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Pathogen risk management considerations for safe household water uses

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Points to be addressed

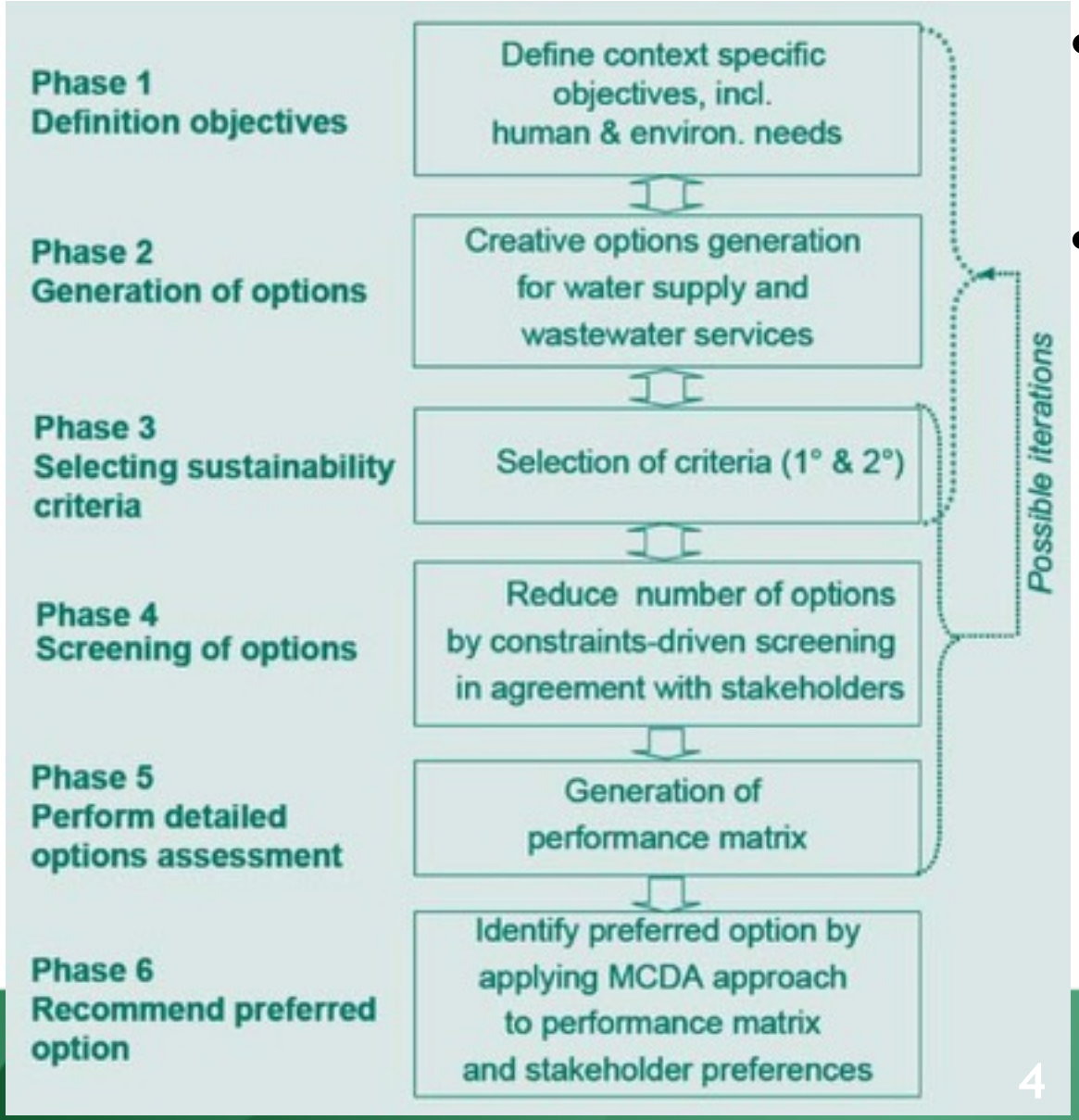
- Remote & Arctic community water services (not ≅central water & sewage):
  - Need for decentralized (household) services
    - Given the pathogen pathways of concern
  - One-Health concept, climate adaptive
  - Management of microbial issues within a waterscape-system's framework

Our common goals - Larry Hartig

- Critical to address **human health**, but also
- Climate change (threatening all systems)
- Engineering issues (fit-for-purpose)
- Operational needs (training/maintenance) &
- **Regulations** (how, what, why); and

