Efficacy of Engineered Wetlands in Removal of Human Protozoan Enteropathogens; Fact of Fiction?

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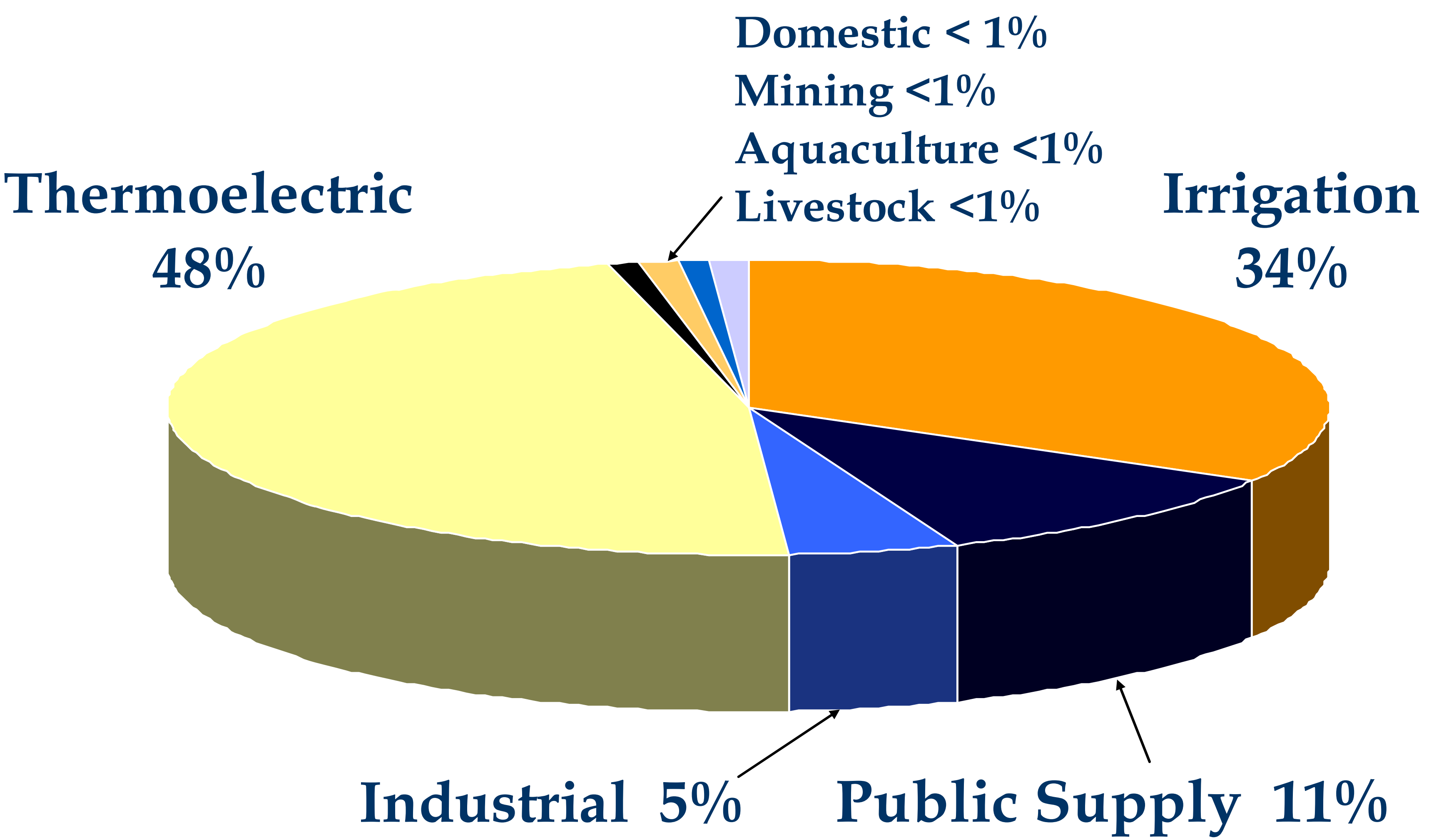
JOHNS HOPKINS UNIVERSITY
CWH
Center for Water and Health

