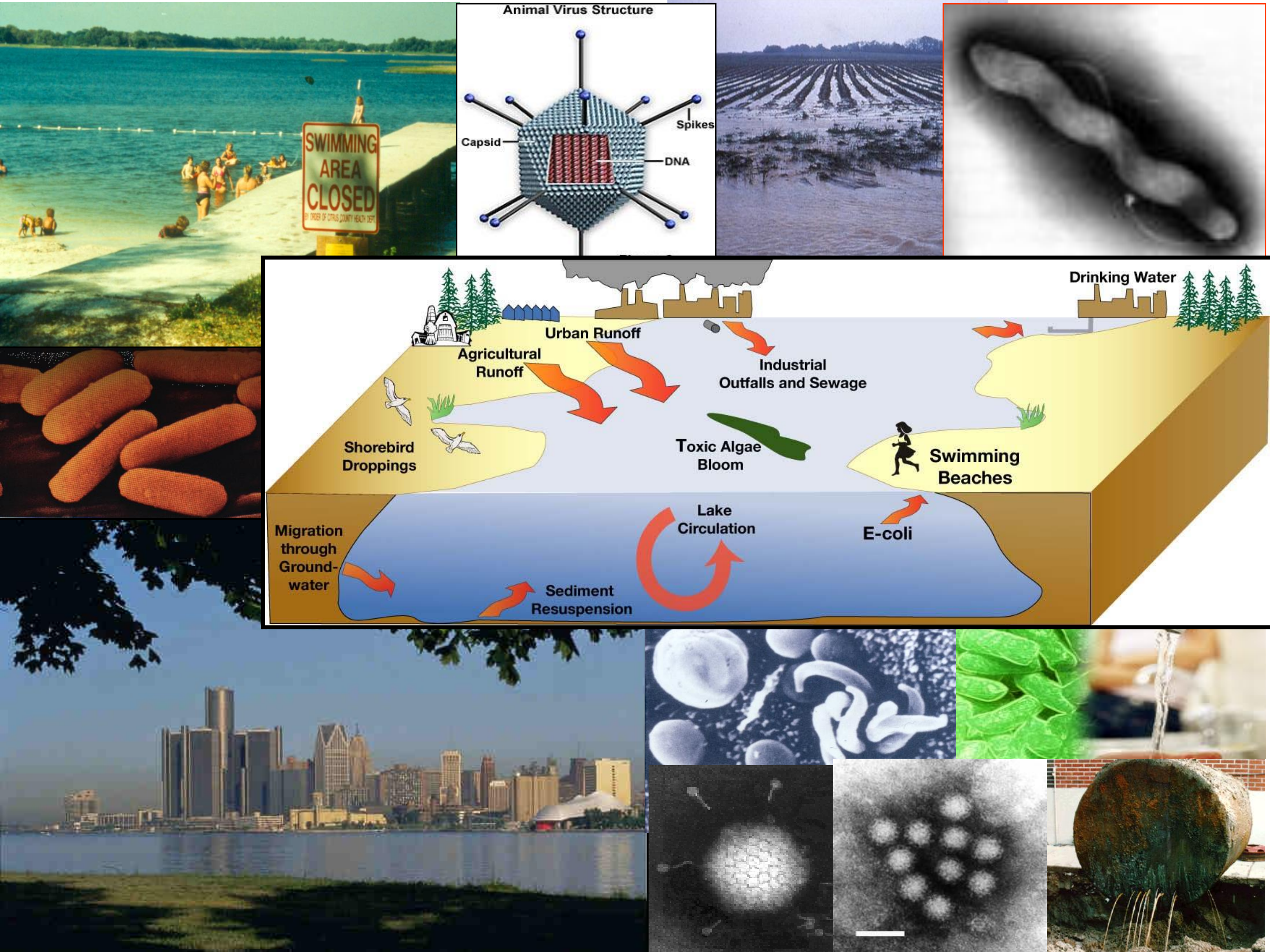
Wastewater, Health and Microbes

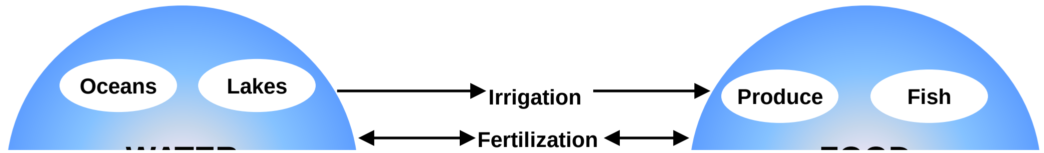
Professor Joan B. Rose
rosejo@msu.edu
Homer Nowlin Chair

MICHIGAN STATE UNIVERSITY

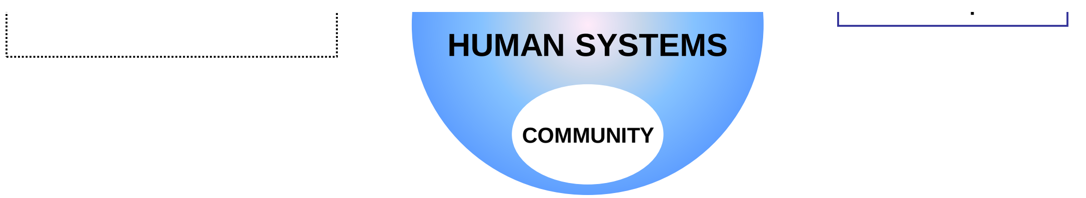


SWIMMING AREA CLOSED
Animal Virus Structure
Capsid
Spikes
DNA
Drinking Water
Urban Runoff
Agricultural Runoff
Industrial Outfalls and Sewage
Shorebird Droppings
Toxic Algae Bloom
Swimming Beaches
Lake Circulation
E-coli
Migration through Ground-water
Sediment Resuspension