How to integrate within waterscape narrative

Sustainable water services selection

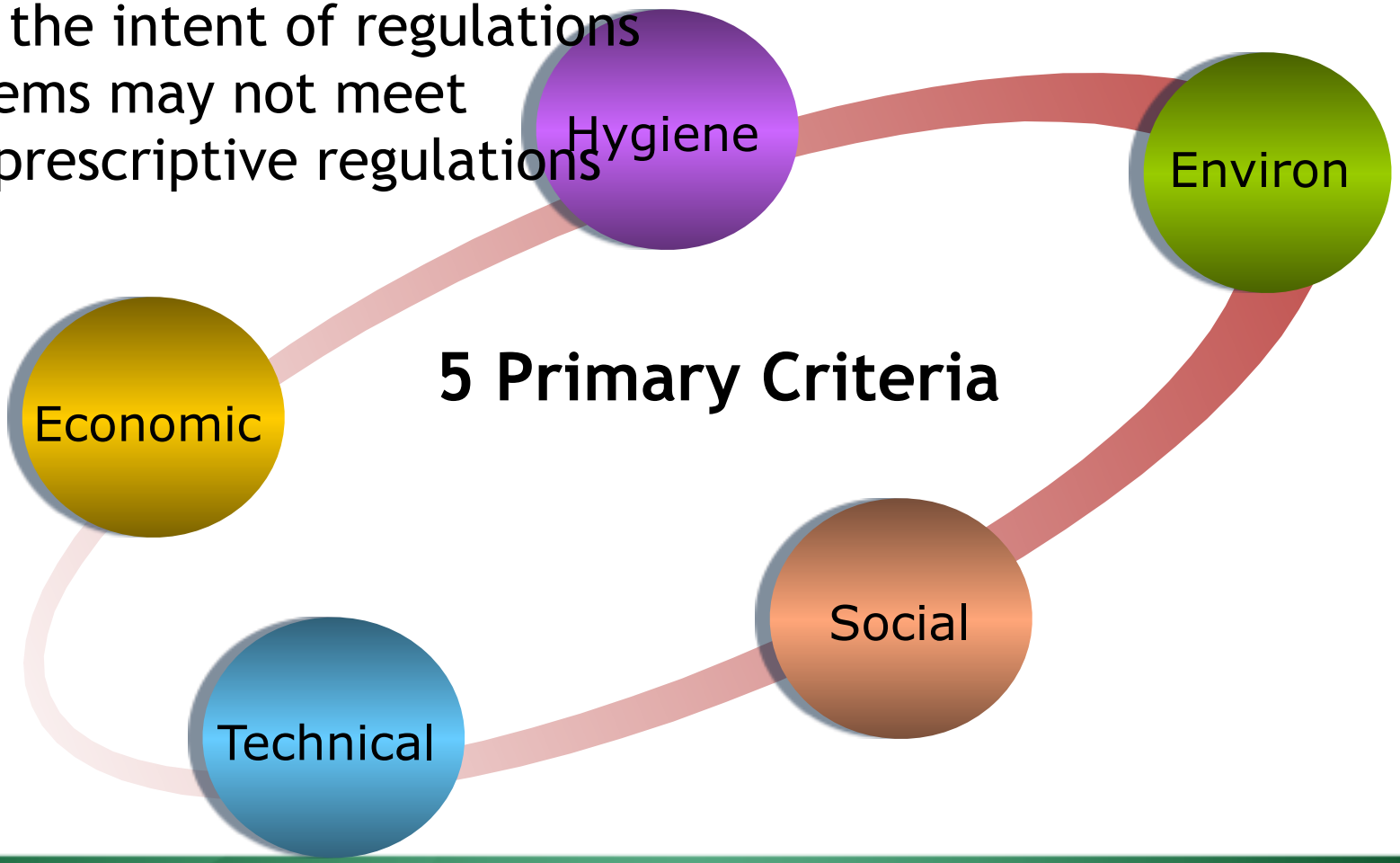


- Stakeholder-driven, so 'pulled' by citizens
- Meeting core sustainability principals
  - Resource recovery ecologically-based
  - Adaptable, & based on risk assessments

Water Services Association of Australia 2008 Framework

Sustainable systems achieved by trade-offs between key criteria with stakeholders

To meet the intent of regulations
i.e. systems may not meet
current prescriptive regulations



‘Honey’ buckets, Atmautluak

http://watersewerchallenge.alaska.gov/photogallery.html

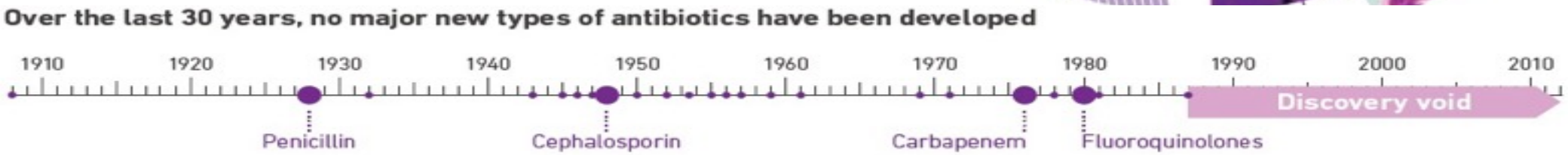
Covered Wastewater Haul & dump!

http://watersewerchallenge.alaska.gov/photogallery.html

Even this ‘preferred’ sewage management has major chemical, pathogen & antimicrobial resistant gene impacts

Antimicrobial Resistance (AMR) via water

- 3rd gen cephalosporin- resistant *E. coli* & MRSA estimated deaths 3.3 per 100,000 in EU in 2015
- Globally 700,000 AMR-deaths, likely 10 million by 2050*
- **Unclear fraction due to water food exposure pathways****



*Hoffman *et al.* (2015) Bull WHO **3**, 66
Ashbolt *et al.* (2013) Env Health Pers **121, 993-1001

Water needs for Arctic health

- Residents may use 1 to 5 gallons per capita per day for all current household uses (drinking, cooking, washing)
  - significantly below recommended by Institute of Medicine / WHO for water-wash disease control (~13 gal/person.d)*
- But supplying more water to homes may not be the answer nor do washeterias necessarily help consumers' health
  - **Because it is costly, generates more wastewater pollution and communal facilities increase respiratory disease transmission (the largest water-related health concern)**

*Howard & Bartram (2003). *Domestic Water Quantity, Service, Level and Health; WHO/SDE/WSH/03.02*

Climate change: loss of permafrost

- Resulting in serious erosion, flooding, and destruction of homes, buildings, and roads from differential settlement, slumping, and/or collapse of underlying base sediments
- Loss of clean lake water for drinking and hygiene, saltwater intrusion, and sewage contamination that could cause respiratory, gastrointestinal and skin infections

