Source to Tap Approach for Quantitative Microbiological Risk Assessment of Pathogens

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Microbiological risk assessment: a scientific basis for managing drinking water safety from source to tap

- Supported by the European Commission as a part of the 5th Framework Program, and contributes to the implementation of the Key Action Management of water in the city within the program: Energy, environment, and sustainable development.
- 11 public and private partners: Sweden (1), The Netherlands (2), Germany (2), United Kingdom (3), France (2), Australia (1)
- Objectives
  - ➔ Quantitative Microbiological Risk Assessment (QMRA) of drinking water in the EU
  - ➔ Development and evaluation of a harmonized framework

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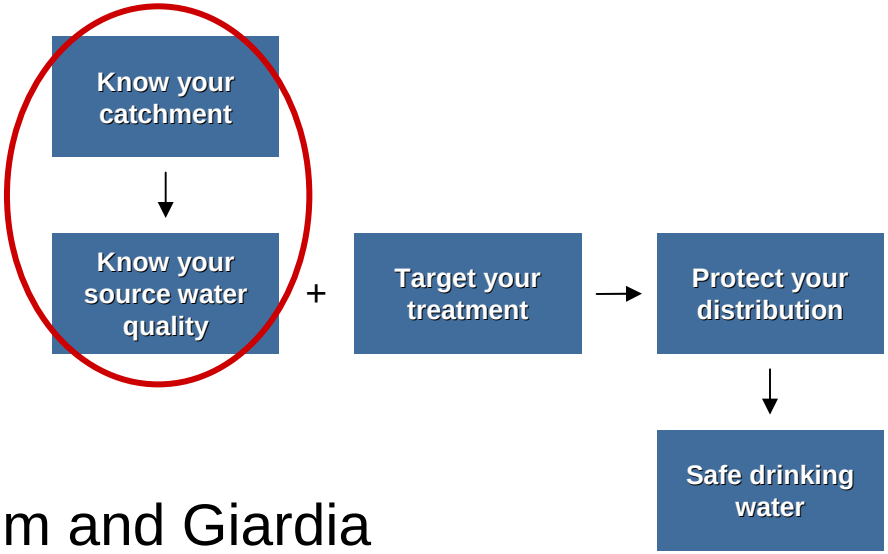
Microbiological risk assessment: a scientific basis for managing drinking water safety from source to tap

- "Source to tap" approach



- 6 pathogens of concern
  - ➔ Protozoa: Cryptosporidium and Giardia
  - ➔ Bacteria: Campylobacter and E. Coli 0157:H7
  - ➔ Viruses: Enterovirus and Norovirus

1. Know your catchment

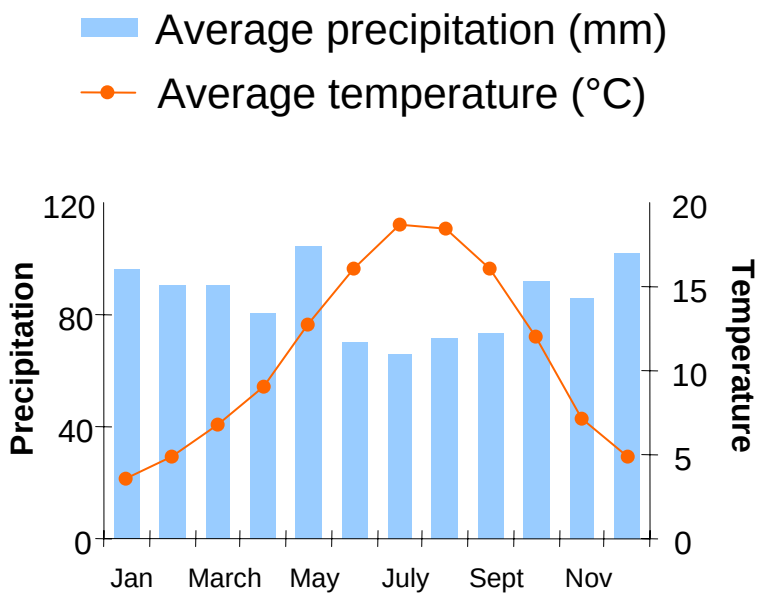
- Objective: provide basic understanding of the catchment
  - ➔ Vulnerability of the source water
  - ➔ Importance and location of pathogen sources
  - ➔ Peak events leading to high contamination risks