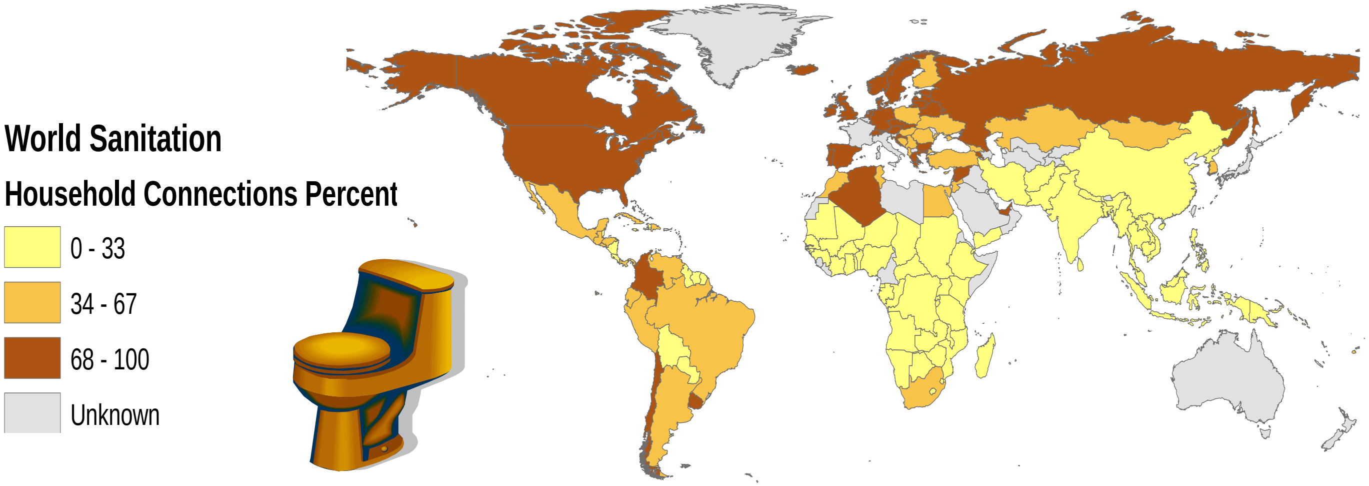
Coupled Water, Food and Human Systems



The global population has reached **7 billion**, and meat consumption rates worldwide have outpaced population growth. **The numbers of cattle, sheep, pigs and chickens are estimated at 1.4, 1, 0.9 and 21 billion,** respectively (FAO http://www.fao.org/docrep). **On average, animals and humans generate 62 and 10 billion kg of excreta per day, respectively** (FAOSTAT). The amounts of nitrogen, phosphorus, and energy that could be recovered from these excreta are approximately 215 million kg, 143 million kg, and 59,998 tera-Joule, respectively, and represent a large amount of nutrient-rich resources (http://www.fao.org/docrep/004/x6518e/x6518e01.htm).



44% of the World's global population (7 billion people) lives within 150 km (93 miles) of the coastline (that is 3 billion people who flush or dispose daily and send fecal pollution into the environment and eventually into waterways). The world's rivers (ten of the longest rivers = 55,734 km or 34,629 miles) are so badly affected by human activity that the water security of 5 billion people are impacted.