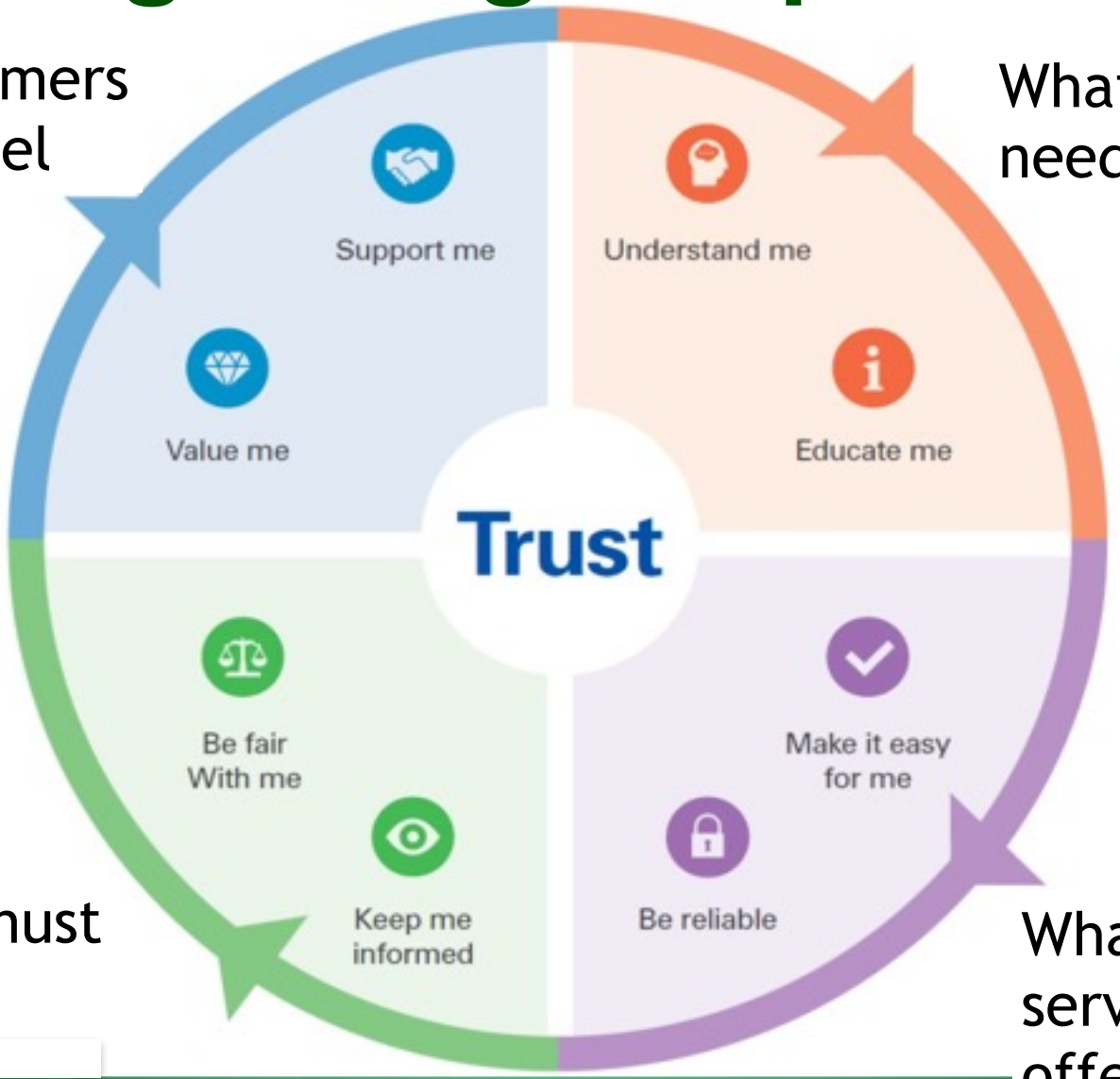
Need more adaptive infrastructure, not just resilient

- i.e. most infrastructure only within homes

Lasting change requires trust

How customers want to feel

What customers need



How we must deliver it

What the service must offer

Understanding water health issues

- Community diseases result from:
  - **Inadequate water and sanitation**
    - waterborne & water-based pathogens
  - **Lack of body and clothes washing**
    - skin infections (primarily bacterial and fungal)
  - **Respiratory infections**
    - person-to-person in group settings + water-based
    - such as reduced with Kivalina washeteria closures [1]
- **Solutions must address aboriginal societal needs** [2]