Bangkok, Thailand, Dec 4, 09

Total Water Withdrawals in the United States

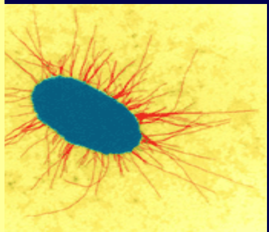


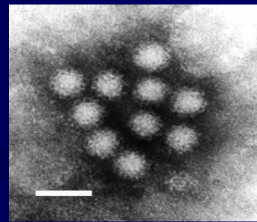
Source: USGS (2004)

Categories of Organisms of Public Health Significance in Wastewater

Bacteria

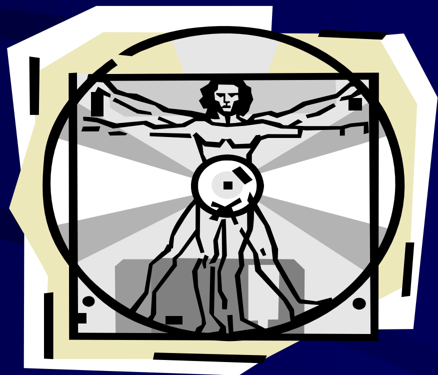
Campylobacter
Salmonella
Shigella
E. coli
Vibrio





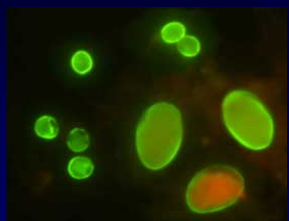
Viruses

Noroviruses
Hepatitis A virus
Rotavirus
Coronaviruses



Protozoa

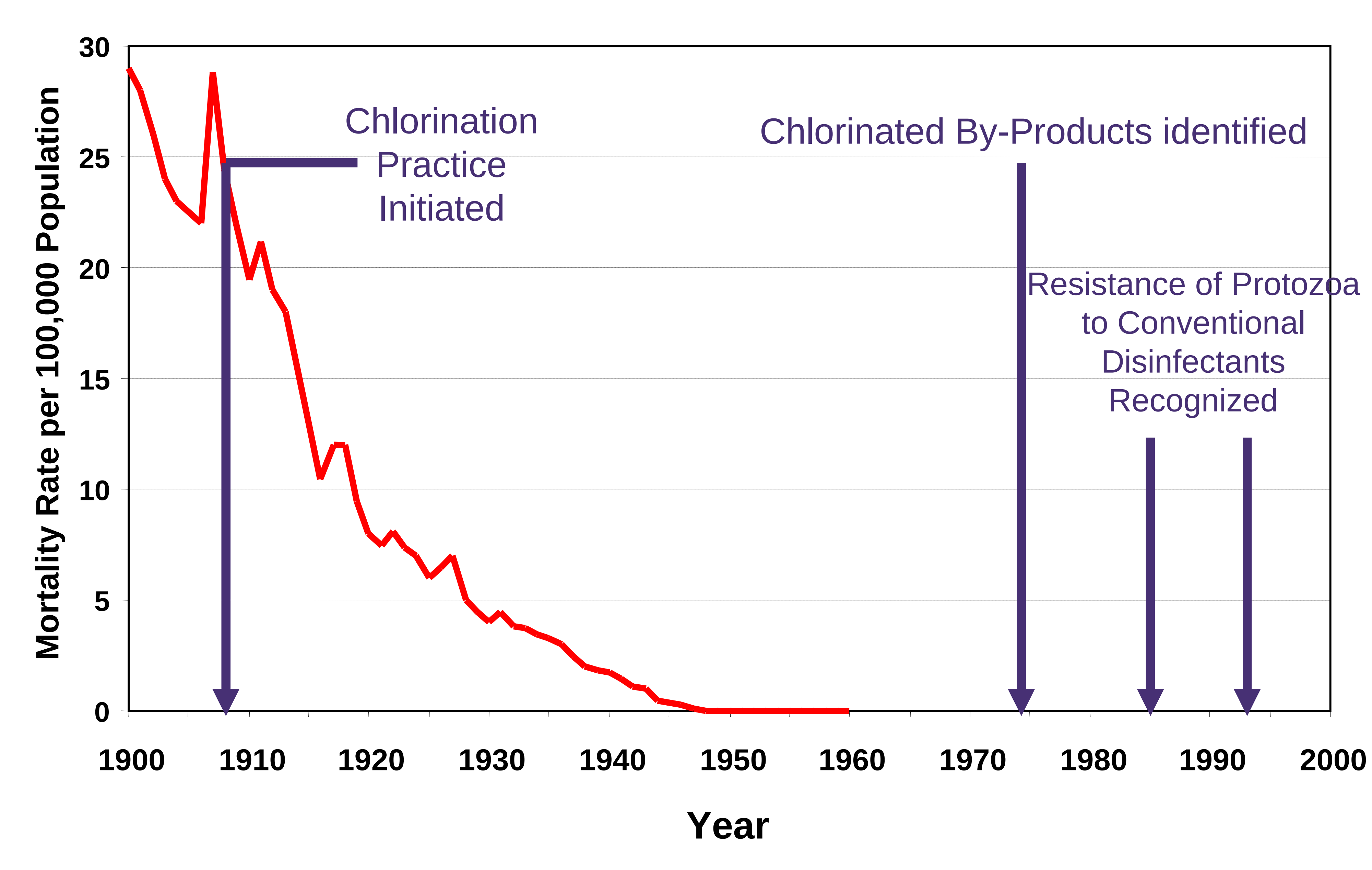
Cryptosporidium
Giardia
Microsporidia,
Cyclospora,
Toxoplasma