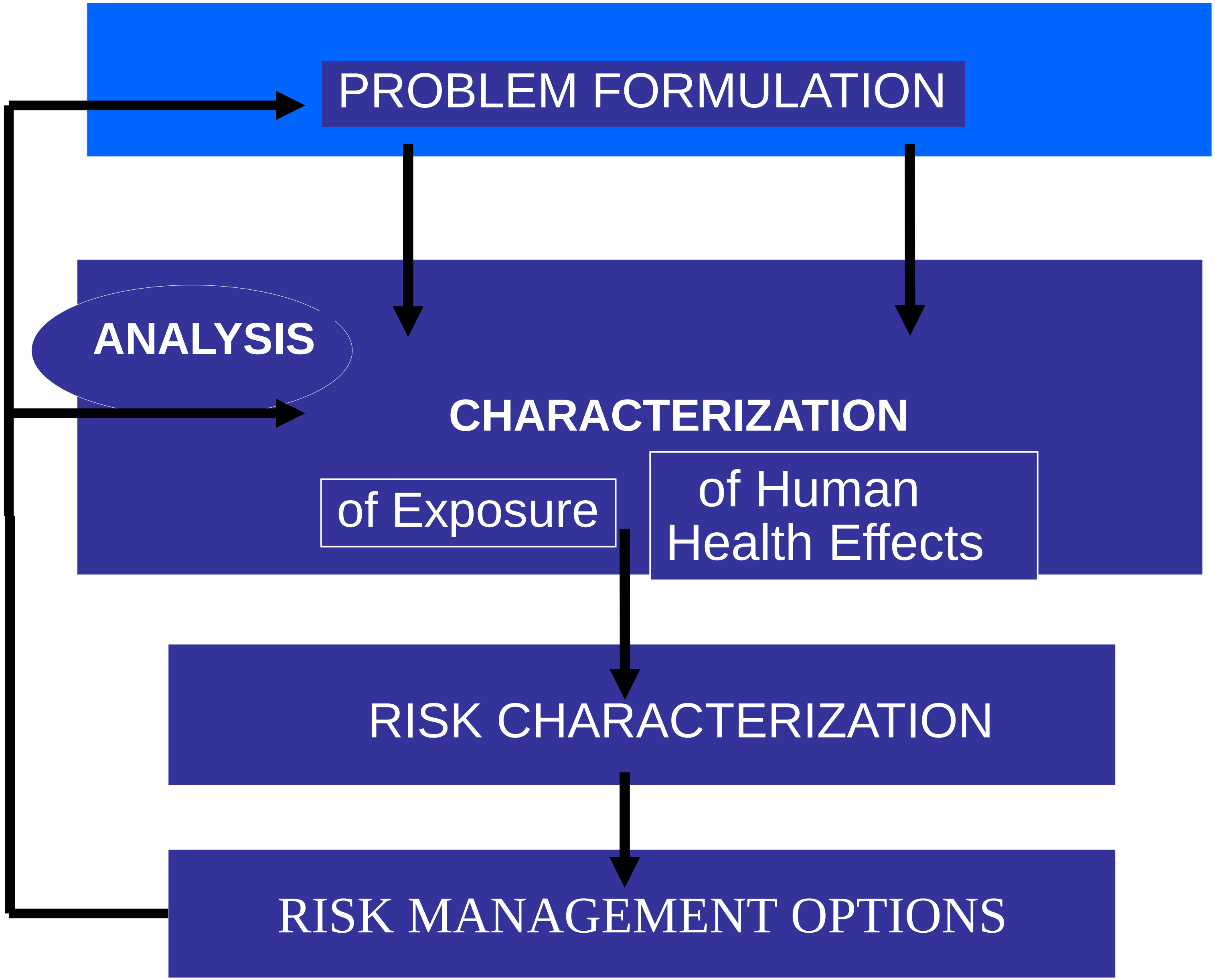


How do we move from disposal to wastewater reuse?
Through the application of
risk assessment,
monitoring and
control of pathogens

Challenges/Opportunities Remain

- **Sanitation for the World**
- **Resource Recovery**
- **One Water**
- **Advancing Technologies for Pathogen Monitoring**

The risk framework allows for the integration of public input, science, health, engineering data to identify and manage the risks



NATIONAL ACADEMY OF SCIENCES RISK ASSESSMENT PARADIGM

- **HAZARD IDENTIFICATION**

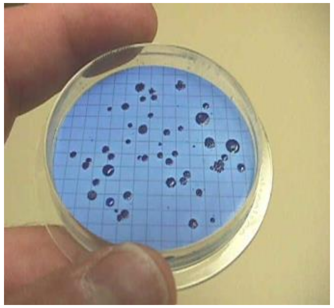
  Types of microorganisms and disease end-points
- **DOSE-RESPONSE**

  Human feeding studies, clinical studies, less virulent microbes and health adults
- **EXPOSURE**

  Monitoring data, indicators and modeling used to address exposure
- **RISK CHARACTERIZATION**

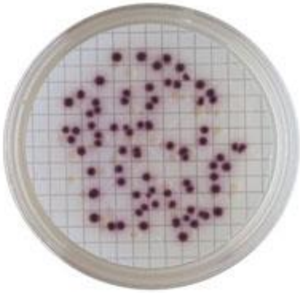
  Magnitude of the risk, uncertainty and variability

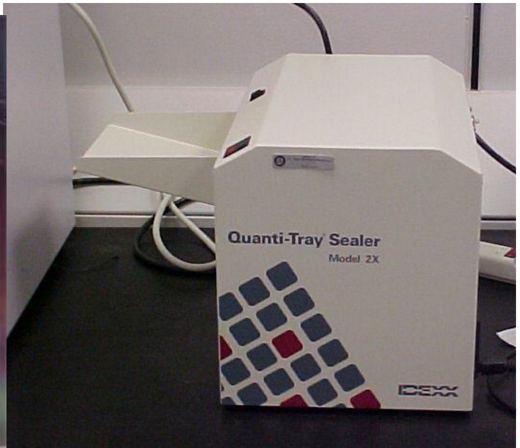
Improving Water Diagnostics

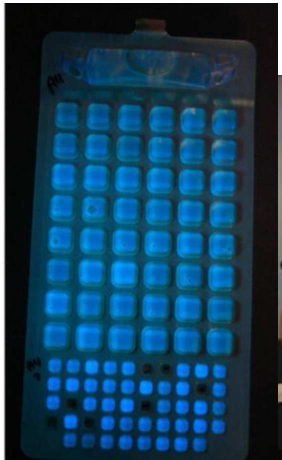


Escherichia coli (*E. coli*)

- General indicator of fecal contamination
- Linked to gastrointestinal illness through epidemiological studies (DuFour et al. 1982; Wade et al. 2006, 2008, 2010)
- USEPA recreational freshwater criterion: 2.5 log CFU/100 ml
- IDEXX Colilert® Quanti-Tray 2000®