4 village study* rates
Pre & Post intervention

GI illnesses
2% & down 38%

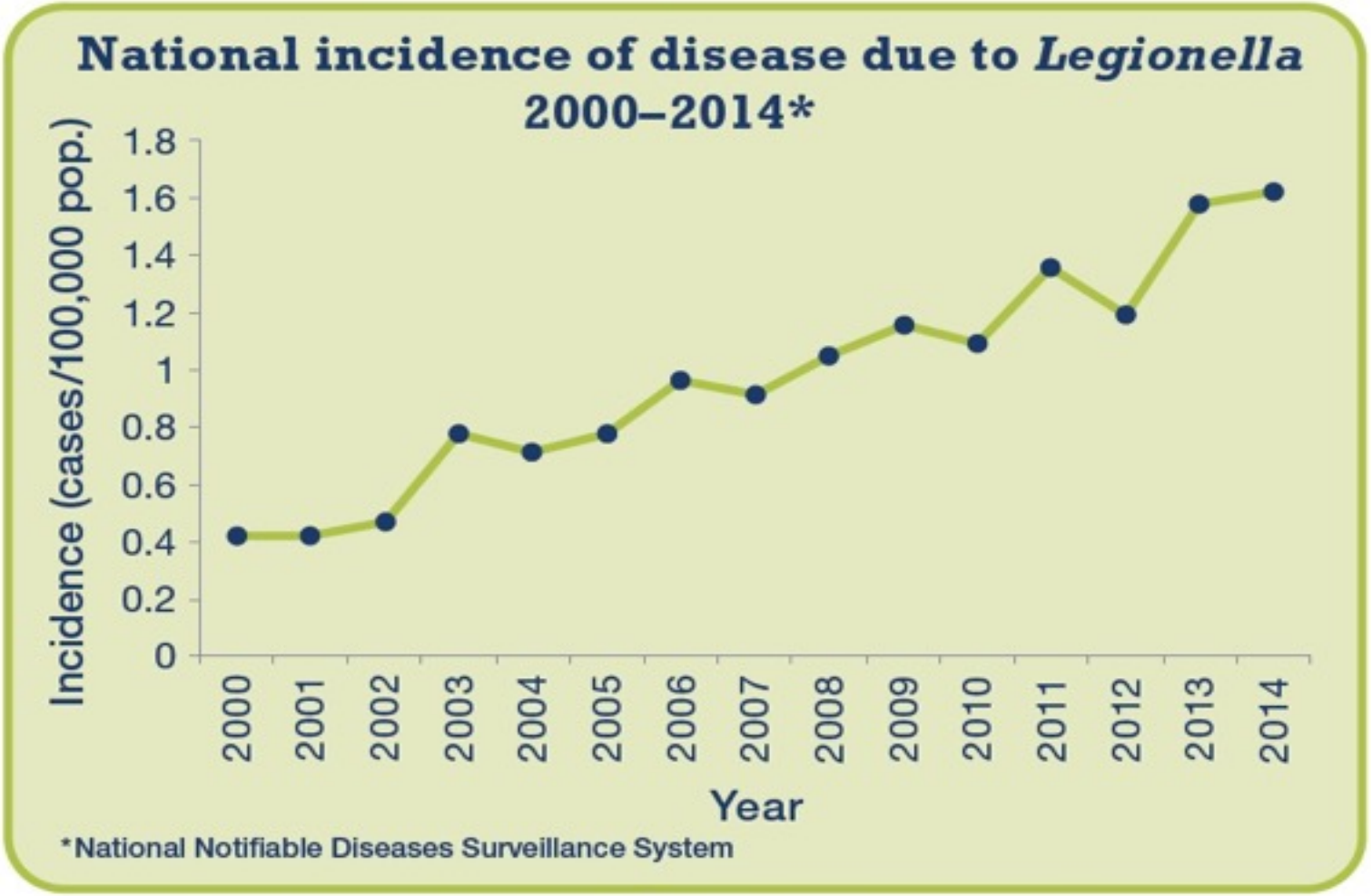
skin illnesses
17% & down 20%

Resp'y illnesses
83% & down 16%

*Thomas *et al.* (2016) Impact of In-home Water Service on the Rates of Infectious Diseases, WIHAH

[1]Thomas *et al.* (2013) Int J Circumpolar Health 72: 480-4
[2]Daley *et al.* (2015) Social Sci & Med 135: 124-132

U.S. reported cases of Legionnaires' disease have increased nearly 300% since 2000



In-building water issue via aerosols e.g. showers

Circumpolar-relevant water pathogens

- **Enteric** waterborne (**human & zoonotic**) diseases
  - *Hepatitis A* liver disease*, Norovirus* gastro, *Shigella* dysentery
  - *Giardia* giardiasis, enteritis *Yersinia & Campylobacter* spp.
  - *Echinococcus multilocularis* (lung disease) via foxes/voles
- **Water-based** (saprozoic) diseases
  - Non-tuberculous mycobacteria (wound/lung), *Helicobacter pylori*?
  - *V. parahemolyticus/vulnificus* gastro via seafood if seawater > 15 °C
- **Person-to-person** spread & **Water-Washed** infections:
  - *Norovirus, Cryptosporidium, Staph aureus, P. aeruginosa* & **helminths**
  - TB, *Strep. pneumoniae, Haemophilus influenzae* along with various multi-drug resistant bacterial and fungal pathogens

Parkinson & Evengård (2009) *Glob Health Action 2: 1-3*
Dudarev *et al.* (2013) *Int J Circumpolar Health 72*: 1-10

Waterborne sequelae – poorly understood

- **Auto-immune diseases**
  - ➢ Diabetes, Heart disease, Liver damage, & Reactive arthritis (enteric viruses, campylobacters)
- **Carcinogens**
  - *Helicobacter pylori,* **cyanotoxins**
- **Renal disease**
  - *E. coli* O157:H7, *Microsporidium* spp.
- **Nervous system disorders**
  - *Campylobacter jejuni*, various *Enterovirus* spp.
- **Heart and liver disease**
  - Adenovirus, Coxsackievirus, **cyanotoxins**

Cyanobacteria that produce cyanotoxins

Managing pathogens via a one-health approach, 2 examples:

- Containment of sewage/stormwater runoff to native animals: for *Toxoplasma gondii*, *Giardia, Echinococcus, etc.* yet
  - **Antimicrobial resistance (AMR) genes/bacteria & CEC not adequately controlled by sewage treatment and disinfection**
- Antimicrobial treatment for *Helicobacter pylori* infection: 58% people positive to below 9% by treatment (Aklavik NWT study) [1] however..