Helminths

Ascaris
Trichuris

Mortality Rate for Typhoid Fever in the United States



Adapted from U.S. Center for Disease Control and Prevention


BACK RIVER WASTEWATER TREATMENT PLANT
Back River
OUTFALL
DISINFECTION FACILITY
BIOLOGICAL NITRATE REMOVAL FACILITIES
MAINTENANCE FACILITY
SAND FILTRATION FACILITY
ADMINISTRATION / LAB
HEAT DRYING FACILITY
PRELIMINARY TREATMENT FACILITIES
SLUDGE DEWATERING / LOADING FACILITIES
PRIMARY TREATMENT FACILITIES
SLUDGE THICKING / DIGESTION FACILITIES

Comparison of Microbial Inactivation or Removal Efficacy by Selected Disinfectants and Filtration Processes

Disinfectants	Bacteria	Viruses	Protozoa	Overall Rating
Free chlorine	Excellent	Excellent	Fair/Poor	Good
Chloramines	Fair	Poor	Very Poor	Poor
Chlorine dioxide	Good/Excellent	Good/Excellent	Fair	Good
Ozone	Excellent	Excellent	Good/Excellent	Good/Excellent
Ultraviolet irradiation	Good/Excellent	Good	Good/Excellent	Good/Excellent
Filtration Processes				
Granular Media Filtration	Good	Fair	Good	Good
Low-Pressure Membranes	Excellent	Excellent	Excellent	Excellent