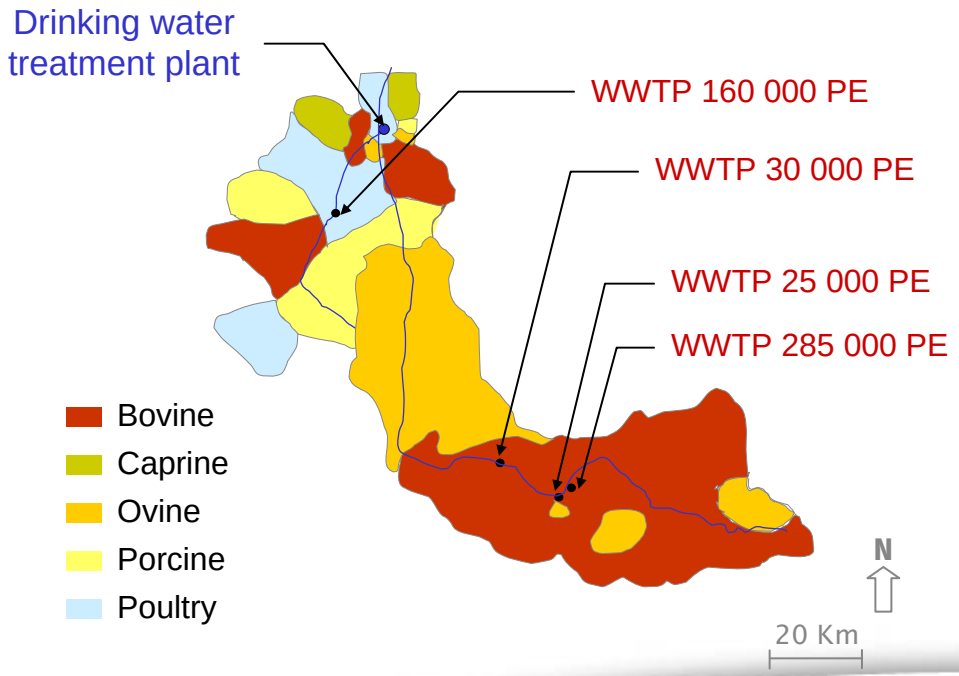
- Guidelines for performing catchment survey

SURFACE WATER	GROUNDWATER
Description of water abstraction	
Water intake description	• Number of wells • Depth • Wellhead
Type of source • River • River with reservoirs upstream • Artificial reservoir (dam) • Natural reservoir (lake)	Type of source • River-aquifer connection (e.g. karstic aquifer) • Shallow hole • Lowland river gravel abstraction • Shallow water table • Confined aquifer
Catchment description	
Size of the catchment, length of river, main tributaries, maximum and minimum height, dimension of reservoir	• Total catchment • 50-days catchment • Surface water catchment (if connected)
Uses of water • Agriculture • Urban • Industry	Uses of water • Agriculture • Urban • Industry
Hydrology & Hydrogeology	
• Average flow • Monthly average flow • Sorted Flows • High flows (1-year, 10-year, 50-year) • Main soils • Slopes	• Description of catchment geology and hydrogeology • Average water pumped (yearly and monthly) • Maximum water pumped (yearly and monthly)
Climate	
Description of the climate including • Temperature (monthly average, minimum and maximum) • Rainfall (monthly average, minimum and maximum)	
Location and description of potential sources of faecal contamination	
• Human – Waste Water Treatment Plants – Combined Sewers Overflows – Biosolids (storage and use in agriculture) • Animal – Animal breeding (manure storage, manure used as fertiliser, grazing) – Roosting birds – Slaughterhouses or livestock markets – Wildlife	• Human – Septic tanks – Biosolids (storage and use in agriculture) • Animal – Animal breeding (manure storage, manure used as fertiliser, grazing) • Other – Wellhead or borehole liable to flooding • If connected to surface water – See potential sources for surface water

1. Know your catchment

- Examples from Chatellerault (France)