Water Diagnostics

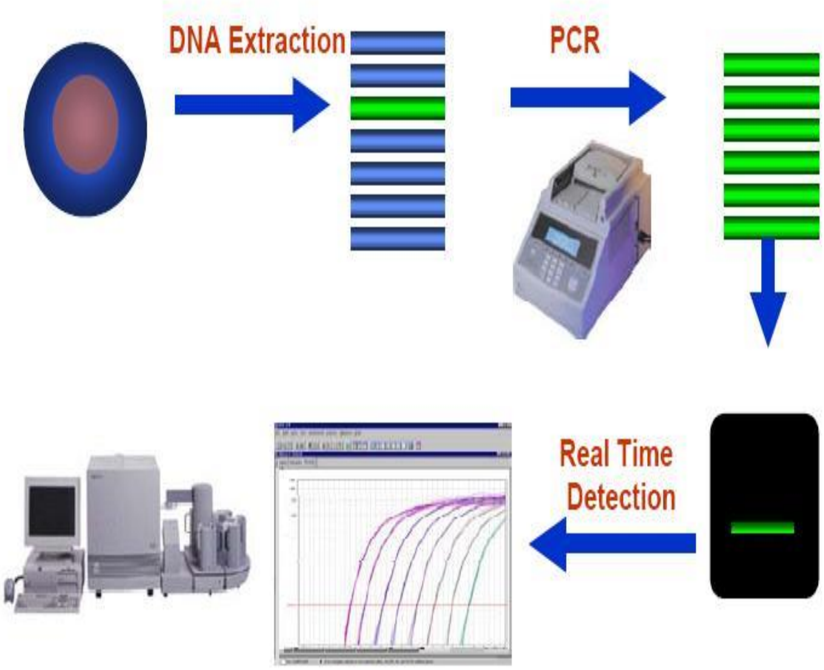
Polymerase chain reaction (PCR):

Small amount of DNA amplified in a thermal cycler

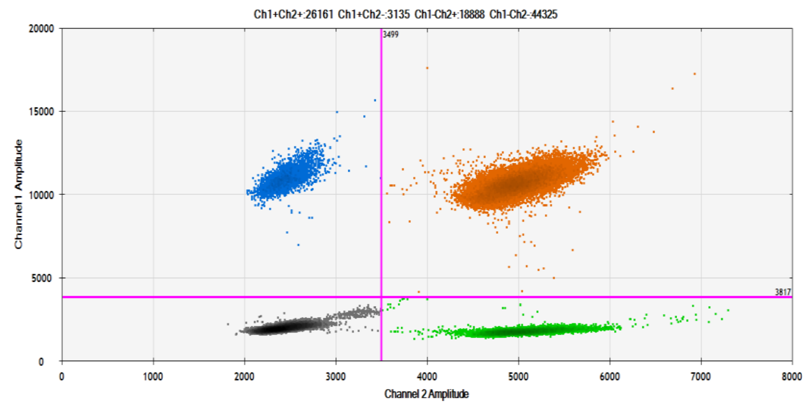
Amplified products are measured at the end point of amplification by agarose gel electrophoresis

Quantitative PCR (qPCR):

Amplified PCR products are detected real-time during the early phases of the reaction.



Approach source tracking and and Pathogen Analysis

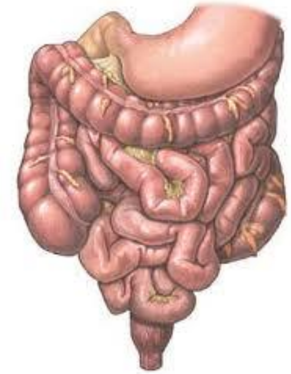


- droplet digital PCR (ddPCR)
  - Absolute quantification
  - High accuracy and precision
  - No standard curve
- Microbial Source Tracker (MST)

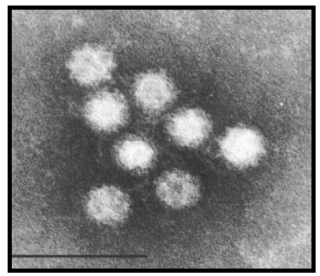
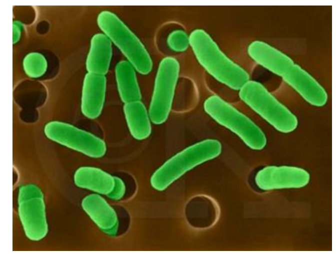
THE MICROBIOME

Sources



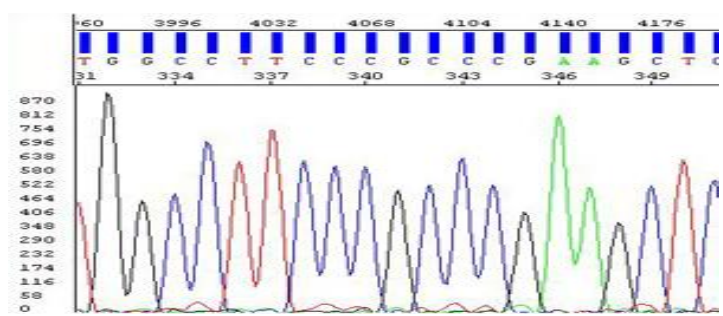


Microbiota

Community DNA

Metagenome library & sequence analysis



An example of 3rd generation sequencer

- Oxford Nanopore
- Single-molecule sequencing platform
- Powered and operated by a laptop via a USB
- Low cost for reagents and instrumentation (USD 1,000)
- Longer reads (average 5 kb)
- Real-time sequence analysis