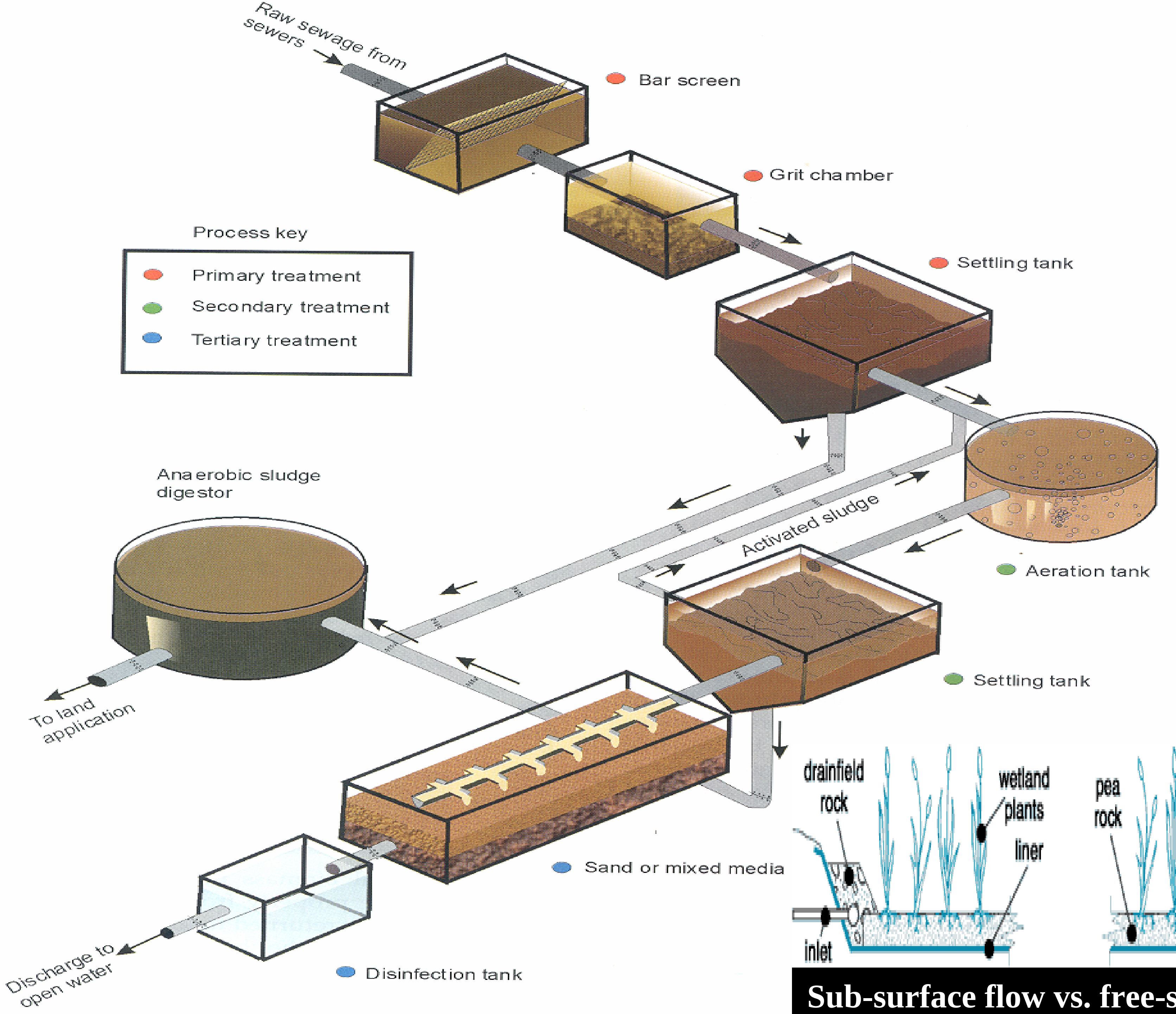
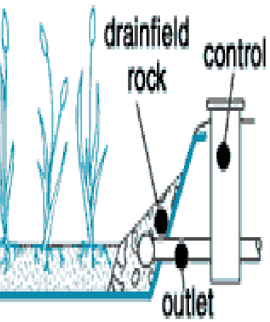


FIGURE 21.3 Schematic of the treatment processes typical of modern v
from Pepper *et al.*, 1996.)