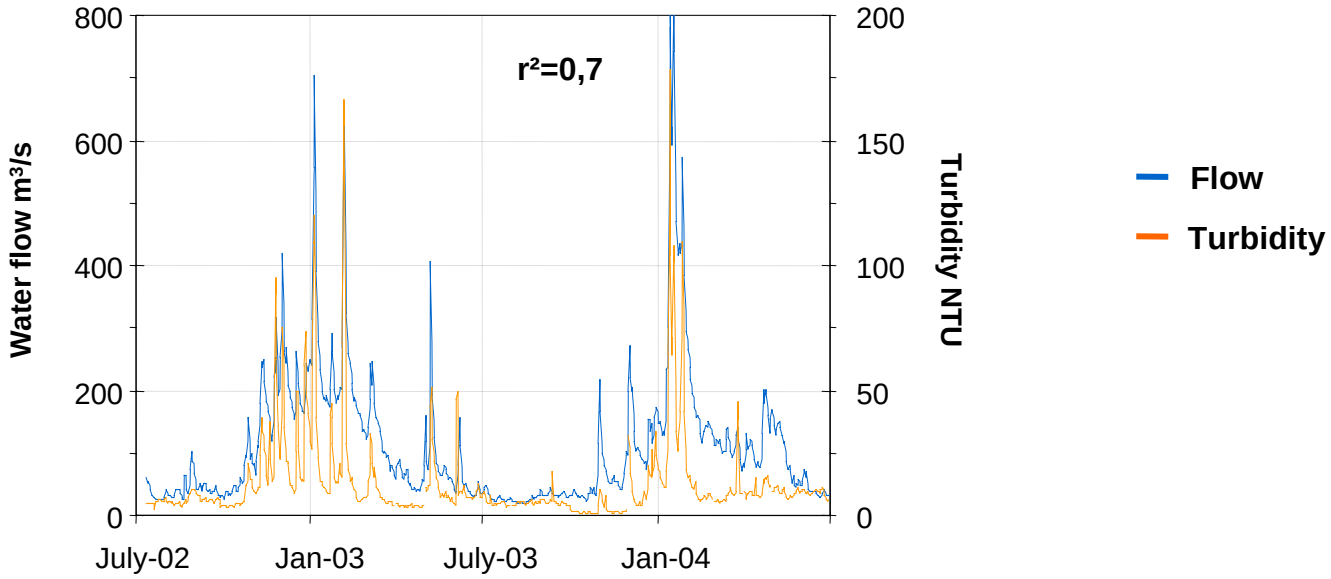


1. Know your catchment

- Identification of peak events
  - ➔ Heavy rainfall
  - ➔ Thaw/snowmelt
  - ➔ Upstream/downstream incidents (failures, waste water discharges …)
  - ➔ Cleaning of the river course
  - ➔ Farming practices

1. Know your catchment

- Historical data analysis
  - ➔ Mostly rainfall events
  - ➔ Example: daily flow and turbidity 2002-2004 in Chatellerault



2. Pathogen monitoring

- Monitoring program
  - ➔ Pathogens (Cryptosporidium, Giardia, Campylobacter, E. Coli 0157:H7, Enterovirus and Norovirus)
  - ➔ Indicator bacteria (E. Coli, Clostridia, Total Coliforms, Enterococci)
  - ➔ Physico-chemical characteristics (turbidity, conductivity, temperature, pH)
  - ➔ River flow

2. Pathogen monitoring

- Chronic contamination
  - ➔ Full year of monthly samples
- Peak event contamination
  - ➔ Surface water : water flow and/or turbidity increase
- Sampling and analysis
  - ➔ Standard methodologies
  - ➔ Large volume samples
  - ➔ Analytical performance

3. Source water quality

- Data for 9 European source waters and 1 Australian

Partner	CTS	Source of water	Climate	Catchment area (km^2)
United Kingdom	1	Surface Water, Unprotected (river)	Humid Oceanic	12,917
The Netherlands	2	Surface Water, Unprotected (River)	Humid Oceanic	198,735
France (Veolia)	3	Surface Water, Unprotected (river)	Humid Oceanic	10,050
France (Veolia)	4	Surface Water, Unprotected (river)	Mediterranean	522
Sweden	5 & 6	Surface Water, Unprotected (river & lake)	Sub-arctic	46,830
Germany	7	Groundwater, Unprotected (river bank filtration)	Humid Oceanic	145
Australia	8	Surface Water, Unprotected (Reservoirs)	Mediterranean	140
The Netherlands	9	Surface Water, Unprotected (Reservoir)	Humid Oceanic	198,735
France	10	Surface Water, Unprotected (Reservoirs)	Humid Oceanic	30
Germany	11	Surface Water, Protected (Reservoirs)	Humid Oceanic	300
France	12	Groundwater, Protected (Aquifer)	Humid Oceanic	100

CTS : Catchment to Tap System

3. Source water quality

- Analytical performance

	Cryptosporidium		Giardia	
	Mean recovery	σ	Mean recovery	σ
CTS 2	12%	16%	6%	5.4%
CTS 3 & 4	30-40%		30-40%	
CTS 5	12%	7%	8%	7%
CTS 7	19.2%	5.7%	14.9%	4.5%
CTS 8	50%	13%	47%	17%
CTS 10	26%	21%	30%	29%
CTS 11	12%	3.1%	10.7%	7.3%

Recovery ≤ 50%

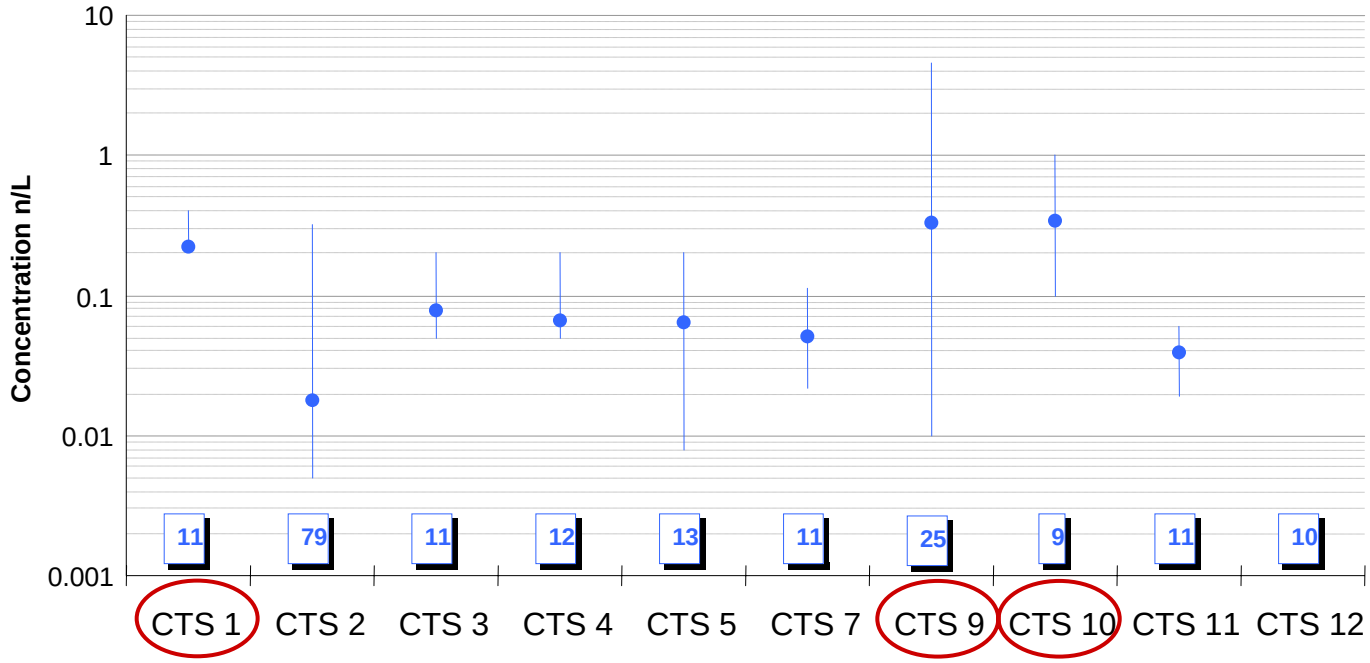
NB: Analytical performance data not being homogeneous, raw results are presented directly

