

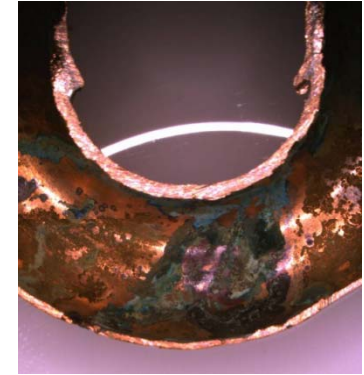
- 1000s working on membrane *treatment techniques* and *product water quality*
- Few look at the product quality *goals*
- We raise the questions:
 - What are the consequences of changing the drinking water's mineral content?
 - Can Copenhagen benefit from desalination?
 - How can a city benefit from managing mineral content?
 - How does it compare with other economic/environmental impacts?

IWA Bonn Charter 2004: "Good safe drinking water that has the trust of consumers"



Health/
Nutrition

Corrosion



What is good
and trusted water?

Resources/
Environment

Aesthetics/
acceptability

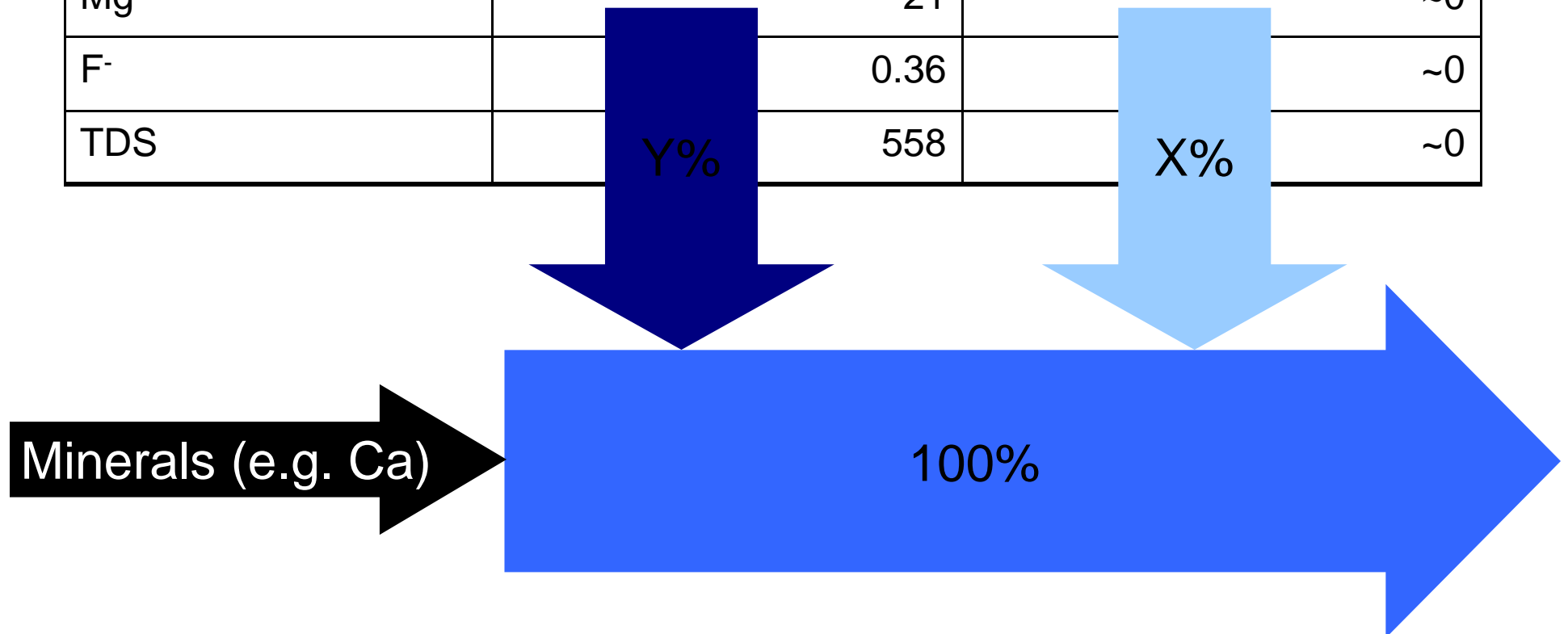


Applicability



Potential for mixing

Parameter (mg/l)	Copenhagen's groundwater	Desalinated water from the Baltic Sea
Hardness (as CaCO ₃)	373	~0
Ca ²⁺	115	~0
Mg ²⁺	21	~0
F ⁻	0.36	~0
TDS	558	~0