Images from University of Oxford

Environmental Surveillance of Viruses in Kenya using Metagenomics

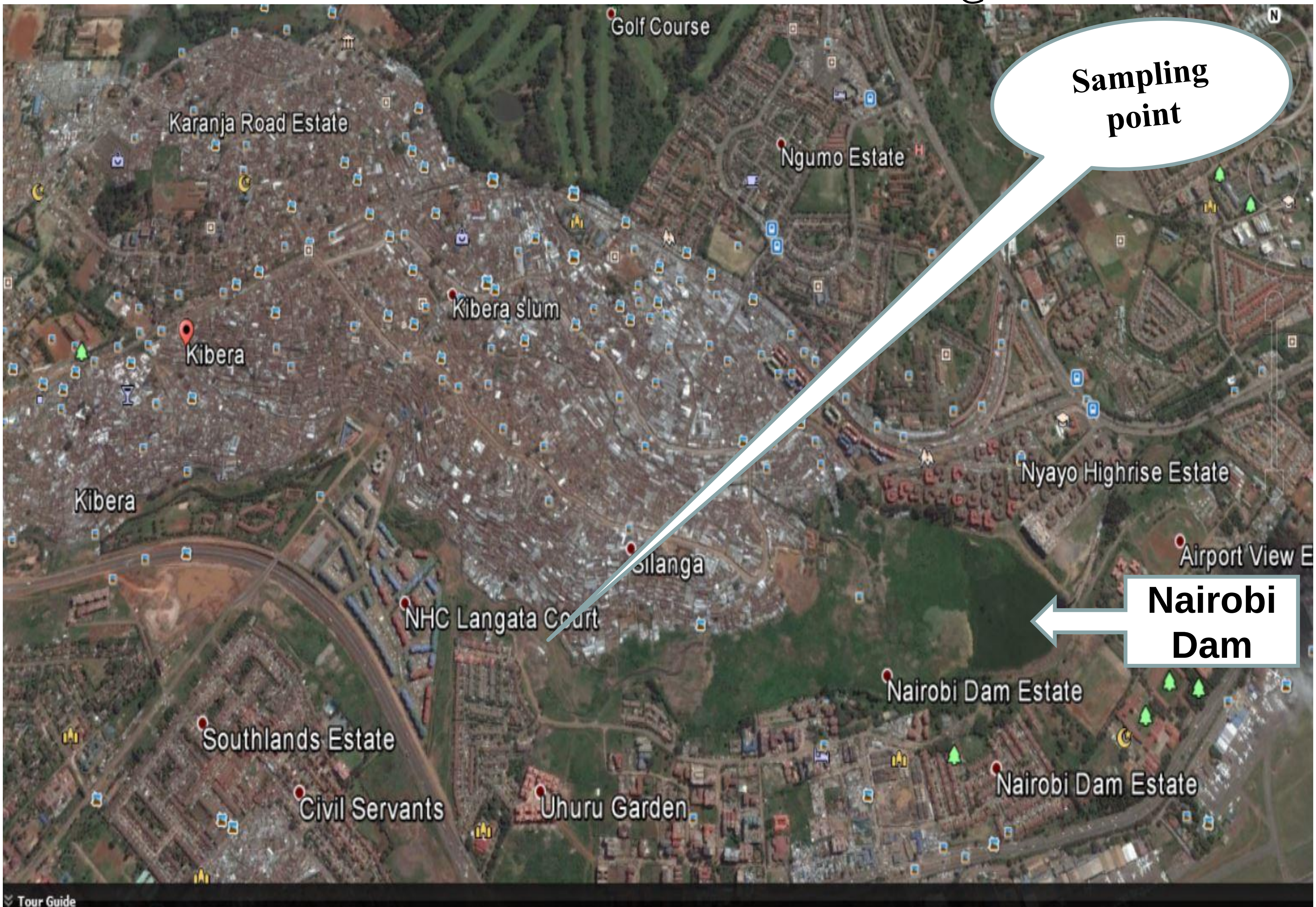
Tiong Aw

Assistant Professor
School of Public Health and Tropical Medicine
Tulane University
taw@tulane.edu

Nicholas Kiulia, Joan Rose
Michigan State University

Kibera slums

Dr. Tiong Aw, Tulane Univ.
taw@tulane.edu



Pit Latrines in Kibera

Dr. Tiong Aw, Tulane Univ.
taw@tulane.edu

Karen lagoon

Dr. Tiong Aw, Tulane Univ.
taw@tulane.edu

Nicholas Kiulia collects untreated sewage samples from a lagoon in Kenya using a novel bag-mediated filtration system.