3. Source water quality

- Data analysis
  - ➔ A picture of source water pathogen contamination in European countries
  - ➔ Assessment of the significance of peak event contamination
  - ➔ Analysis of correlation between indicator bacteria and/or turbidity and pathogens

3. Source water quality

- Cryptosporidium contamination in chronic conditions



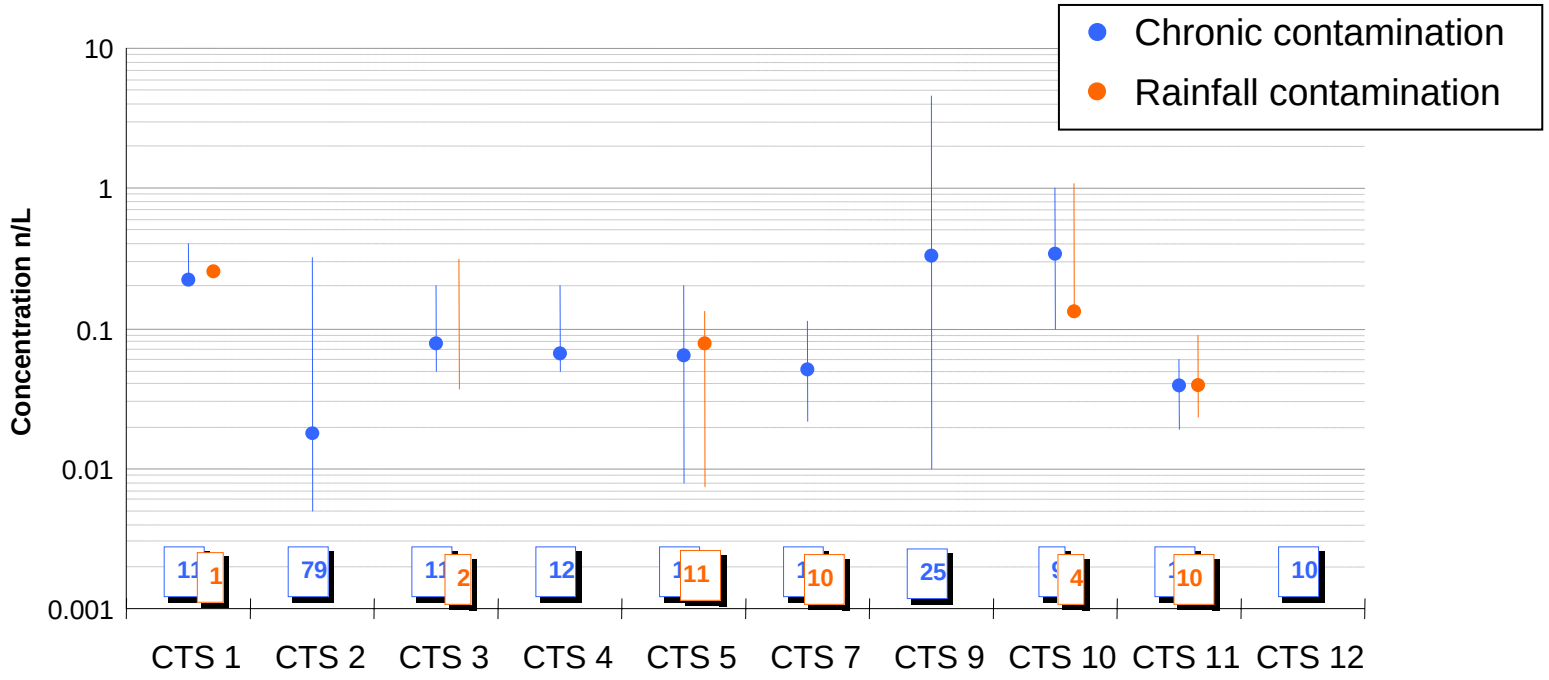
n Number of samples

MicroRisk : ~ 0.1 oocyst/L (up to 4.5 oocysts/L)