Sub-surface flow vs. free-surface flow
“removal” vs. “source-tracking”

Address http://www.constructedwetlands.org/cw/index.cfm

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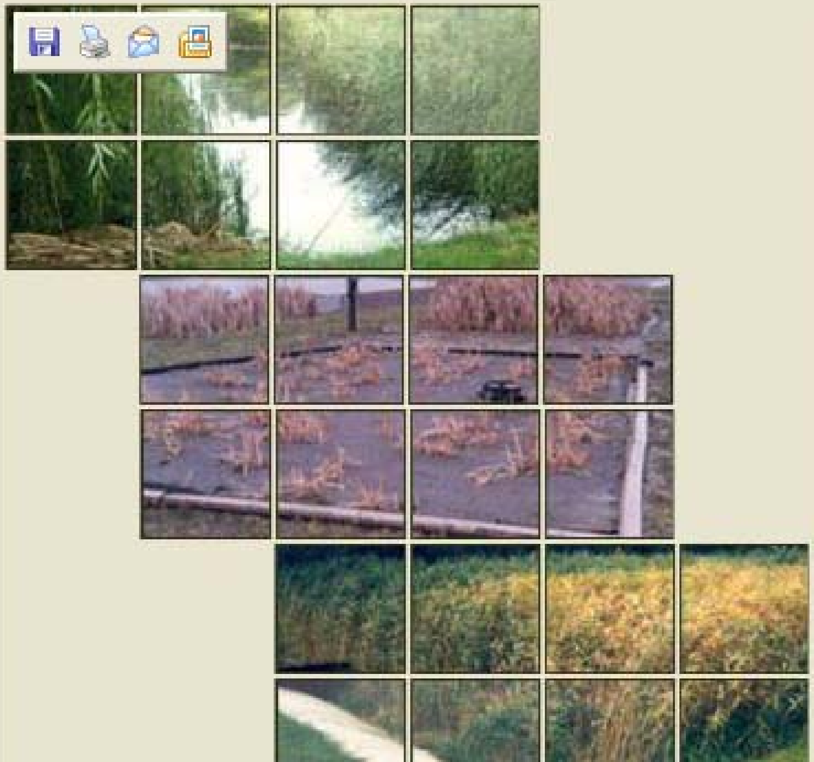
Constructed Wetlands for Low-Cost Wastewater Treatment and Nature Conservation



Constructed wetlands are marshes built to treat contaminated water. They have four key components:

- Soil and drainage materials (such as pipes and gravel)
- Water
- Plants (both above and below the water)
- Micro-organisms

Constructed wetlands purify the water that flows through them. Compared to conventional treatment methods, they tend to be simple, inexpensive, and environmentally friendly. Constructed wetlands may be used to treat water from many different sources:

- Sewage (from small communities, individual homes, and businesses)
- Stormwater
- Agricultural wastewater (including livestock waste, runoff, and drainage water)
- Landfill leachate
- Partially treated industrial wastewater
- Drainage water from mines
- Runoff from highways

er: The information in this website is entirely drawn from a 1993 publication, and has not been updated since the original publication date. Users are cautio
rmation reported at that time may have become outdated.