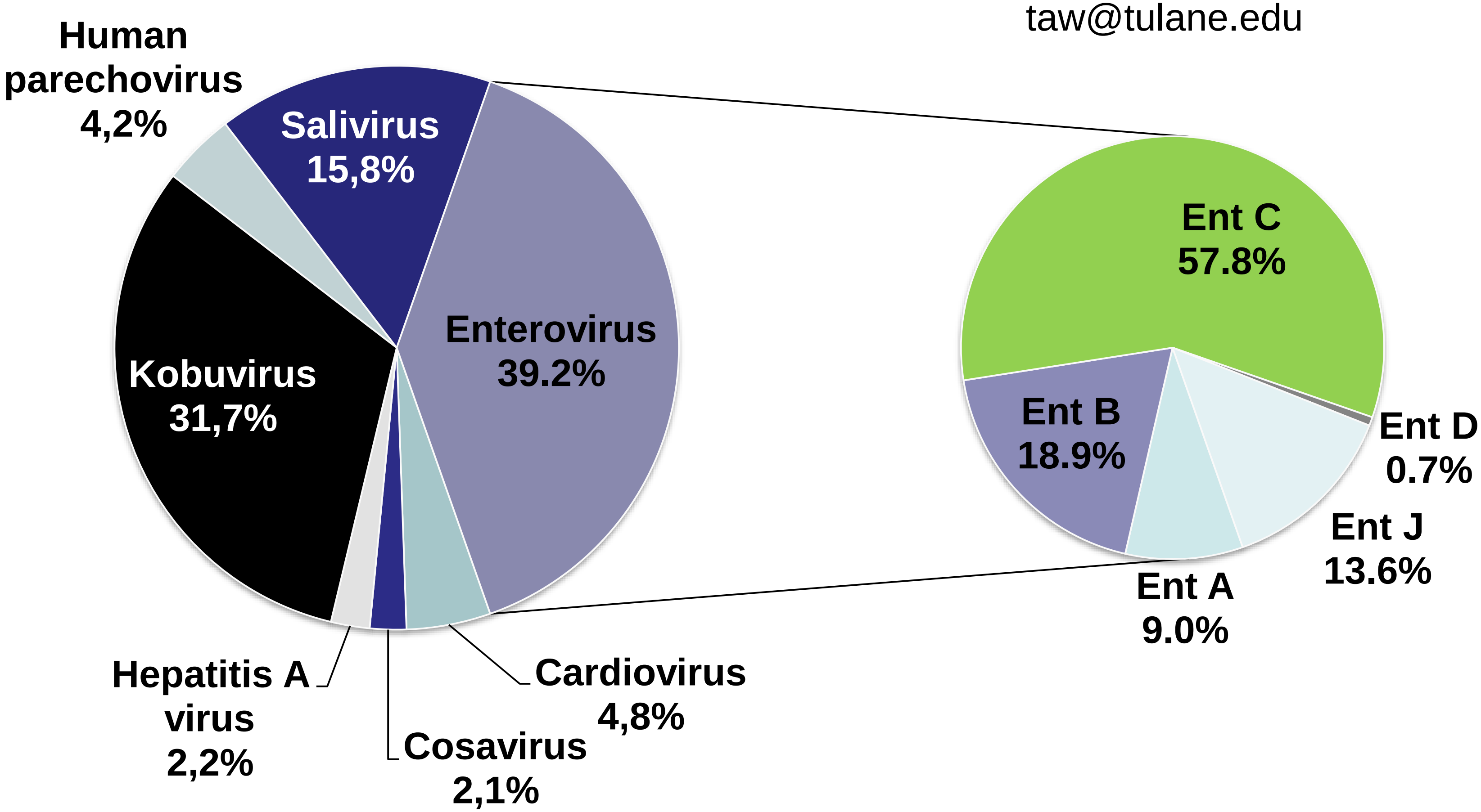
Source: http://engagedscholar.msu.edu/magazine/volume11/

Maua Hospital Lagoon

Dr. Tiong Aw, Tulane Univ.
taw@tulane.edu

Distribution of Picornavirus and Enterovirus sequences for Kenya wastewater virome

Dr. Tiong Aw, Tulane Univ.
taw@tulane.edu



Detection of rotaviruses and enteroviruses in Kenya Wastewater Using digital droplet RT-PCR

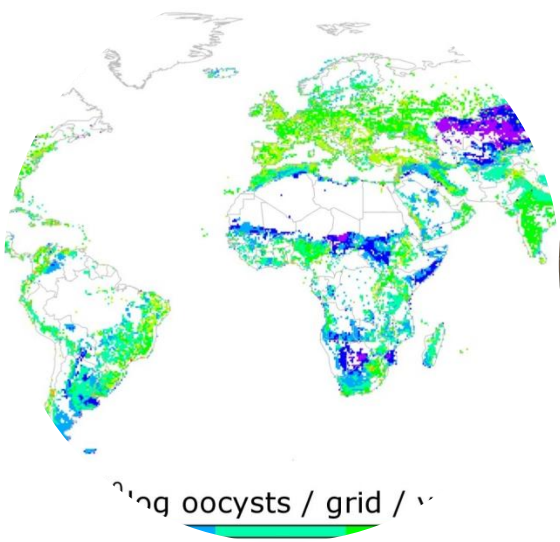
Mr. Nicholas Kiluia

			Rotavirus	Enterovirus
Sampling Location	Sample ID	Samples # (n)	Concentration (GC/L)	Concentration (GC/L)
Karen	KA-1	2	5.52E+03	1.30E+03
	KA-2		1.50E+04	1.71E+04
Kibera	KD-1	2	3.04E+04	1.92E+03
	KD-2		7.92E+03	4.86E+02
IPR	IPR-1	2	3.24E+03	2.51E+04
	IPR-2		4.20E+03	4.19E+04
Maua	MM-1	4	5.84E+02	1.26E+04
	MM-2		3.01E+05	1.24E+04
	MM-3		6.12E+04	3.33E+03
	MM-4		7.24E+04	1.64E+04

Mapping waterborne pathogens in surface waters worldwide

Nynke Hofstra, Asli Aslan, Joan Rose

nynke.hofstra@wur.nl



Global pathogen assessment – Why?