Literature review : 0.006-250 oocysts/L

3. Source water quality

- Cryptosporidium contamination in rainfall conditions

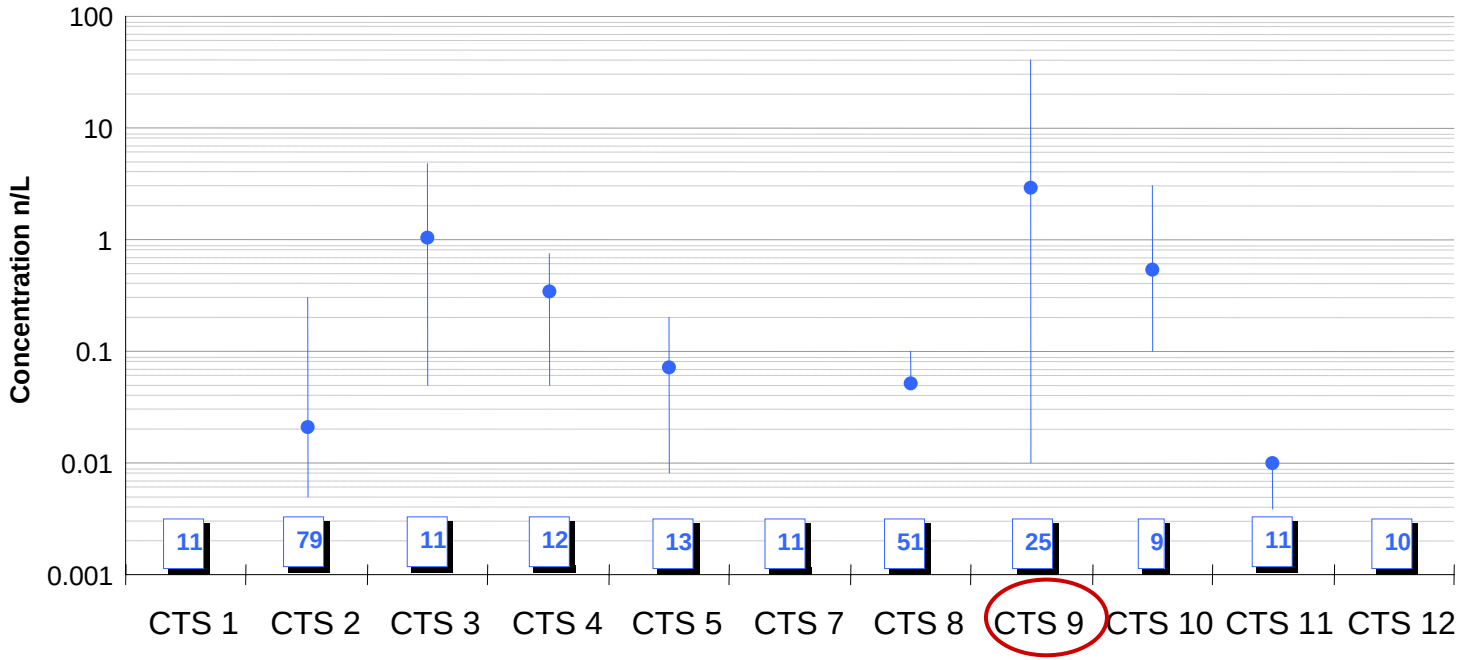


n Number of samples

Rainfall concentrations are not clearly higher

3. Source water quality

- Giardia contamination in chronic conditions

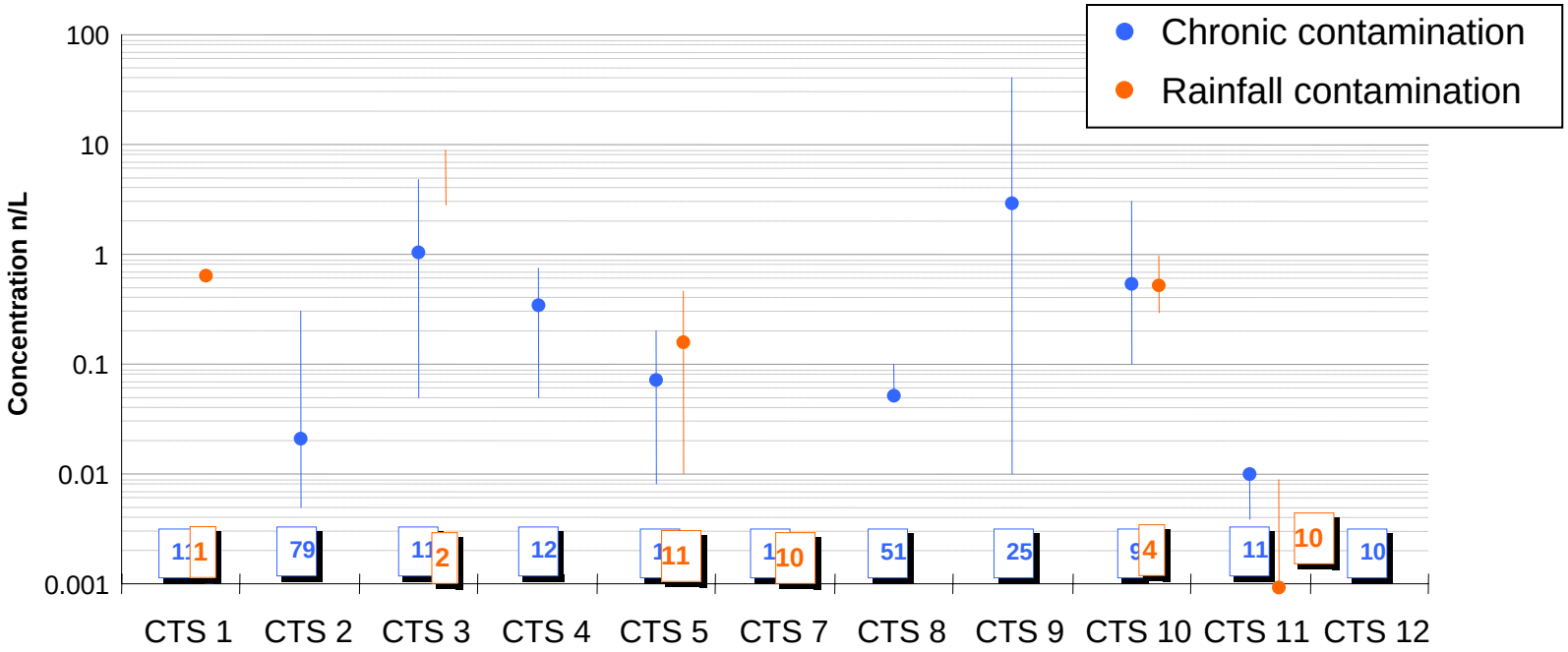


n Number of samples

MicroRisk : 0.1-1 cyst/L (over 40 cysts/L in one case)
Literature review : 0.02-100 cysts/L

3. Source water quality

- Giardia contamination in rainfall conditions



n Number of samples

Rainfall concentrations are not clearly higher

3. Source water quality

- Levels of contamination in surface waters

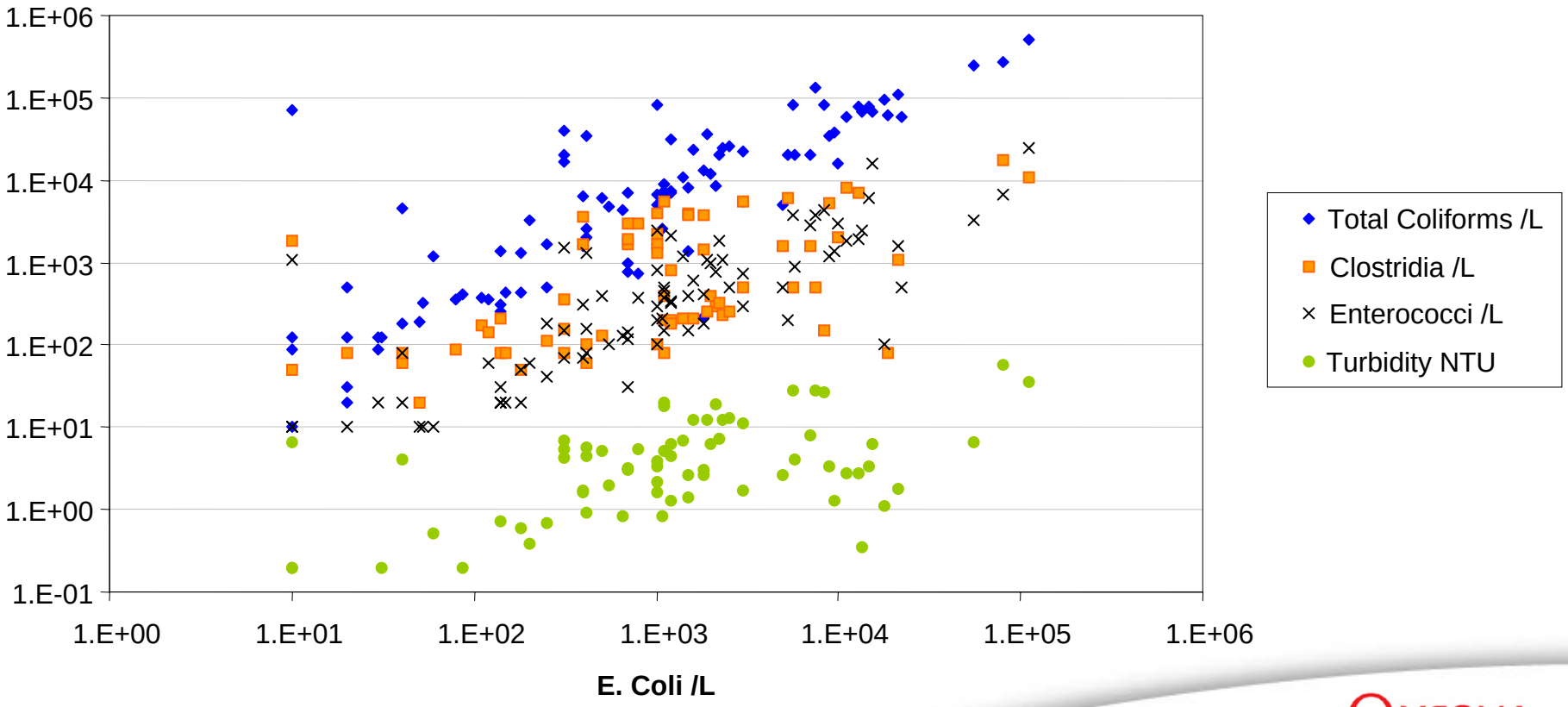
	Chronic contamination	Rainfall contamination
Test Germs		
E. Coli	10^2-10^4 MPN/L	10^3-10^4 MPN/L and up to 50,000 MPN/L
Clostridia	≈ 3000 n/L and up to 17,500 n/L	5,000-6,000 n/L
Enterococci	10^2-10^3 n/L	> 10^3 n/L
Total Coliforms	10^3-10^5 MPN/L	30,000-130,000 MPN/L
Pathogens		
Cryptosporidium	≈ 0.1 n/L and up to 4.5 n/L	Concentrations not clearly higher
Giardia	0.1-1 n/L and over 40 n/L in one case	Concentrations not clearly higher
Campylobacter	< 100 n/L but not often detected	Concentrations not clearly higher
E. Coli 0157:H7	10-100 CFU/L and up to 1,000 CFU/L	1,000 CFU/L and up
Enterovirus	< 1 PFU/L and up to 150 n/L	≈ 300 n/L in one CTS
Norovirus	< 100 n/L in one CTS	100-200 n/L in one CTS