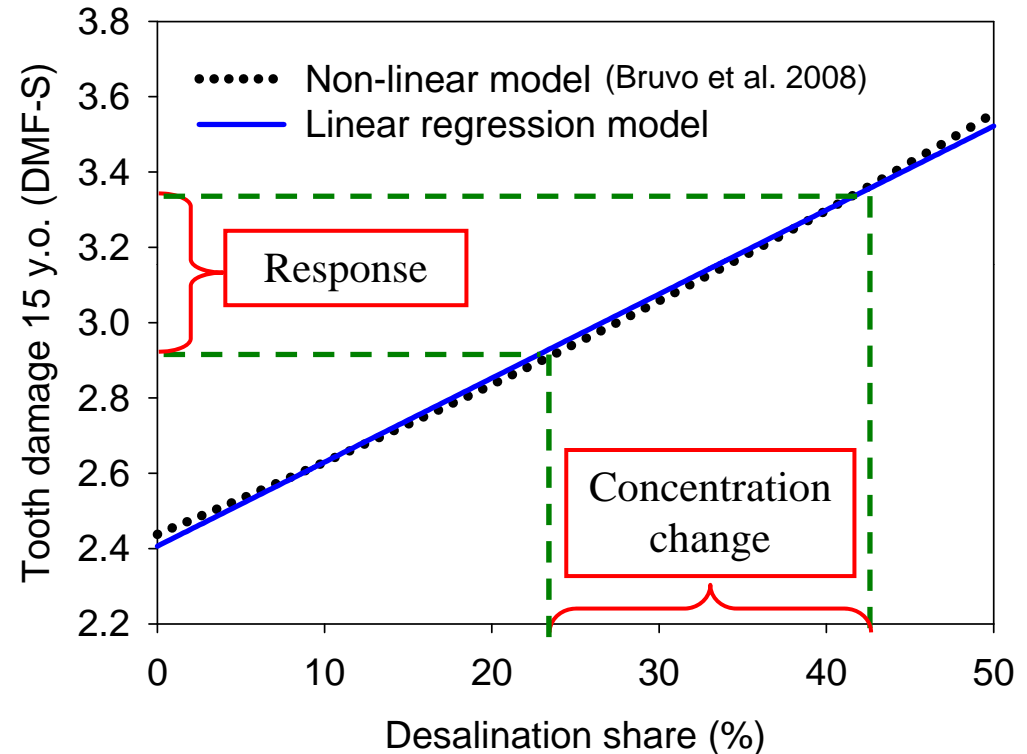


Method

- Litterature review of impacts
- Establishment of concentration-response relationships:

$$R_i = s_i \cdot dc_i \cdot P_i$$

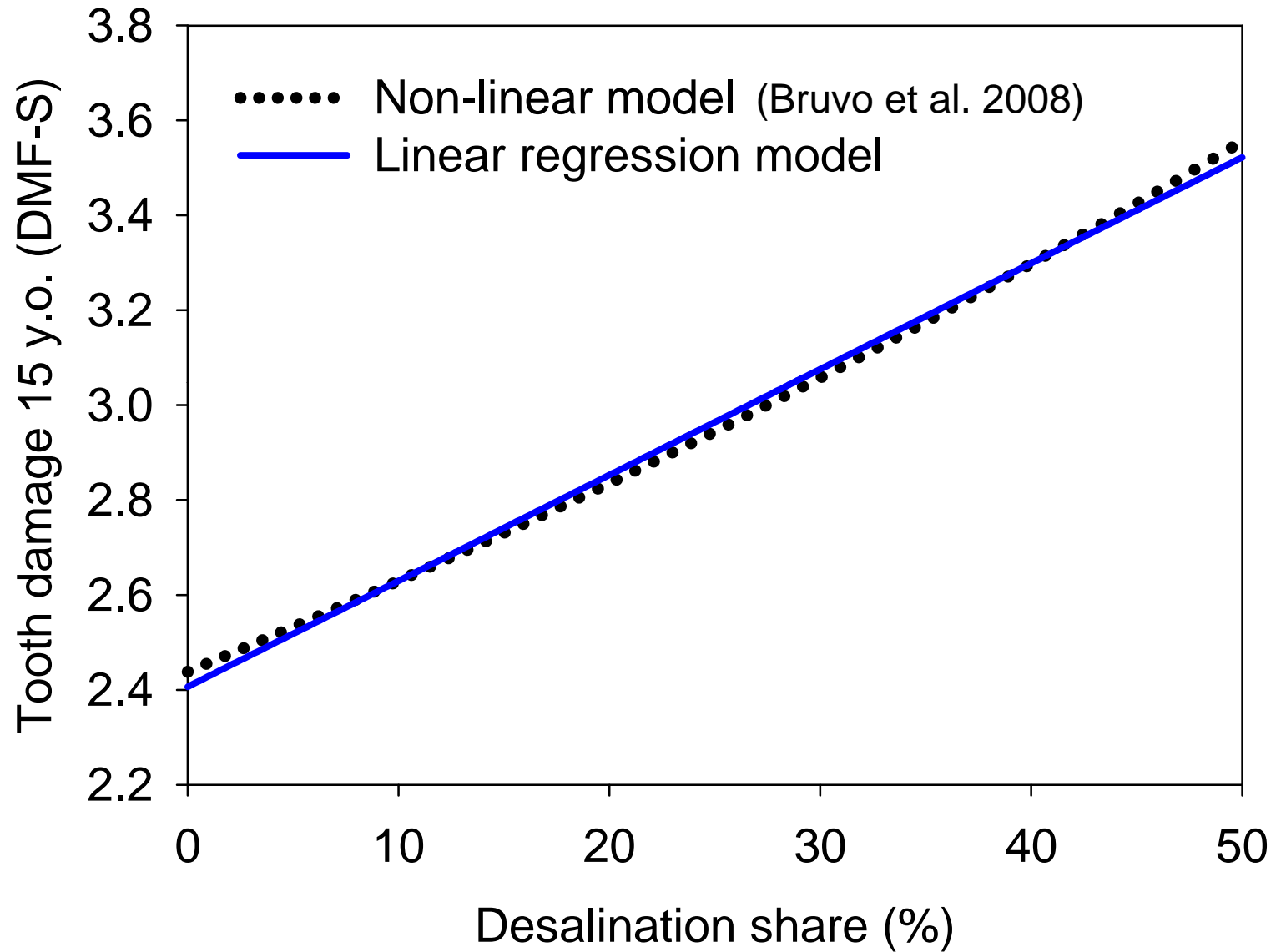
- R = response,
- s = slope,
- dc = change in mineral content,
- P = scaling factor (e.g. number of persons affected), and
- i impact category