- Hotspot identification
- Better understanding trans-boundary water contamination issues
- Highlight links between land-use, climate, water quality and health
- Examine scenarios for decision making

Cryptosporidium emissions

Global data bases on population
Demographics
Sewage coverage,
Type of treatment

Pathogen specific information
Incidence of disease
Excretion rates
Concentrations in sewage
Removal by Treatment

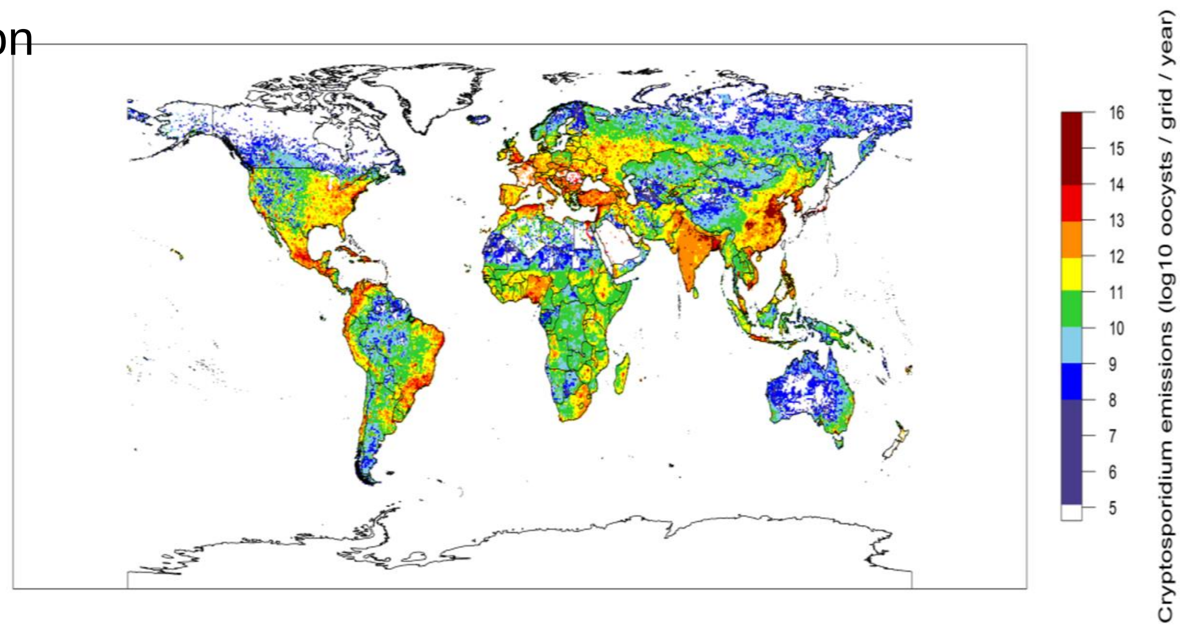
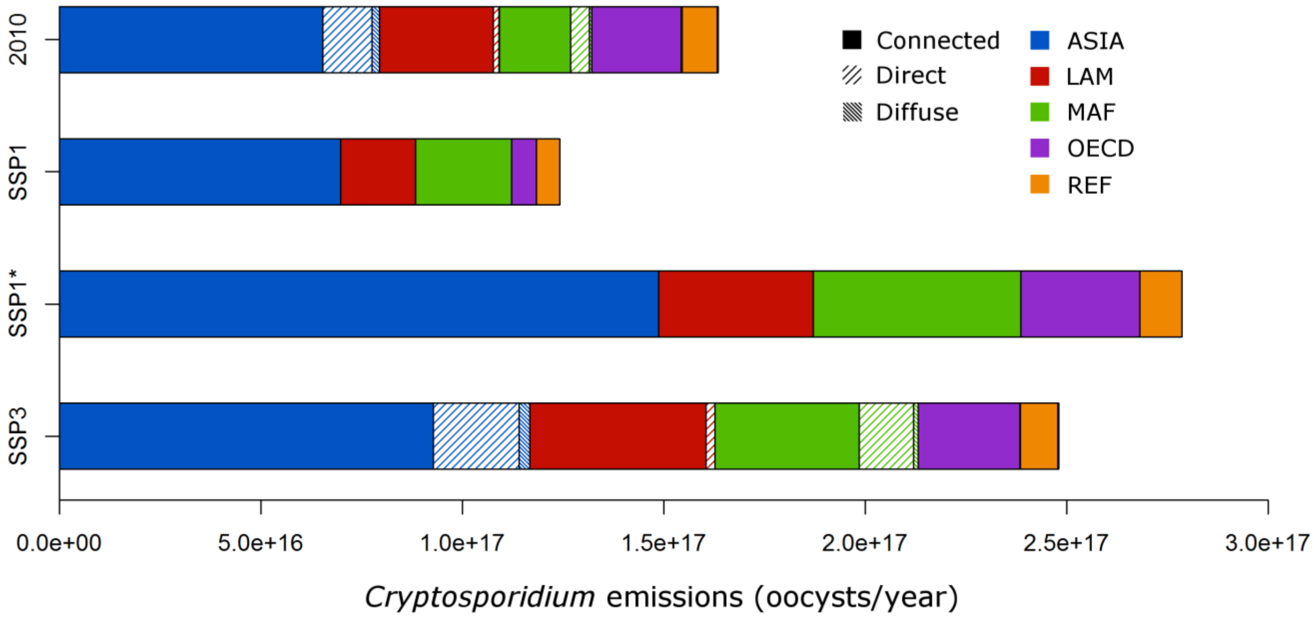