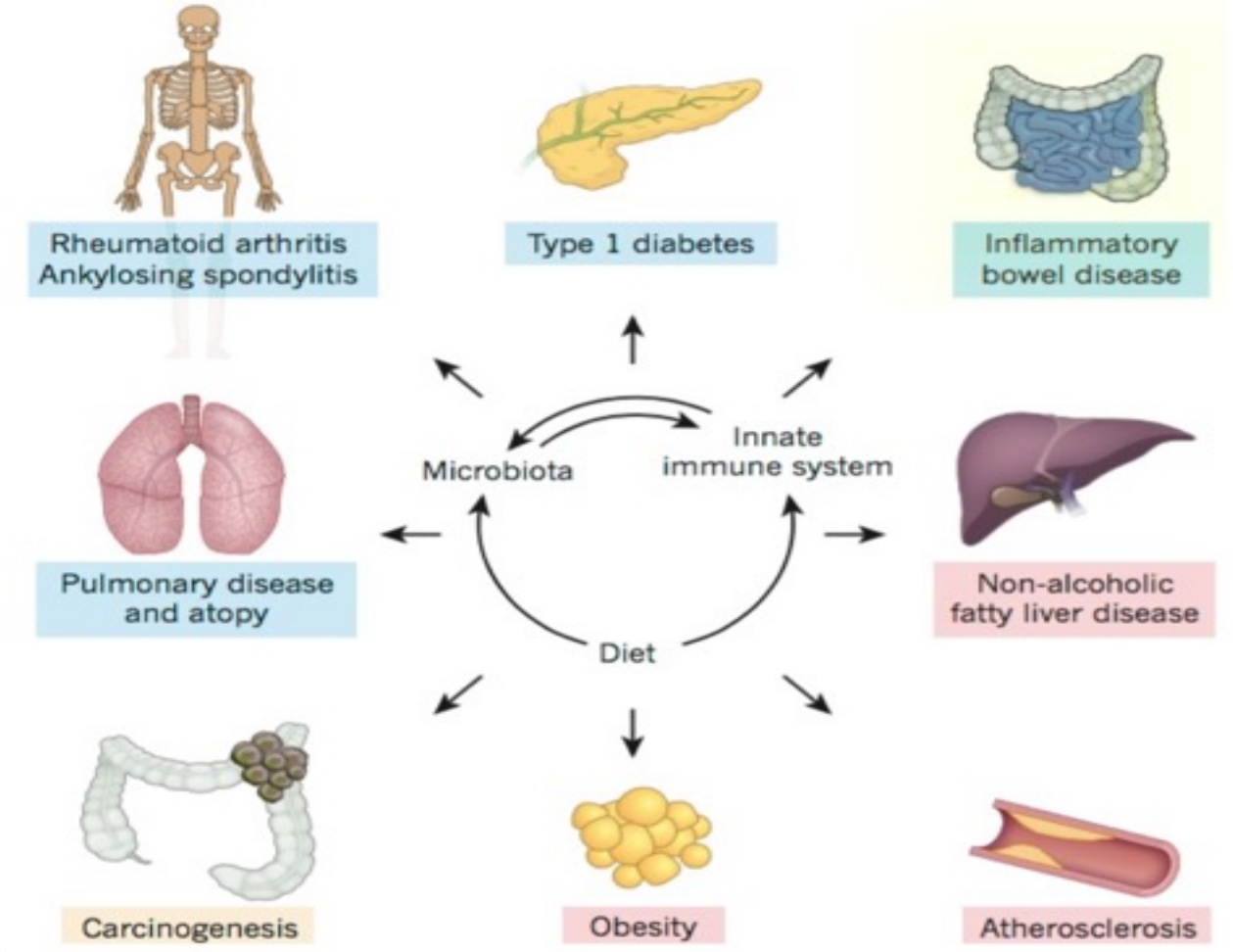
One Health approach include interactions between and among humans, animals, plants, parasites, microbes, and chemical contaminants in terrestrial, aquatic, & marine ecosystems

[1]Carraher *et al.* (2013) *Int J Circumpolar Health* 72:21594
Cheung *et al.* (2014) BMJ Open 4:e003689

Helicobacter pylori, ulcer & cancer bug, is it waterborne?

- CDC estimate 2/3 of all humans **harbor** *H. pylori*
  - < 20% in developed regions, e.g. generally in USA
  - **50-80% in Indigenous Peoples of Arctic regions**
- Most infections do not cause illness, but
  - Major risk factor for peptic ulcer disease
  - 1994 *H. pylori* classified as a **carcinogen** (mucosa-associated lymphoid tissue [MALT] lymphoma)
  - But also reduces risk of esophageal adenocarcinoma

Microbiome–innate-immune-system interactions



- Many inflammatory disorders are influenced by alterations in the crosstalk between innate immunity and our microbiome
- These include metabolic (red boxes), neoplastic (orange box) and autoimmune or autoinflammatory (blue boxes) disorders

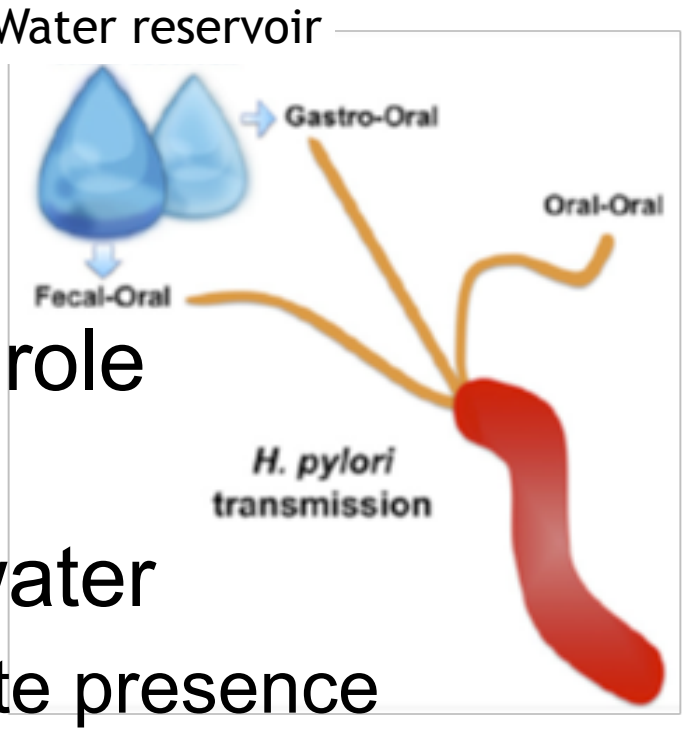
Thiass *et al.* (2016) *Nature 535*(7610): 65-74

So not necessarily good to treat all *Helicobacter pylori* cases

- Based on an international experts' review of evidenced-based benefits and harms for screening & treatment of *H. pylori* in high-prevalence countries
  - In Arctic countries where *H. pylori* prevalence exceeds 60%, treating *H. pylori* infection should be limited to peptic ulcer disease and mucosa-associated lymphoid tissue lymphoma and
  - **test-and-treat strategy may not be beneficial for those with dyspepsia***