3. Source water quality

- Rainfall events yield higher indicator bacteria concentrations
- Results are not as clear for pathogens
  - Rainfall event population may not be fully representative
  - Analytical performance may be affected by higher turbidity
  - Dilution effect on concentrations but pollution flows are greater

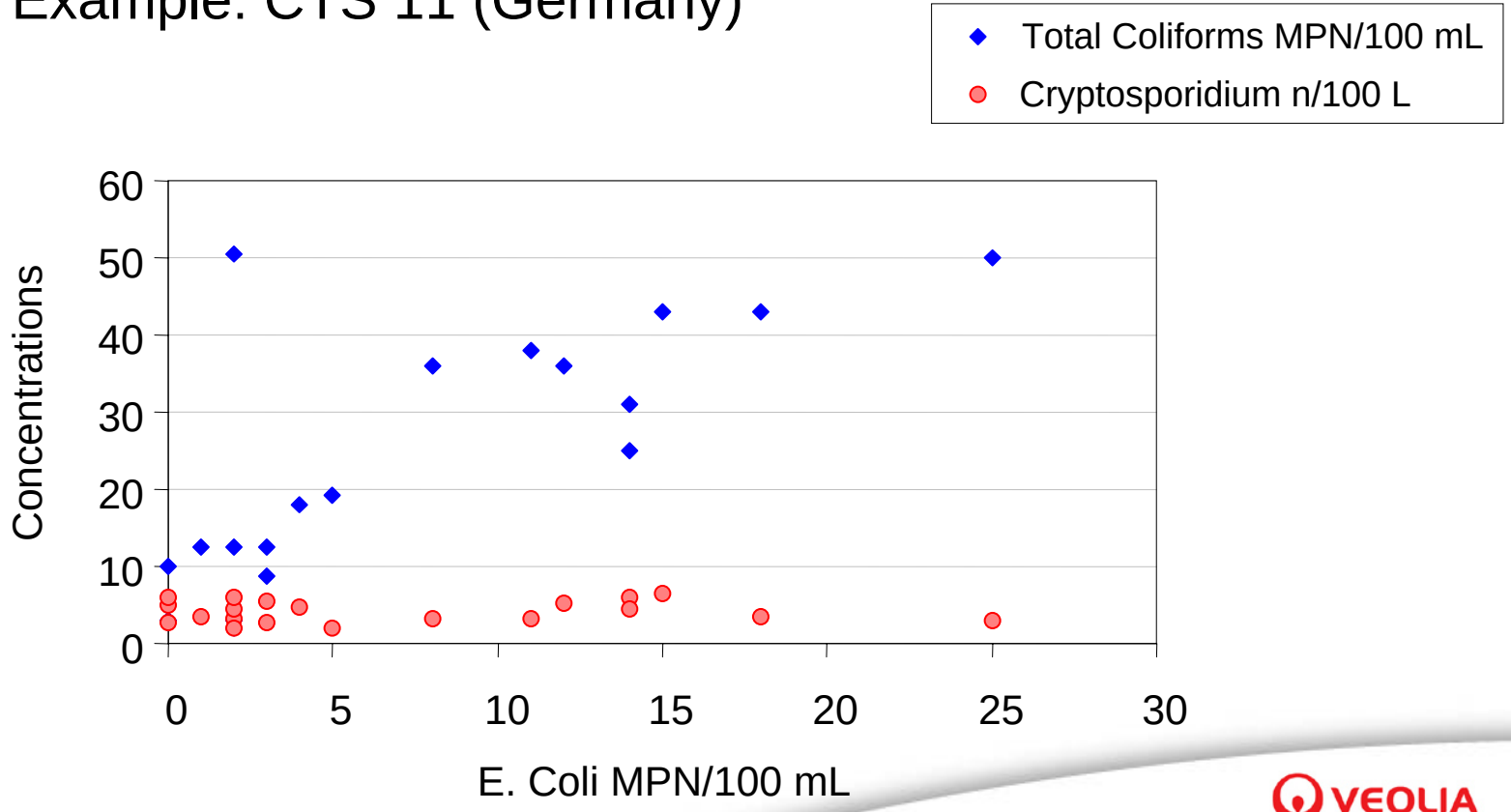
3. Source water quality

- Correlation analysis
  - ➔ Test germs vs. E. Coli (all systems)



3. Source water quality

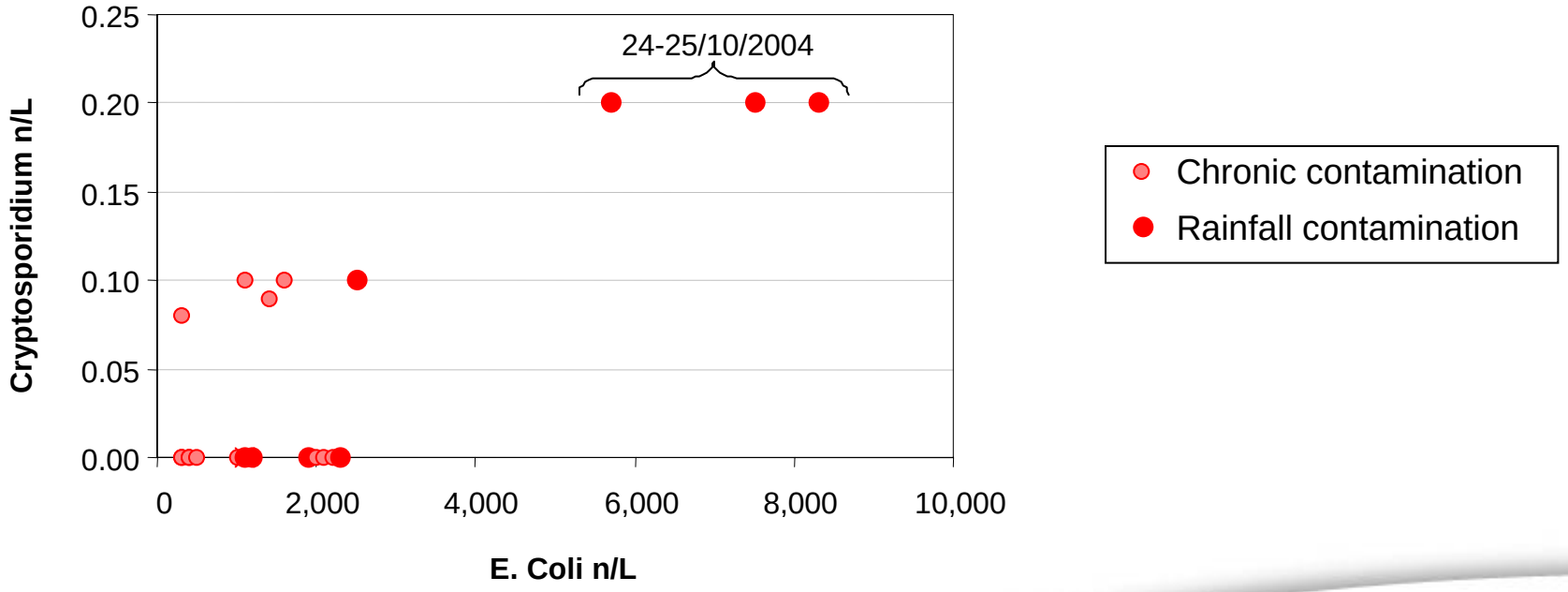
- Correlation analysis
  - ➔ Results are not as clear for pathogens
  - ➔ Example: CTS 11 (Germany)



3. Source water quality

- Correlation analysis
  - ➔ Cryptosporidium in chronic and rainfall conditions

    CTS 5 (Sweden)



Conclusion

- Levels of pathogen contamination

- Significance of peak events
  - ➔ Hydrological peak events yield higher indicator bacteria concentrations in surface waters
  - ➔ Groundwater seems unaffected
  - ➔ Results are not as clear for pathogens

- On the question of indicator bacteria and pathogens correlation
  - ➔ Indicator bacteria and turbidity
  - ➔ Pathogen correlations are scarce and site specific

Conclusion

- Laboratory performance
  - ➔ Method sensitivity (underestimation of pathogen contamination)
  - ➔ Viability of (oo)cysts ?
  - ➔ Turbidity/analytical performance relationships ?

- Prescriptions for source water risk assessment
  - ➔ Catchment survey
  - ➔ Identification of peak concentrations
  - ➔ Monitoring campaign

- MicroRisk publication: Guidelines for QMRA (WHO Drinking-water Quality Series of IWA)