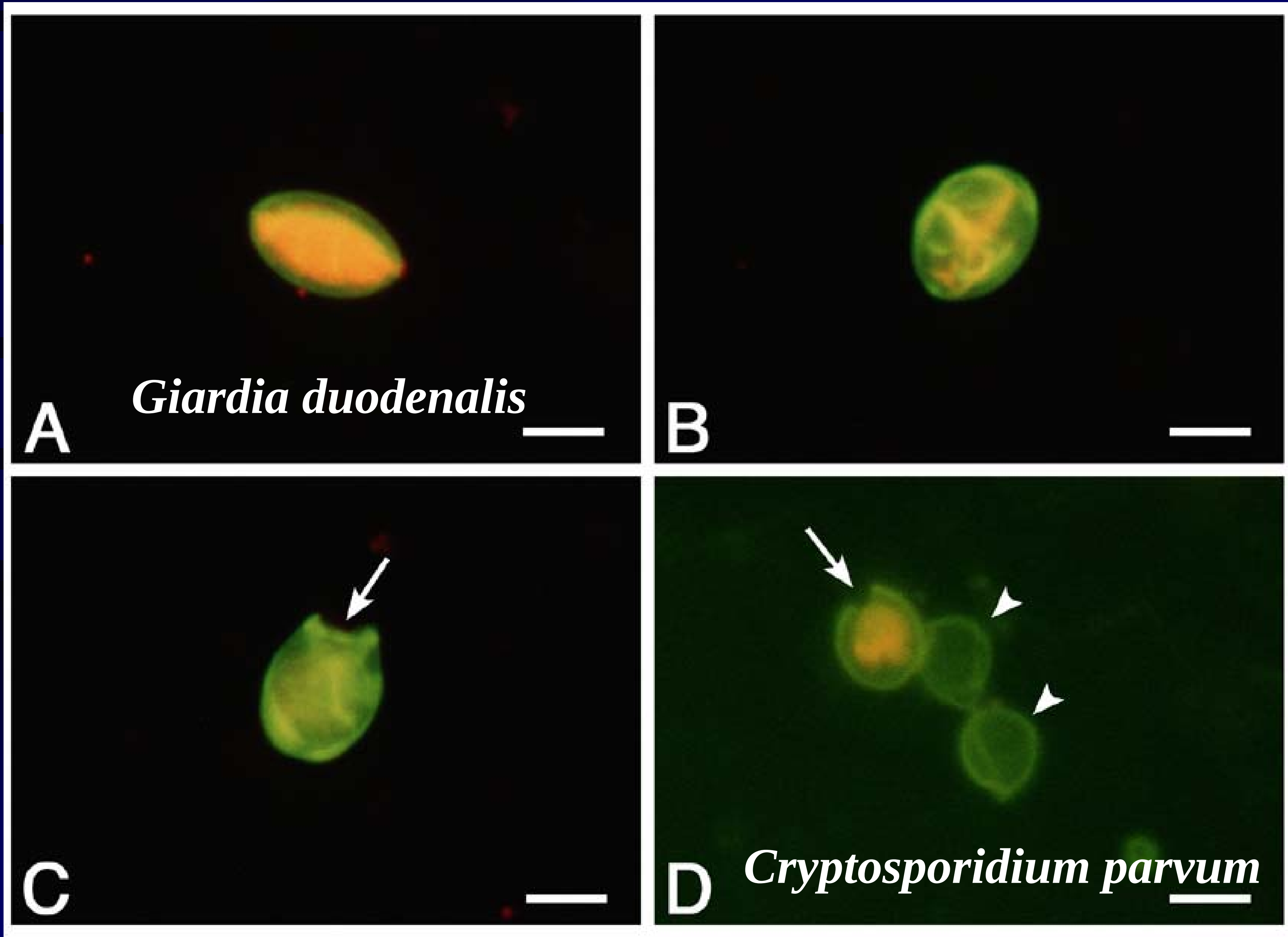
United States
Environmental Protection
Agency

EPA832-R-93-005
September 1993

Constructed Wetlands for Wastewater Treatment and Wildlife Habitat

17 Case Studies

The Graczyk's Lab: Fluorescence *In Situ* Hybridization (FISH)