Method

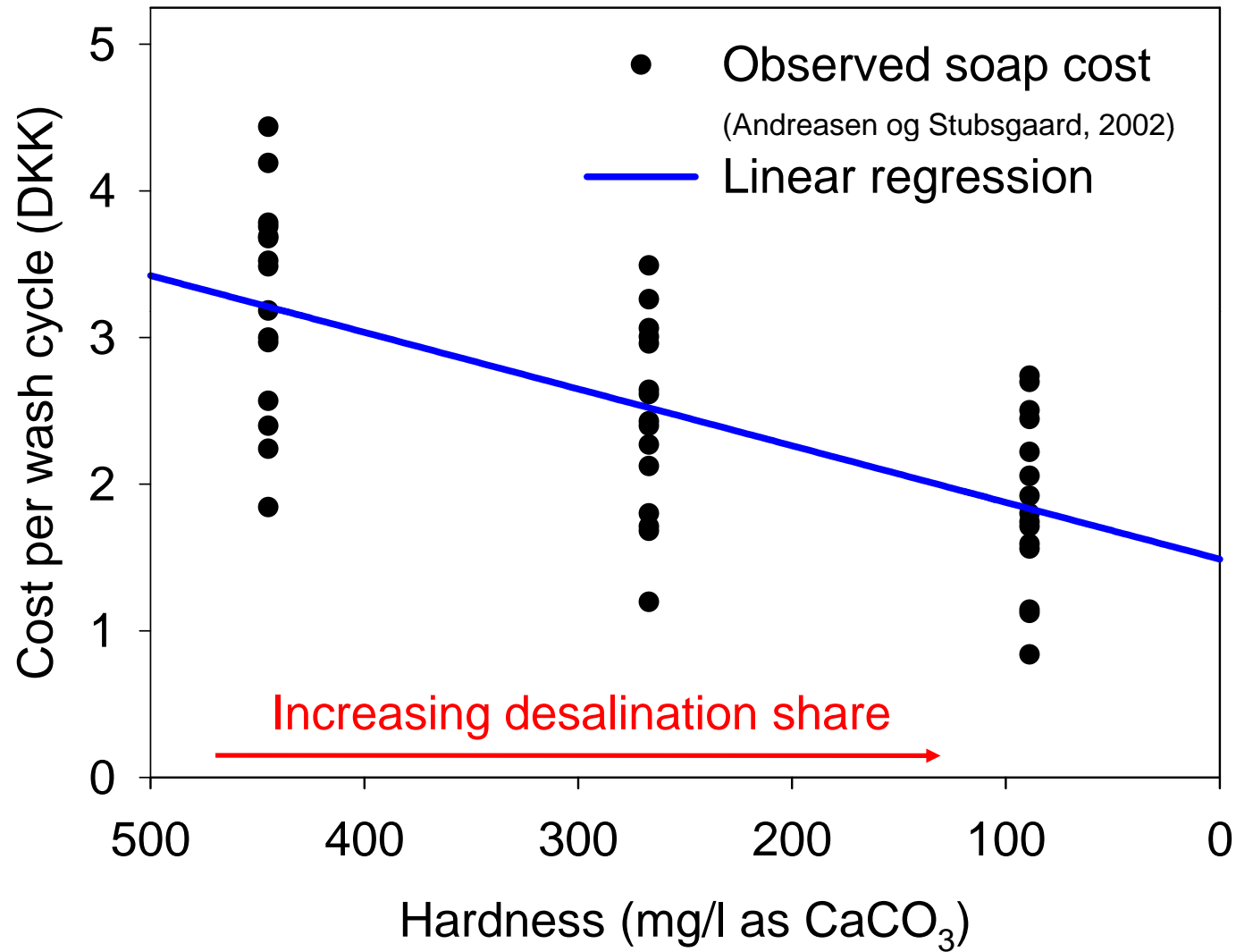
- The predicted response may be an increase or decrease of occurrences/lifetime/consumption etc.
- Assigning a price of the response reveals a benefit or cost for the society or consumer
- Effects assessed for 2005
- 2 scenarios compared:
 - Current water supply system vs.
 - 1:1 groundwater:desalination → mineral content 50 % of current levels

Dental caries



Nutrition/
Health

Soap cost - clothes washing



Applicability

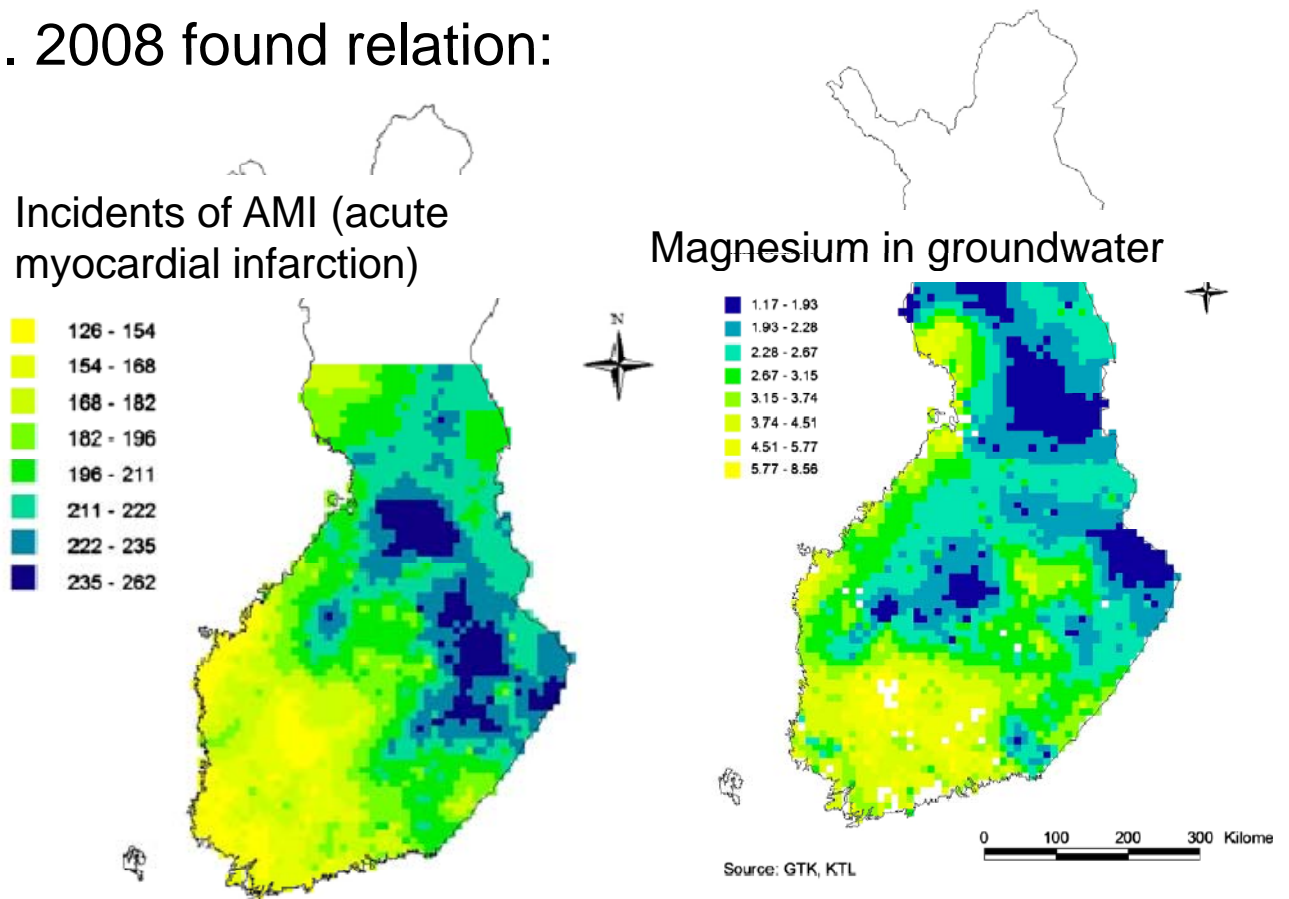
Expected consequences (without remineralization)

