Cryptosporidium & Giardia Removal in Small Systems

Assessment Procedures & Performance

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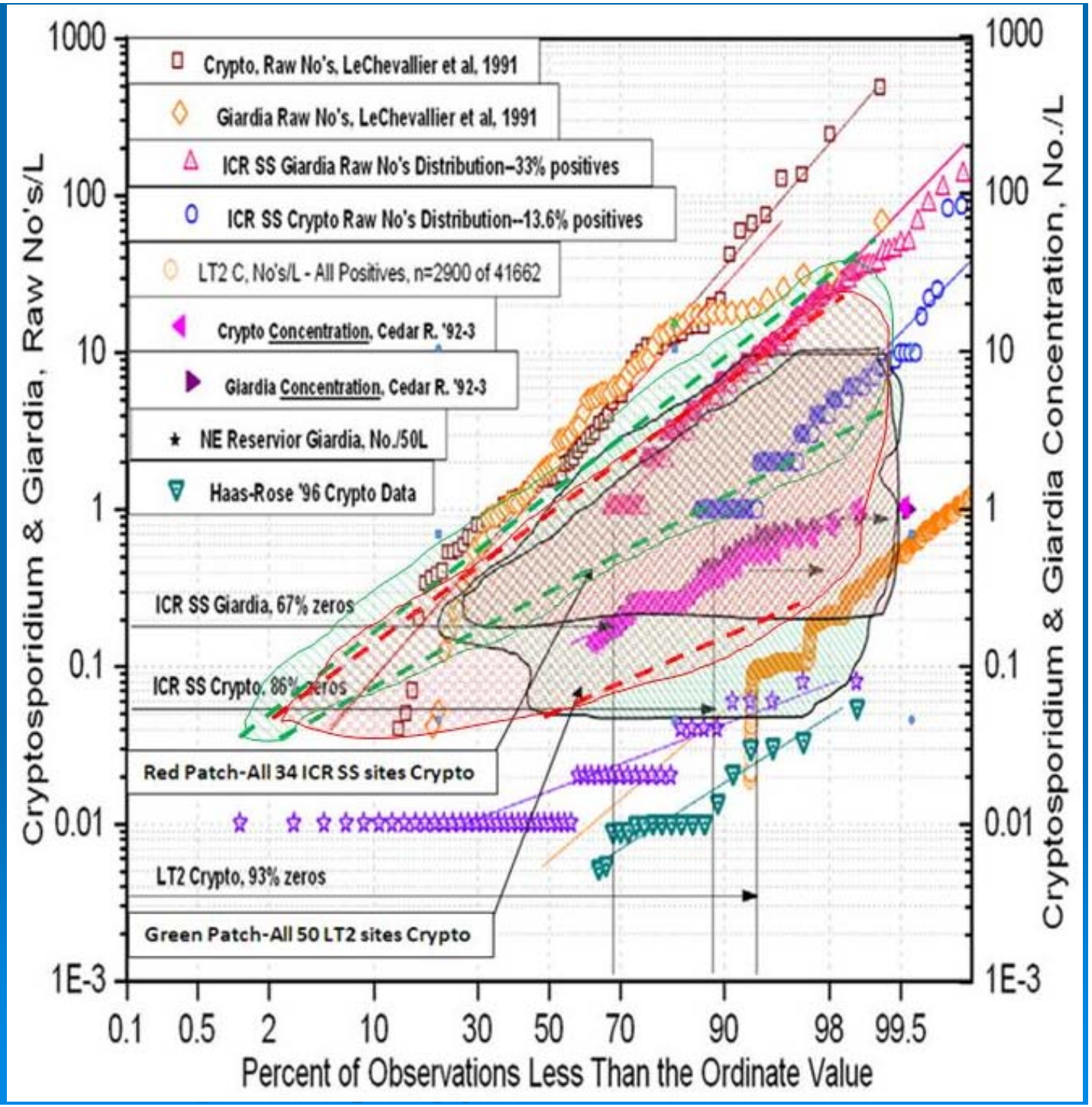
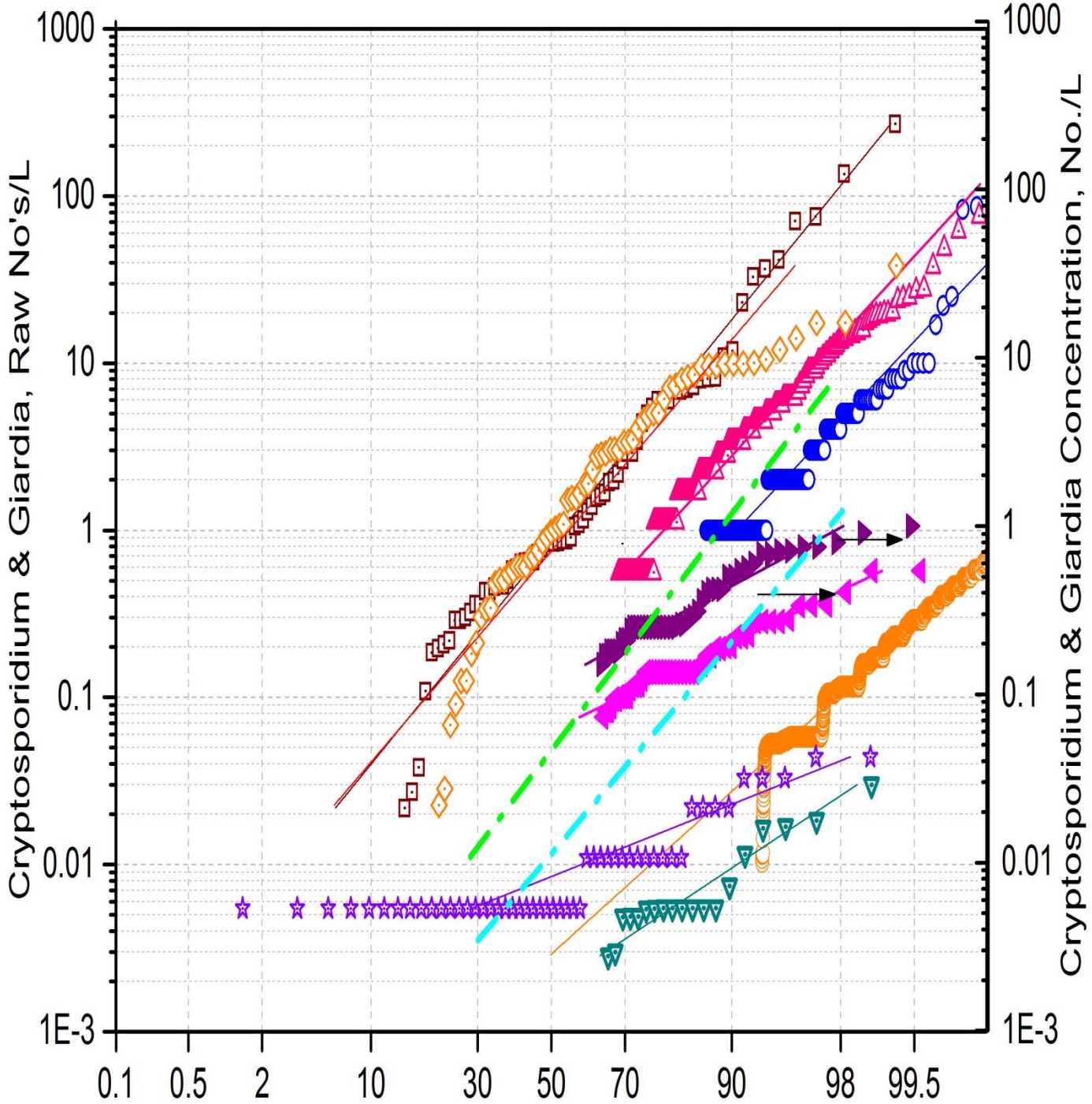
OBJECTIVES