Figure 2. A map of *Cryptosporidium* emissions to surface water in oocysts/grid/year based on data for approximately the year 2010

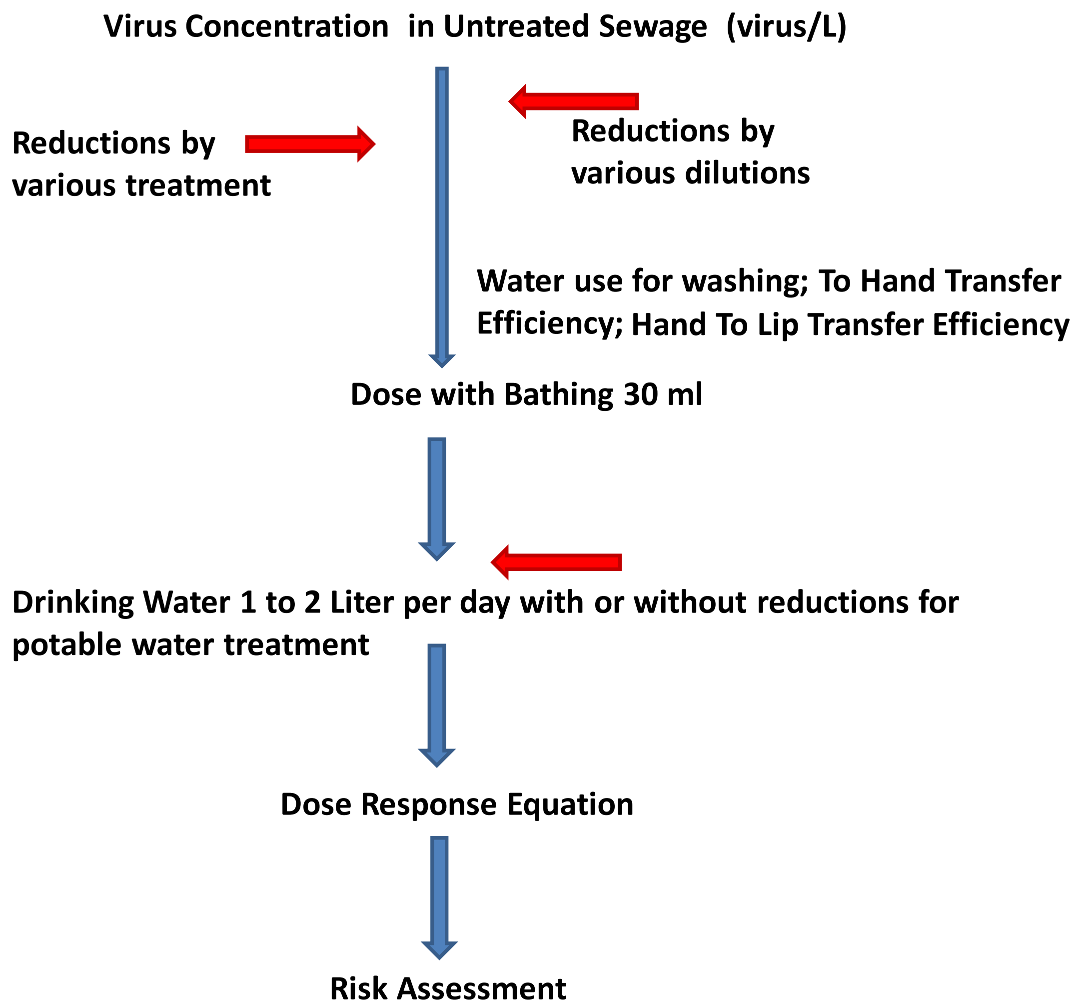
Produce interactive global maps with high resolution; Address scenario planning Nynke Hofstra



ssp3 assumes improvement to sewers but no treatment Nynke Hofstra et al. 2016 risk assessment should be used to examine wastewater treatment

How much treatment is needed?

What is safe?



For rotavirus 99.9% reductions are needed to achieve safe reuse for ecosystem services down stream with 1/10 dilution

RECOMMENDATIONS

- ESTABLISH WATER DIAGNOSTIC LABORATORIES AS CENTERS OF EXCELLENCE
- FILL DATA GAPS ON PATHOGEN OCCURRENCE IN KEY REGIONS OF THE WORLD
- MAP PATHOGEN DISCHARGES MOVE TO RISK MAPS AND SCENARIO PLANNING

MICHIGAN STATE UNIVERSITY

Major contributors:
Dr. Tiong Aw,
Mr. Nicholas Kiluia

THANK YOU

Joan B. Rose
rosejo@msu.edu
ROSE GANG