Year 2005	Current level	Response		Cost	Total cost	
	[No]	[No]	[Change]	[DKK/unit]	[10 ⁶ DKK]	[DKK/m ³]
Dental health (DMF-S)	1.4 x 10 ⁶	540838	39%	47	-25	-0.75
Annual replacements of washing machines	2.1 x 10 ⁴	-1270	-6%	5122	6.75	0.21

Expected economic consequences in Copenhagen (DKK/m ³)		No remineralization	With remineralization
Health	Dental health	-0.75	-0.14
	Cardiovascular diseases	-3.83	0.00
	Atopic eczema	0.47	0.45
Lifetime	Clothes washers	0.21	0.21
	Dish washers	0.09	0.09
	Water heaters/exchangers	0.24	0.23
	Distribution network	0.13	0.13
Consumption	Bottled water consumption	-0.85	-0.85
	Soap (clothes washing)	1.16	1.13
Mitigation	CO ₂ -mitigation	-0.13	-0.13
	Fluoridation	-0.00	-0.02
	Remineralization (magnesium)	-0.00	-0.04
Sum		-3.26	1.05

Uncertainties

- Morris et al 2008 fandt: *“Hard drinking water does not protect against cardiovascular disease...”*
- However, Kousa et al. 2008 found relation:

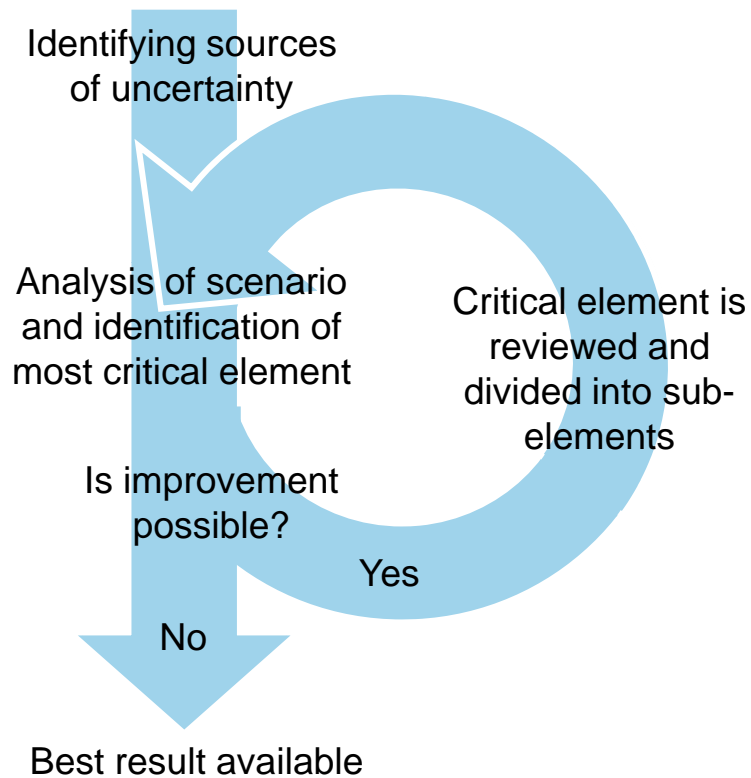


Picture from Kousa et al. *Magnesium in well water and the spatial variation of acute myocardial infarction incidence in rural Finland* (2008)