- Crypto & Giardia…universal presence
- Summary of data on C & G in Europe
- Measuring treatment performance
- C & G in alternative treatment systems

Crypto & Giardia Global Summary



Crypto & Giardia Global Summary



FACTORS AFFECTING FILTER PERFORMANCE

- Water Quality: turb; DOC; part. no. & type
- Chem. Coag: Chem(Fe;Al); Coag/Filt. aids
- Flocculation -> (Settling)
- Filter Design: media size/profile; media comp.; media depth
- Filter Operation: flow/loading (6->30 m/hr); flowrate contr; term. criteria; backwashing

WATER TREATMENT QUESTIONS

- Overall Physical Removal? (...%; or logs)
- Performance of Treatment Components?
- Effect on Performance of Differences in:
  - design features? (eg. different media size)
  - operating features? (eg. different loading rates)
  - water quality features? (eg. high vs low turb.)
- Note: All questions require statistical ans.

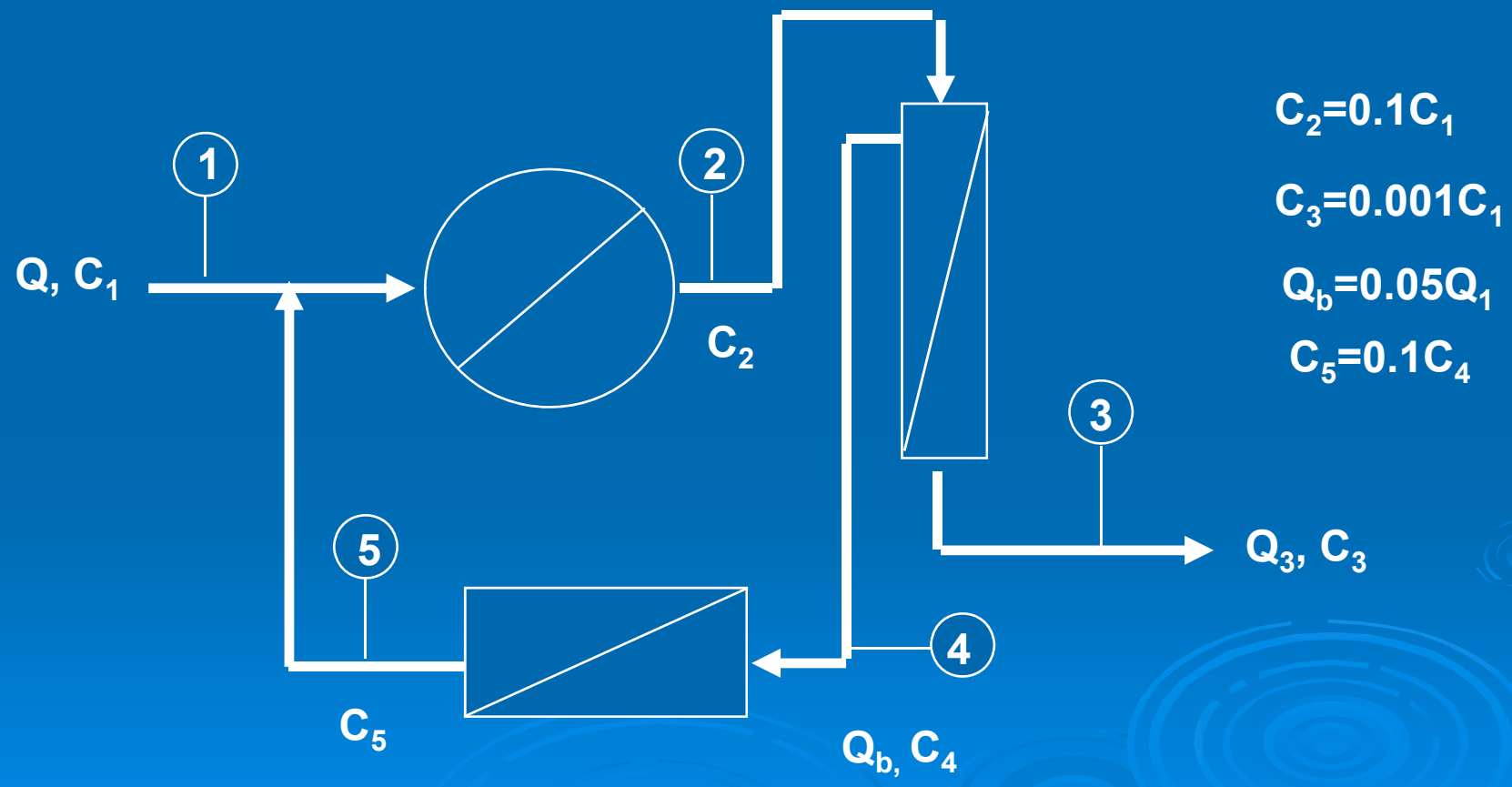
WATER TREATMENT QUESTIONS...CONT.

- Statistical Analysis--Resolve the difference between two measurements...eg. “t” tests
- Ability to Resolve Differences Depends on:
  - Precision (reproducibility) of the assay
  - Number of replicates for each condition
  - Variability in underlying processes
- At Best...Can Resolve Differences ca. 0.2 to 0.5 logs using n=3 (three replicate meas.)