*McMahon *et al*. (2015) Epi Inf 144: 225-233

Waterborne *H. pylori?*

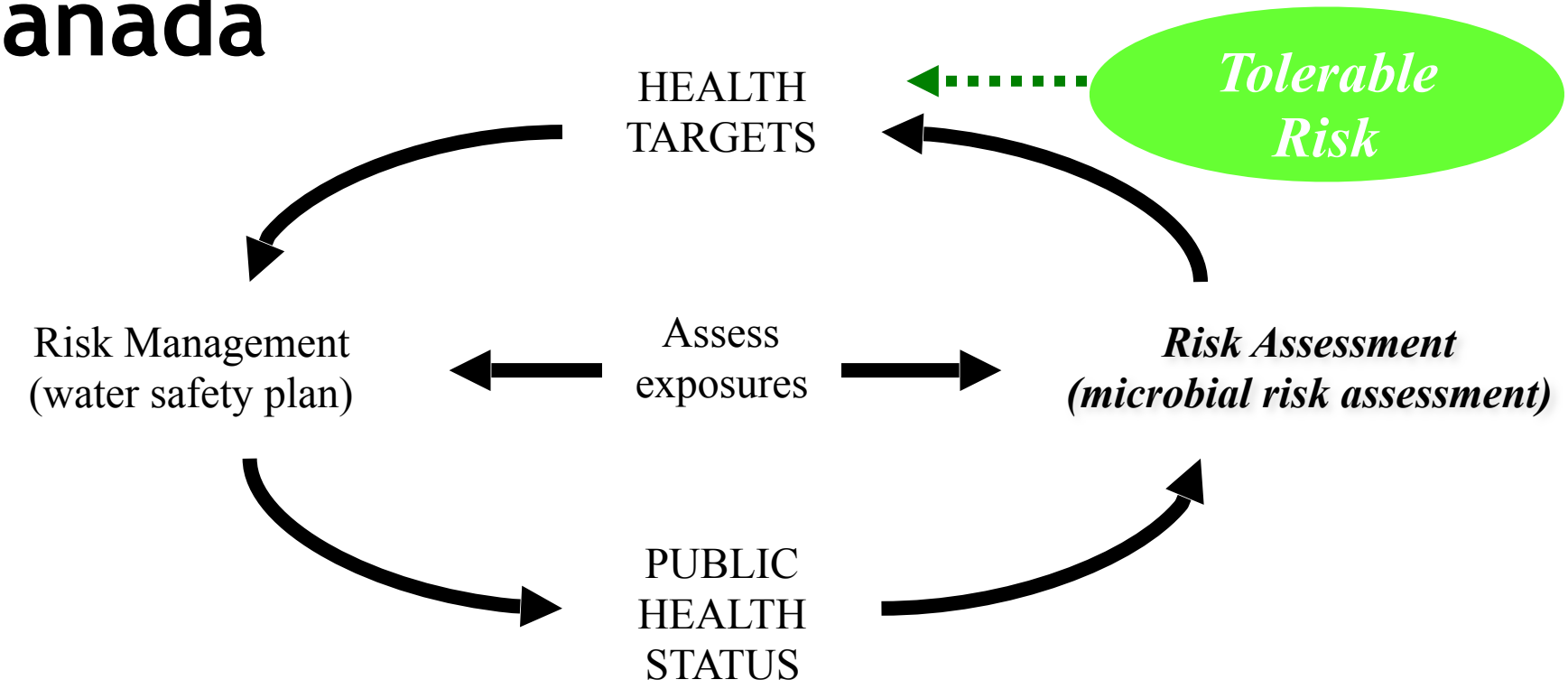


- Contaminated water plays a key role
- *H. pylori* survives in a viable but non-culturable (VBNC) state in water
  - Traditional culture does not estimate presence
- Rafik Dey in my group has demonstrated intracellular growth within free-living amoebae
  - Hence detect infectious VBNC forms & natural site for growth within biofilms (of chlorinated drinking water)

Aziz (2016) *J Adv Res 6*, 539-547

WHO Risk-based water safety plans

Basis of regulations now in Alberta, Canada



Fewtrell & Bartram (2001) Water Quality: Guidelines, Standards and Health. Risk Assessment and Management for Water Related Infectious Diseases, WHO

Pathogen control starts with a toilet

Loowatt-toilet (http://loowatt.com)