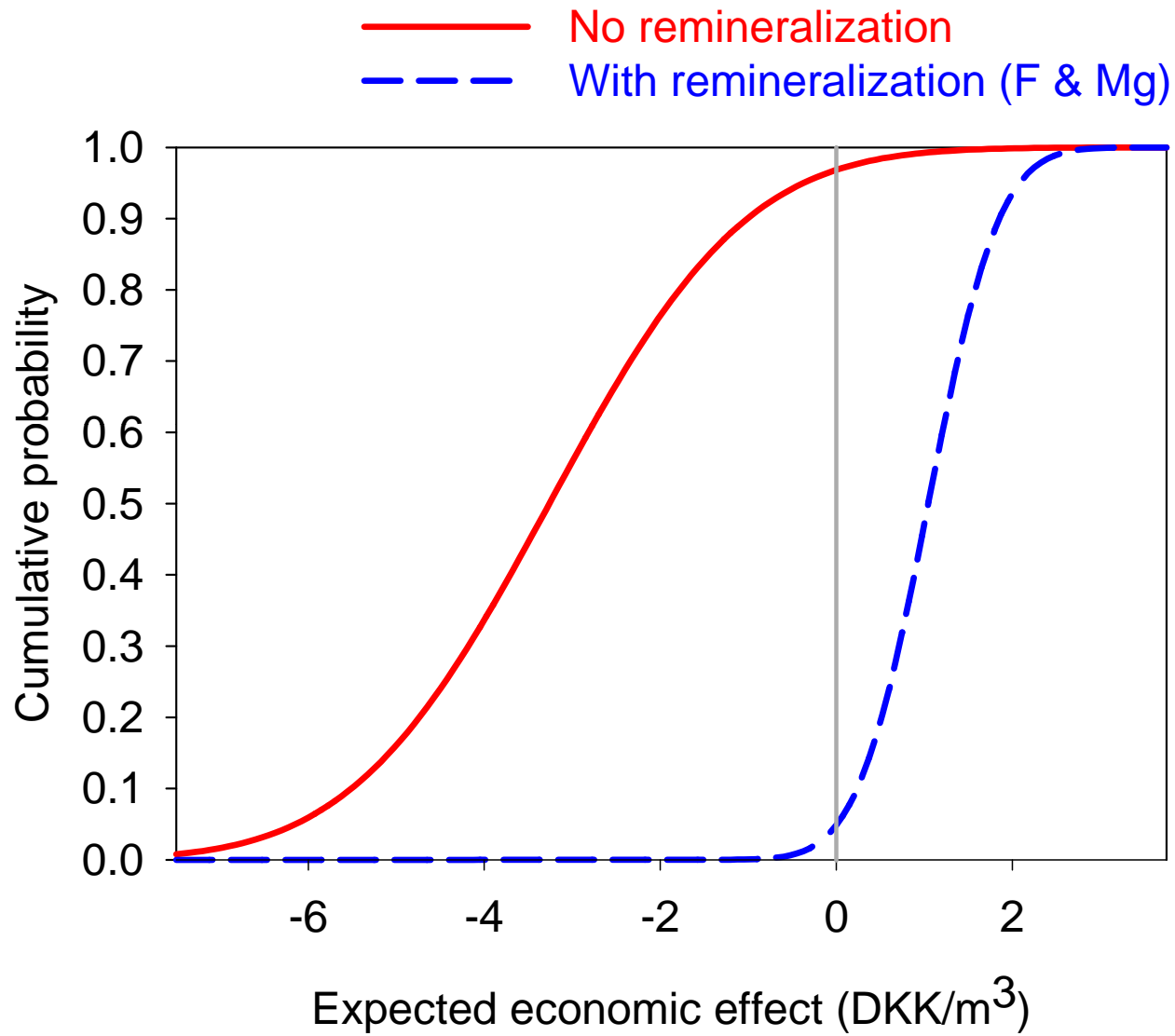
Uncertainties/Successive principle

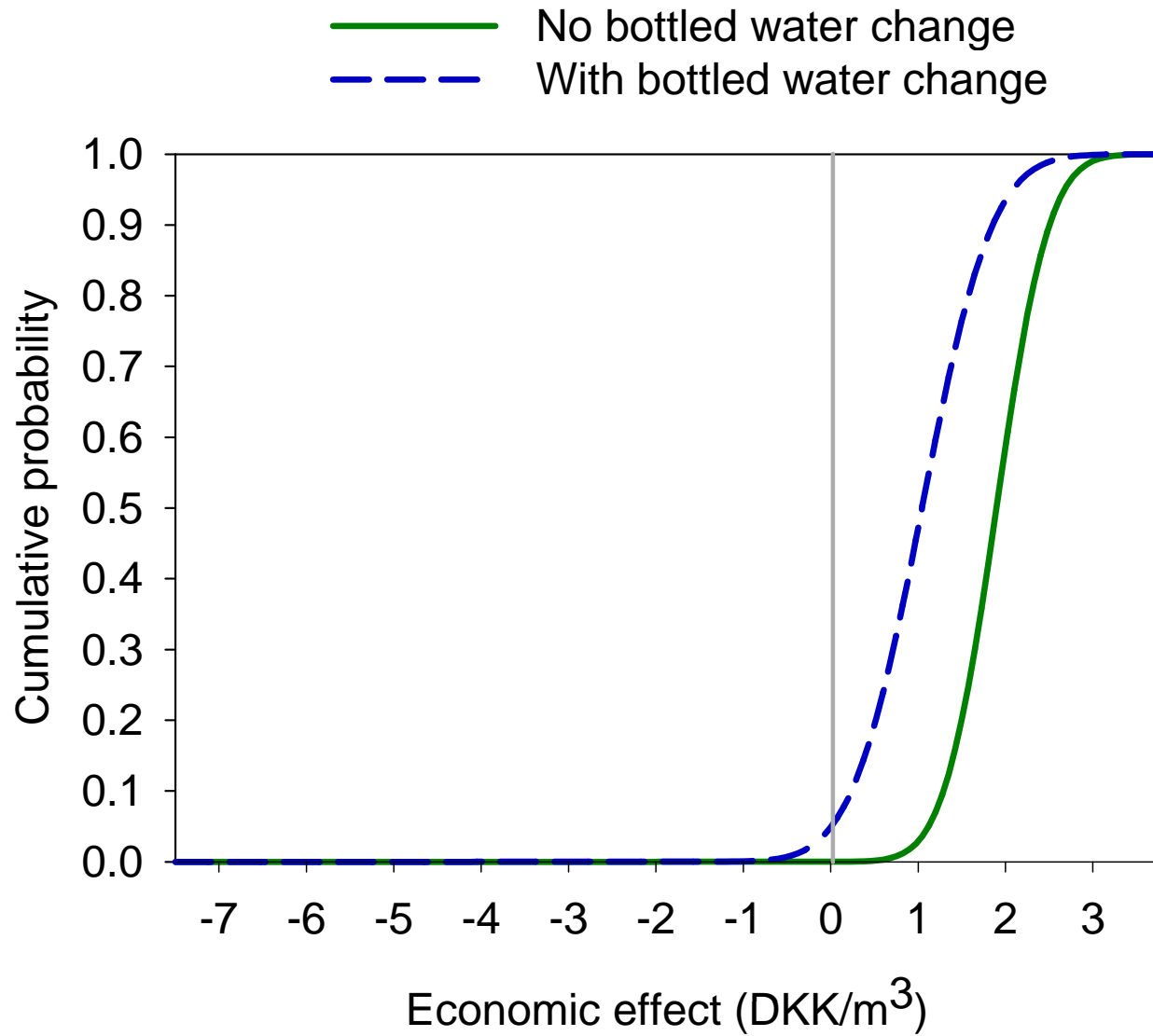


Original concept: Lichtenberg (2000)