DESIGN OF PERFORMANCE EVALUATION STUDIES

- Organisms (seed): 10^8-10^9 for most runs
  - Organism condition is important
- Application of Seed
- Sampling: locations; volumes; time; control
- Analysis: control (quality); replication (method precision); nonzero results, minimum relative error
- Full-scale plant performance

TREATMENT PERFORMANCE EVALUATION



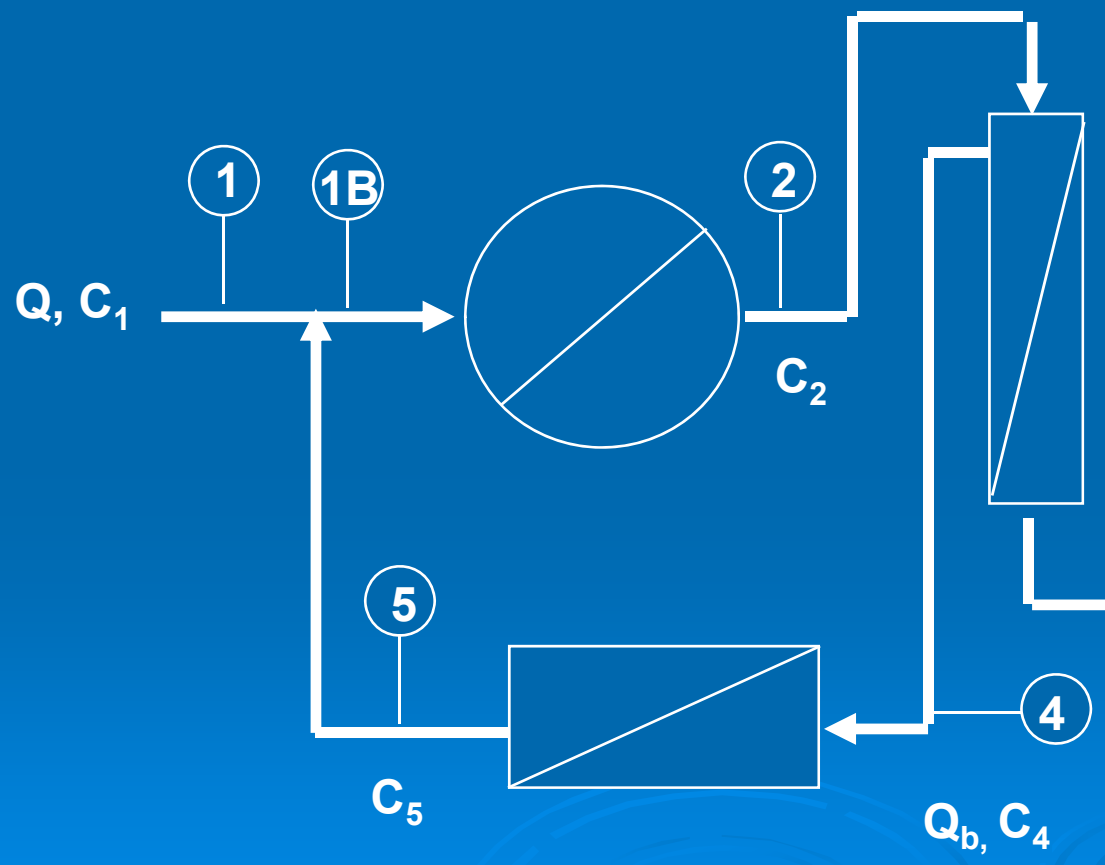
$C_2=0.1C_1$

$C_3=0.001C_1$

$Q_b=0.05Q_1$

$C_5=0.1C_4$

TREATMENT PERFORMANCE MEASUREMENTS



C_1=0.23 / L

C_{1B}=0.235 / L

C_3=0.0005 / L

C_4=4.9 / L

C_5=0.37 / L

Treatment System Types

- Slow Sand Filtration
- Pressure Filtration-Automatic Backwash
- Package Complete Rapid Sand Filtration
- Complete Rapid Sand Filtration
- Direct Filtration
- In-line Filtration
- Diatomaceous Earth Filtration