Vacuum toilet components

Flush water needs 0 – 1 pint – 0.26 gallons

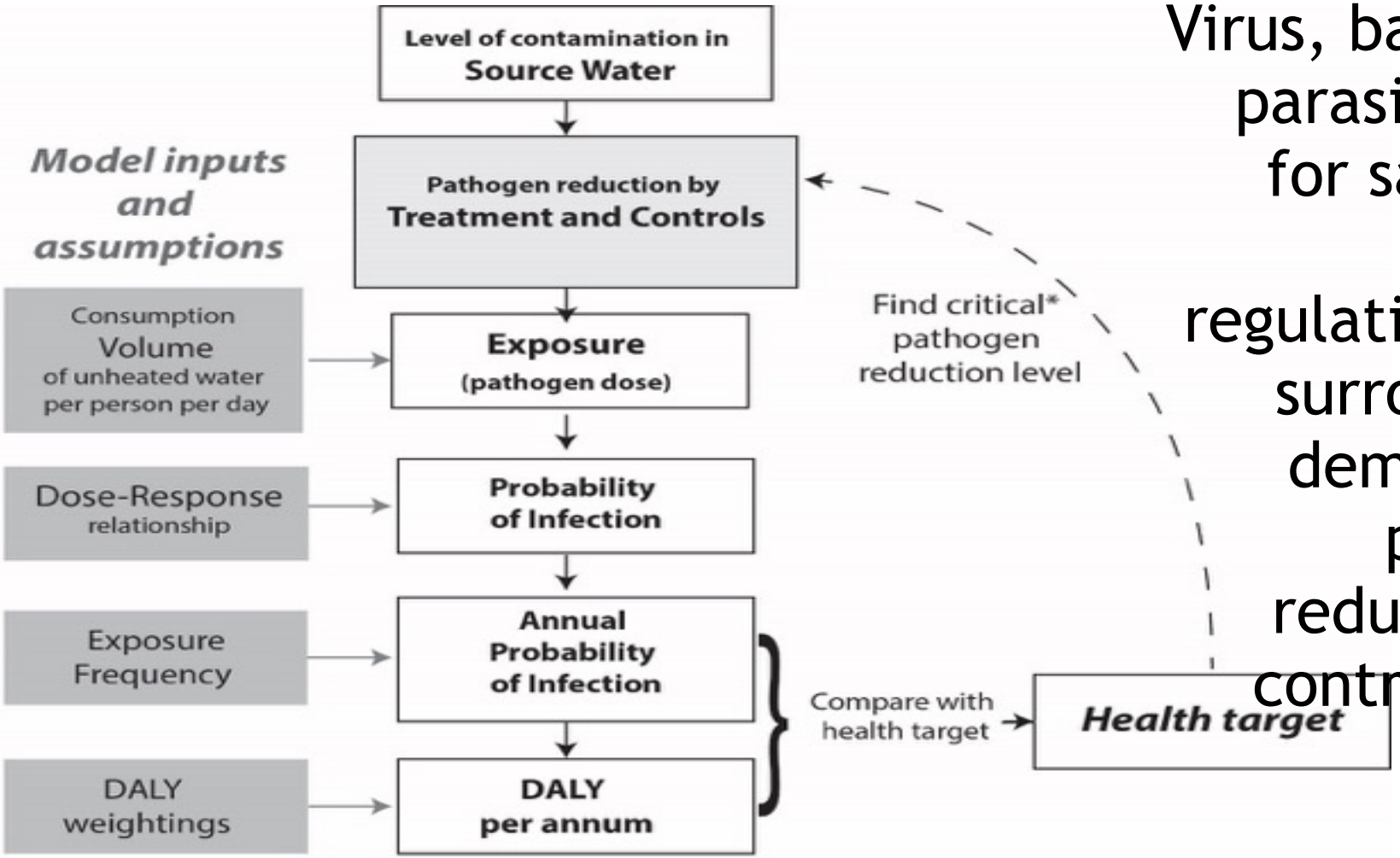
Air-water forced toilet

Blackwater energy recovery: socio-economic driver for alternative systems

- Household-scale
  - Possible, but community energy & nutrient recovery better
- Community-scale
  - Full-cost recovery & net energy generation
  - Also provides local economy with jobs

Blackwater sewer (daily pulsed flow, not heated?)

Risk-defined treatment requirements



Virus, bacteria & parasite levels for safe uses. Drives regulations then surrogates to demonstrate pathogen reductions at control points are met

Petterson & Ashbolt (2016) J Wat Health 4(4): 571-589
WHO (2016) *Quantitative Microbial Risk Assessment*, Geneva

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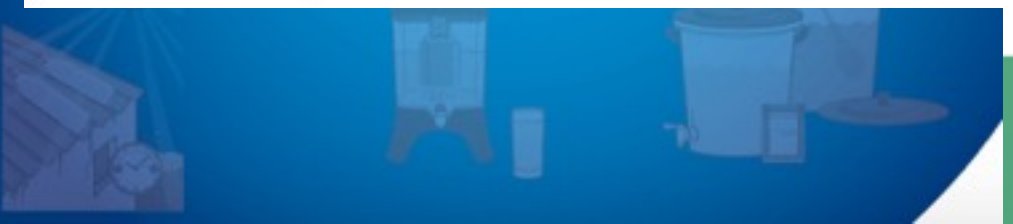
World Health Organization

http://apps.who.int/iris/bitstream/10665/204284/1/9789241509947_eng.pdf

Results of Round I of the WHO International Scheme to Evaluate Household Water Treatment Technologies

- Criteria based on quantitative microbial risk assessment of surface drinking waters

Performance classification	Bacteria (log_{10} reduction required)	Viruses (log_{10} reduction required)	Protozoa (log_{10} reduction required)	Interpretation (assuming correct and consistent use)
★★★	≥ 4	≥ 5	≥ 4	Comprehensive protection (very high pathogen removal)
★★	≥ 2	≥ 3	≥ 2	Comprehensive protection (high pathogen removal)
★	Meets at least 2-star (★★) criteria for two classes of pathogens			Targeted protection
–	Fails to meet WHO performance criteria			Little or no protection



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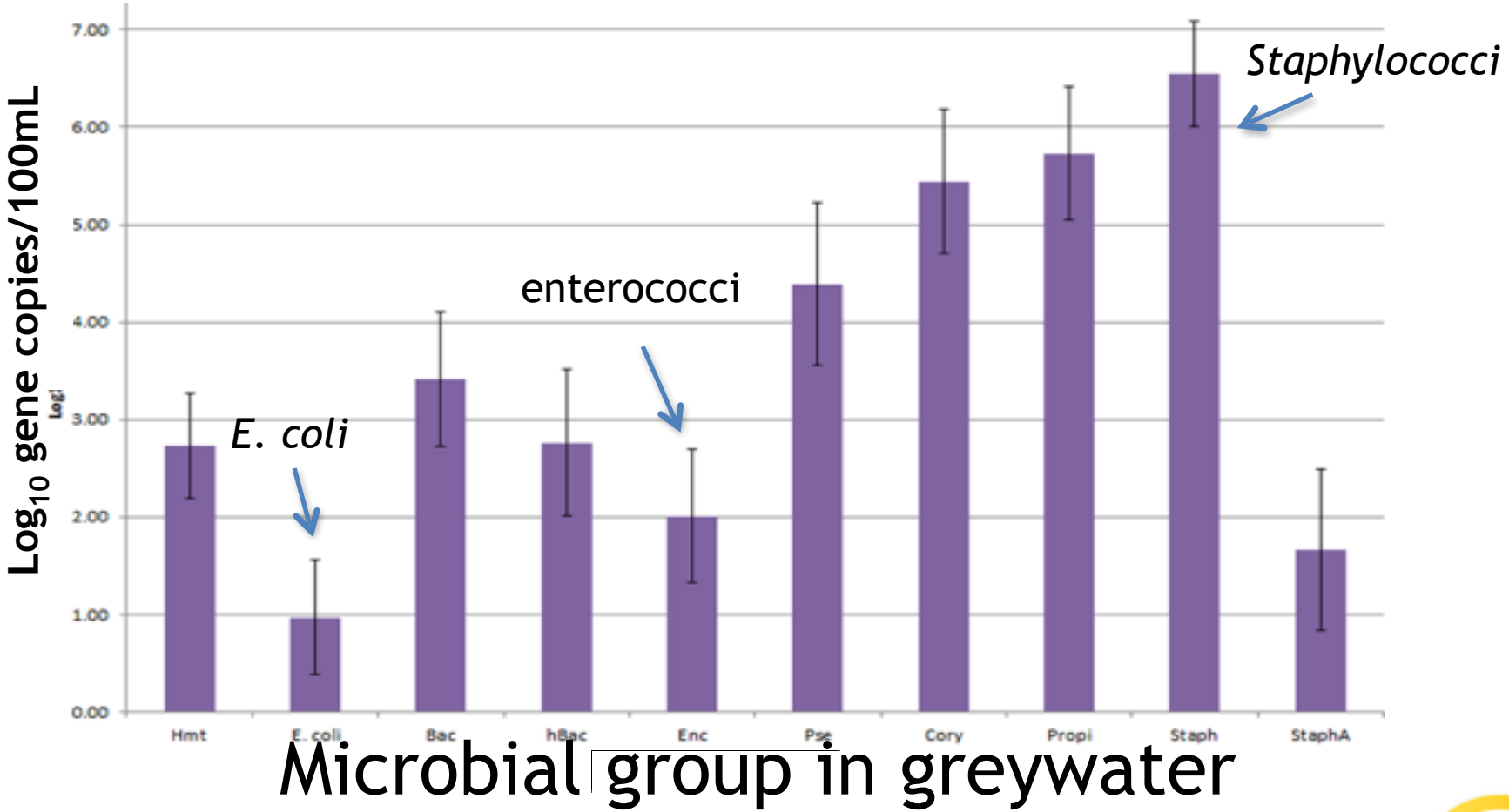
Pathogen log reduction targets for non-potable household uses