- Technique developed for civil construction management influenced by subjective expert judgment (Lichtenberg 2000)
- Construction costs are typically dependent on the duration of several sub-processes, with labor costs as the best example
- Such costs may be represented by Erlang distributions
- Similarly, we assume that impacts induced by the mineral content of the drinking water will constitute independent events occurring at an average rate





Limitations

- Responses are assumed instantly effective
- Conservative economic assessment, neglecting:
 - Externalities like loss of work ability and life quality:
Children with mild to severe eczema *and* their parents were found to lose 1-2 hours of sleep per night compared to healthy families! [Su, 1997]
 - Failure rates of piping systems, including costs of water damages to property
 - Environmental effects, etc...

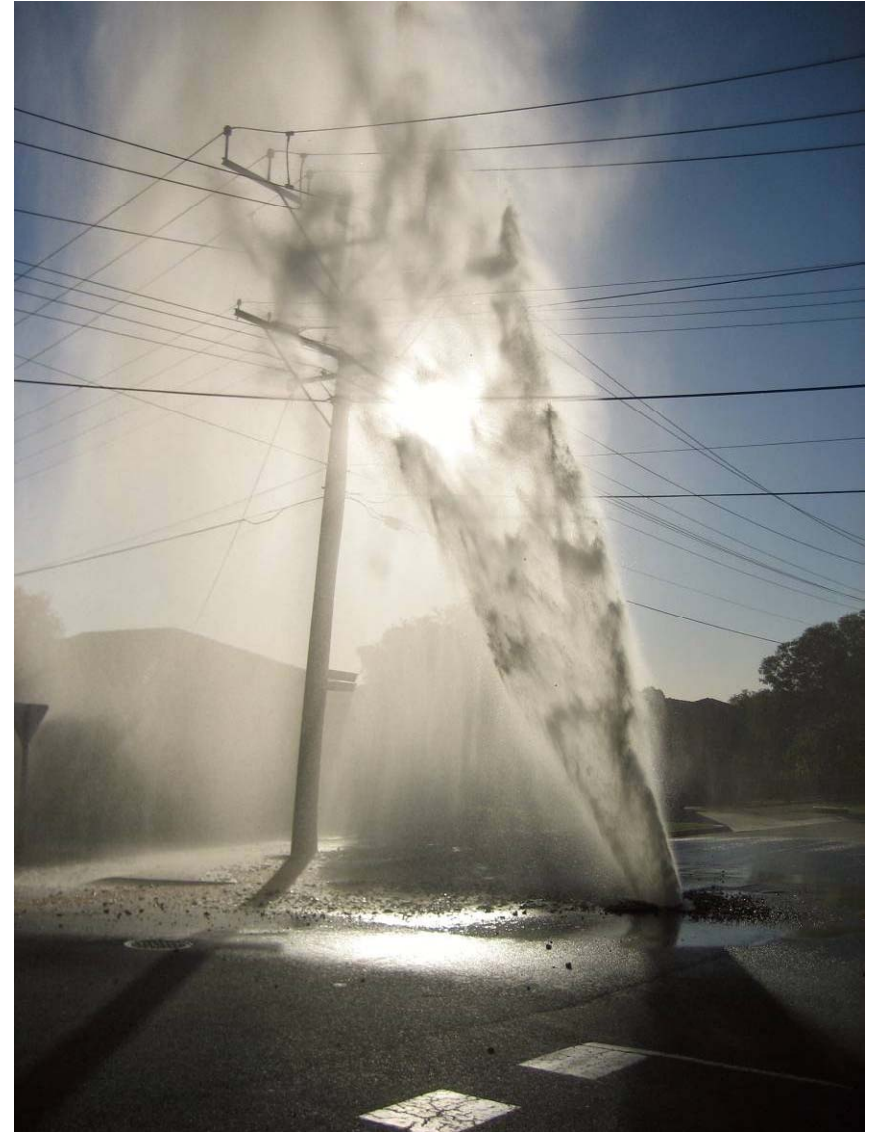


Photo by Luke Roberts

Future work

- “What is the optimal drinking water composition?”
- 2 cases:
 - Perth in Western Australia (a mix of desalinated water, groundwater and surface water)
 - Copenhagen (desal and groundwater)



Lime clarifier, Perth.

Photo by Andrew Bath (used with permission)

Small changes/huge scale

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