Treatment Facilities Included

Location	Filtration Type	Capacity mgd	Seed Organism *Giardia*	Seed Organism *Crypto.*	Ref.
100 Mi. House, B.C. Canada	Slow sand	1		+	1
Northern Idaho, USA	Slow sand	0.07-0.29	+	+	2
Darrington, WA, USA	Package, direct	0.57	+		3
Grey Eagle CA, USA	Pressure, auto	4.0	+		3
Huntington UT, USA	Complete & direct	0.9		+	4
Seattle WA, USA	Complete & direct, pilot	1(gpm)	+	+	5
Orchard Hills, NSW, Aust.	Complete conventional	15		+	6
Wellington NSW, Aust.	Complete conventional	5	+	+	U1*
Guerie NSW, Australia	Complete conventional, auto	0.2	+	+	U1*
Macarthur, NSW, Aust.	Direct, pilot	19.6		+	U2*
E. Gippsland, VIC, Aust.	Complete conventional	4		+	U3*
Crystal Mtn, WA, USA	Diatomaceous earth	0.016			3
UNSW, Sydney NSW, Aust.	Diatomaceous earth, pilot	$1ft^2$			7,8

C & G Removal Performance

Filtration Type	Component	*Giardia* cyst Log Removal	*Crypto oocyst* Log Removal	Comments
Slow Sand		0.5-0.7	0.5-0.7	Requires regular maintenance
Package Pressure		1-1.5	- -	On-off between bw limits removal
Package Complete		1.5-2.5	1.5-2.0	Requires chemical conditioning
Complete		2-2.5	2-2.75	Removals depend on design & op
	Sedimentation	0.5-1	0.7-1	Pond removals may be < in tanks
	Filtration	1.8-2.2	1.5-2.3	Operation quality affects removal
Complete Pilot		2.8-3.7	1.9-2.8	To examine design & op's effects
Direct		3.8	2.5-2.9	Limited to low turbidity raw water
Direct Pilot		3.0-3.6	2.7-3.1	Removals ca. 0.5-1 log > full-scale
Diatomaceous Earth		2-3	- -	Removal varies w/ DE grade, but
DE Pilot		- -	4.5-6.5	not w/ filter rate @ 1 or 2 gpm/ft^2

Summary

- Likely C&G concentrations ca. 10-100/L
- C&G removal
  - Slow sand filtration: < 2-logs
  - Untended rapid sand: ca. 2-logs
  - Optimised rapid sand: 2 to 3-logs
  - DE & Membranes: > 5 to 6-logs
- Confirm performance by direct sampling

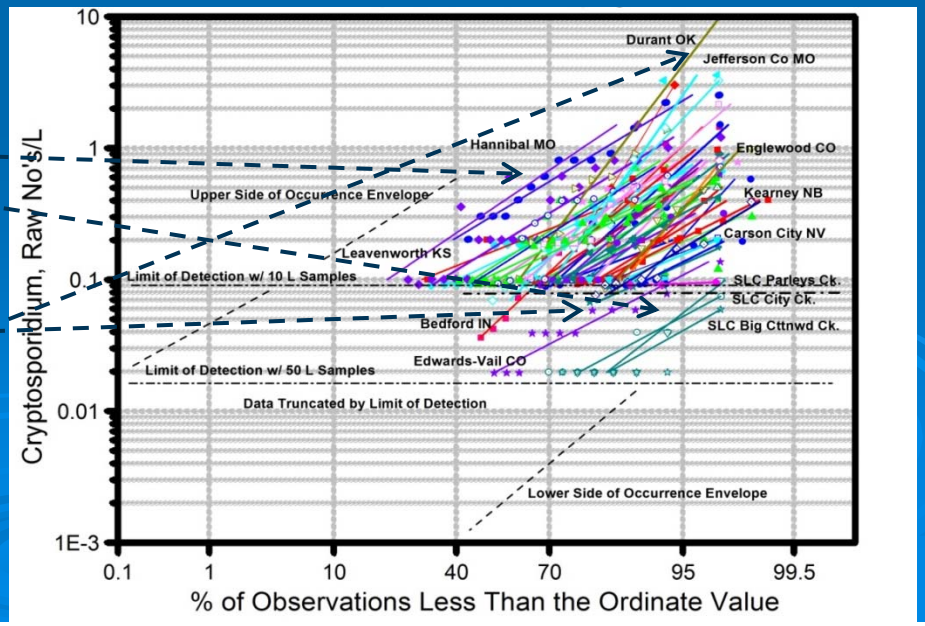
Conclusions

- C & G…Always present…require control
- Effective treatment can be provided
- Design must match local capability
- Can measure & monitor performance

Questions?