Water Source	Use	Pathogen log_{10} reduction target to meet < 1 infection / 10,000.y			How?
		Viruses	Bacteria	Parasites	
Roof	Drinking	?	3.5	?	MF + UV
Roof	Washing	?	3.5	?	MF + UV
Snow-melt	Drinking	4.0	3.5	4.0	MF + UV
Snow-melt	Clothes washing	3.0	3.0	3.0	MF + UV
Shower/clothes	Showering	7.0	4.5	5.5	UF + UV
Shower/clothes	Clothes washing	6.0	3.5	4.5	UF + UV

Adapted from: Sharvelle, S.; Ashbolt, N.; Clerico, E.; Hultquist, R.; Leverenz, H. L.; Olivieri, A. I(2016). *Risk Based Framework for the Development of Public Health Performance Standards for Decentralized Nonpotable Water Systems*. Water Environment Research Foundation Alexandria, VA

Bacterial genera in laundry greywater – identifying surrogate



Zimmerman *et al.* (2014) *Env Sci Tech 48: 7993-8002*

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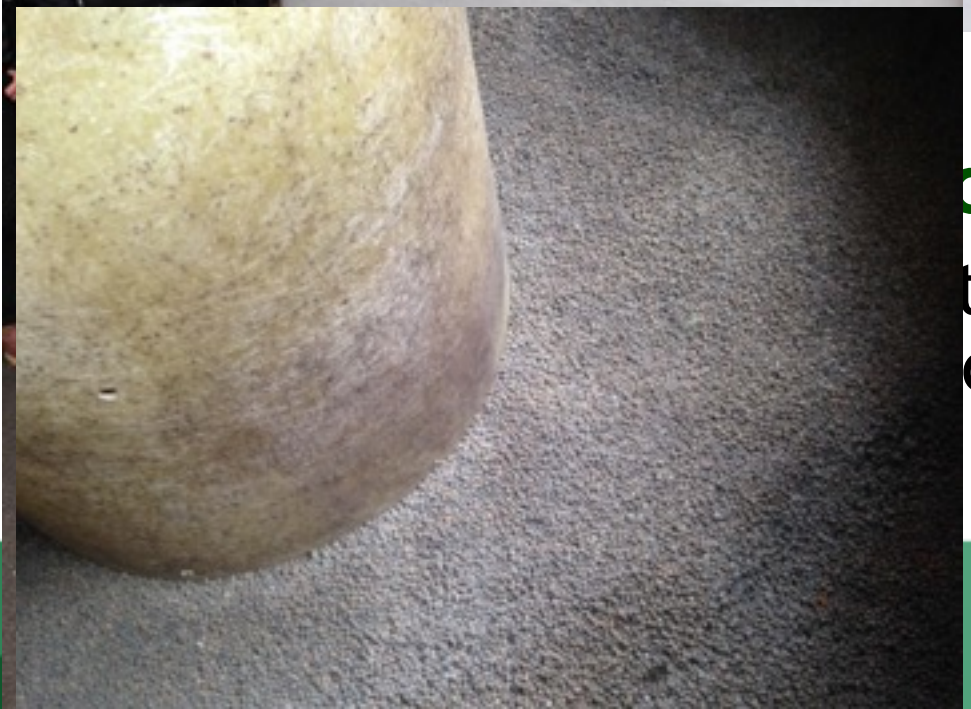
Alternative systems: suitable for Arctic?

old (pathogen log reduction target –

Greywater/treatment (48 gpd)
4-7 LRT by unsaturated filter,
UV, or Cl_2

Electrochemica
l

Electrochemical blackwater
treatment & recovered
flush water loop **4 LRT**



odel & political will for:

t of drinking water and re-
clothes greywater & separate

modeled water safety plan

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Key take home points

- **'Traditional' centralized water services should not be our aspirational goal for most small Arctic communities (nor elsewhere)**
  - Need a systems' & community view to identify alternatives
  - Including energy, heat, fertilizers + water fit-for-purpose
  - Manage system within a proactive water safety plan
  - Demonstration at scale (e.g. Alaskan water/san challenge) to identify sustainable/adaptable water service options