Information to Limit Outbreak Potential

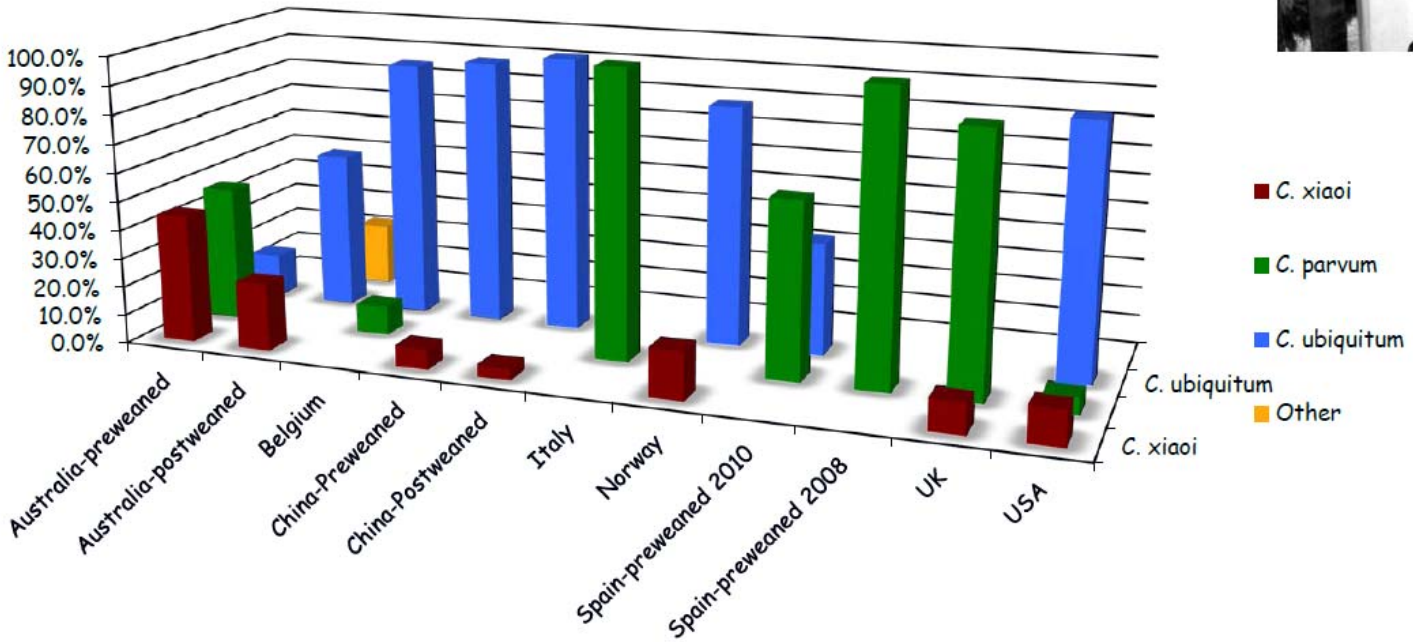
- Must ASSUME presence of *Crypto* & *Giardia*
- Need to know:
  - The concentration of all organisms
    - Live or dead
    - All species
  - Concentration characteristics--level & variability
    - Is concentration high or low?
    - Is concentration constant or variable



Reasons for Monitoring All Species & Live or Dead...Example

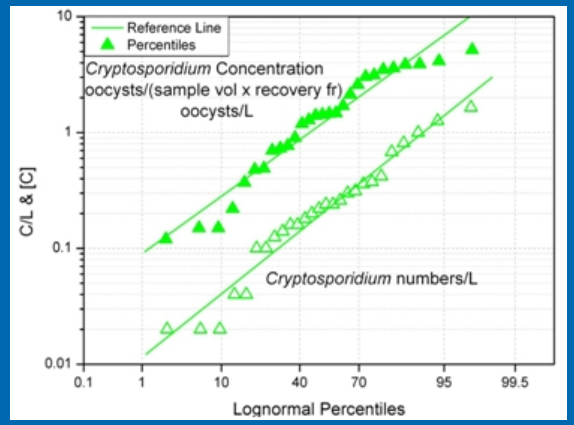
Cryptosporidium in sheep

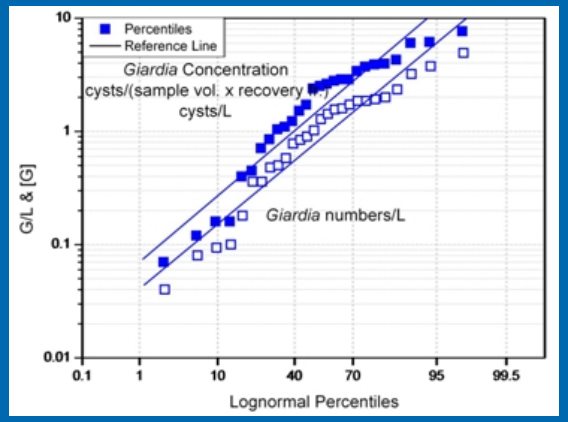
- Prevalence's ranging from <10% to >80%
- At least 10 genotypes identified
- Mean environmental loading rate ~17-145 oocysts/g^{-1} (0-6,897)
- Significantly associated with diarrhoea and production loss



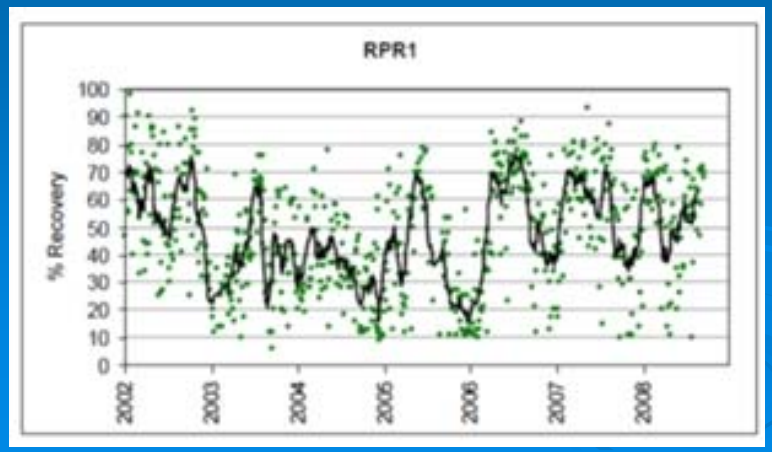
Why Measure *Concentration?*

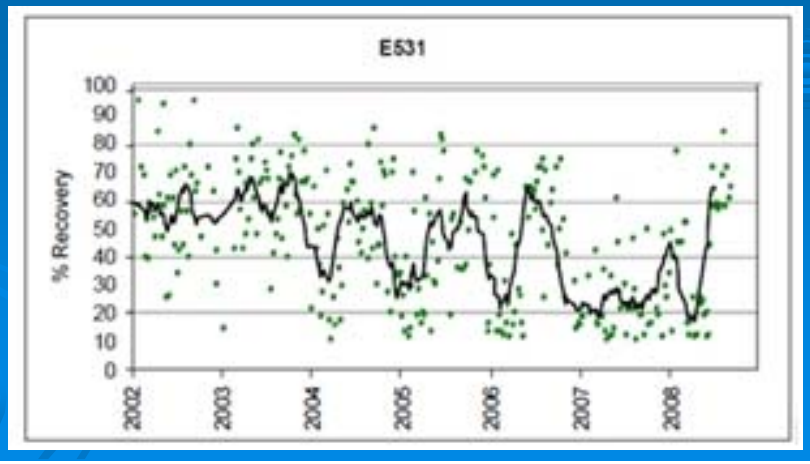
- Numbers ≠ Concentration





- Recovery efficiency varies systematically over annual cycles...different by location



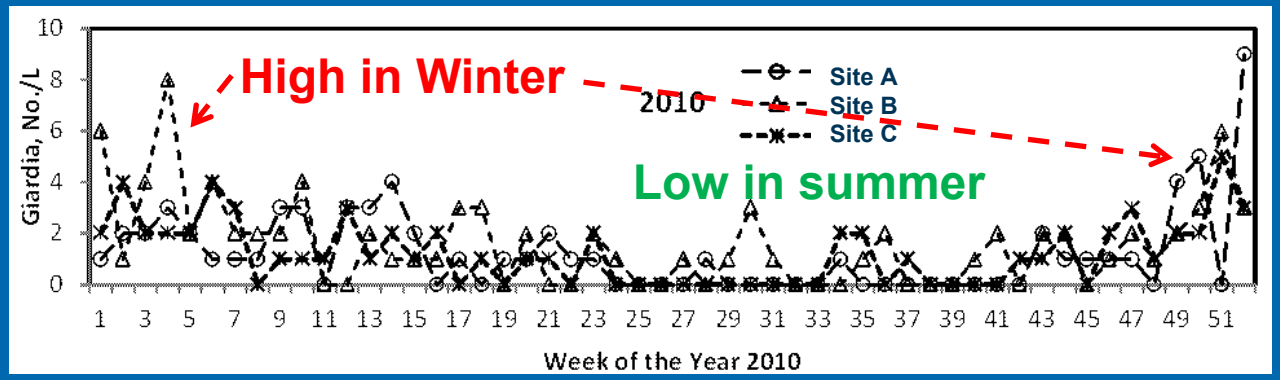


Water Sampling & Analysis

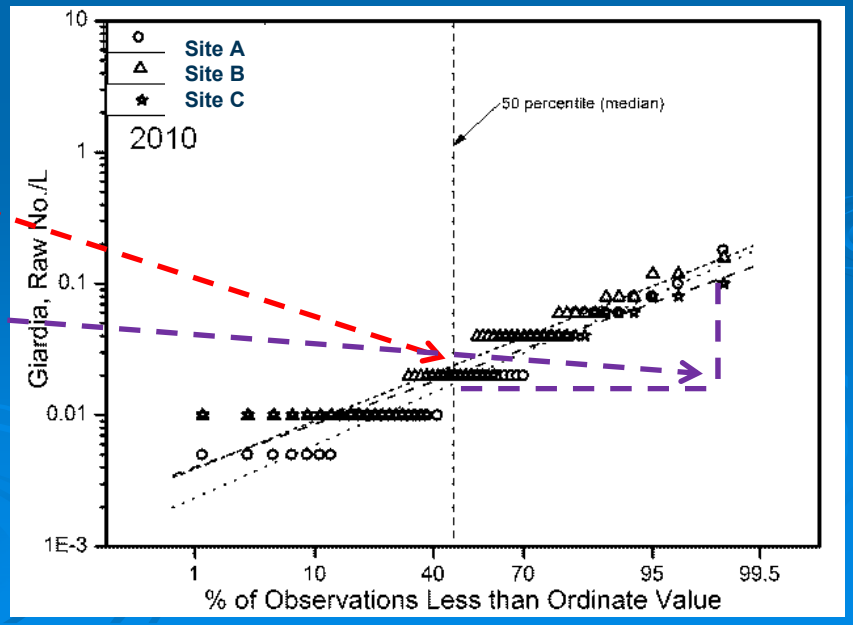
- Protozoan cysts are:
  - Discrete particles ca from 2 to 20 µM
  - Hardy in the environment...persist for months
  - Concentrations in water are low...ca 1 in 10 L ±
  - Not growing...must find among 10^6 other particles
- Analysis: *Zeros give no useful information!*
  - Samples--volume to give *nonzero* result...>10L
  - Collect particles ≥ organism...e.g. 2µm filter; ppt
  - Concentrate organisms...e.g. IMS (Method 1623)
  - Identification: e.g. IFA Microscopy

Data Analysis

- Concentration over a typical annual cycle:
  - When high & low



- Cumulative Frequency Distribution:
  - 50%ile → level for comparison
  - Slope or Std Dev.→ variability… high = greater risk



Other Possibilities

- Can Discriminate by Species or Type...but not useful for potential outbreak control
  - Various PCR-based schemes
- Can Discriminate by apparent viability...but not useful for potential outbreak control
  - Vital staining--e.g. DAPI
  - Cell culture
- LAMP...can digest particle concentrate w/o separation...but still difficult to quantify

Monitoring Approach

- Analyse monthly samples for a year at a time
- Analyse volumes to give non zero results
- Analyse samples for *both* Crypto & Giardia
- Use mAb's for detection of all species...most commercially available mAb's
- Do not discriminate on apparent viability...*all* cysts or oocysts present *show the real risk potential*
- MUST *measure* recovery efficiency and calculate concentration for *each* sample
- Analyse data to show both LEVEL and VARIABILITY ...*risk depends on both*.
- Annual data will show season of high concentration