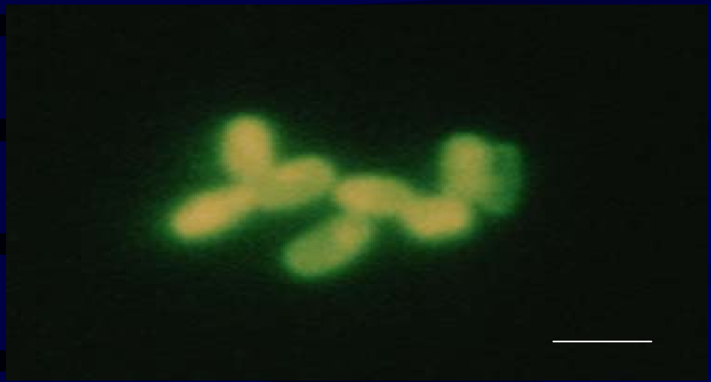


The Graczyk's Lab: **Multiplexed Fluorescent *In Situ* Hybridization (FISH)**

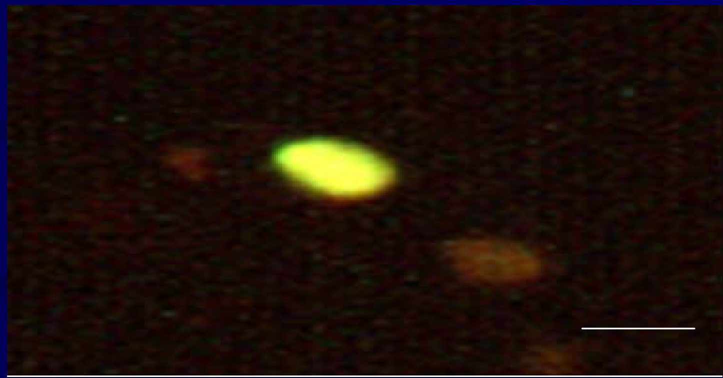
E. hellem Hester et al. (2000) *J Eukaryot Microbiol* **47:**299-308.

Graczyk et al. (2007) *J Clin Microbiol* 45:1255-60

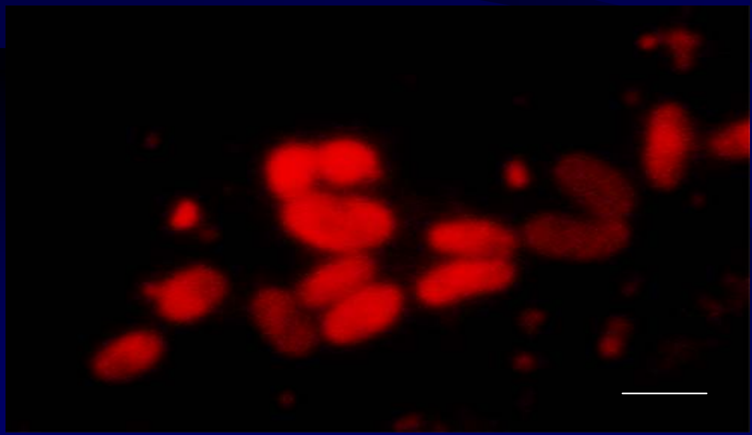
E. hellem



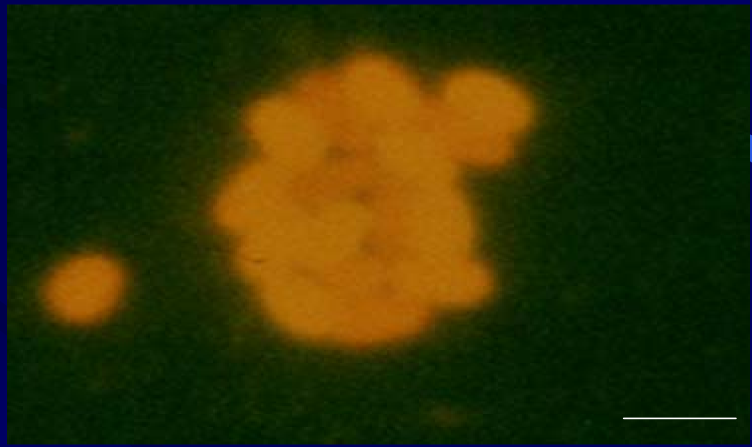
E. bieneusi



E. intestinalis



E. cuniculi



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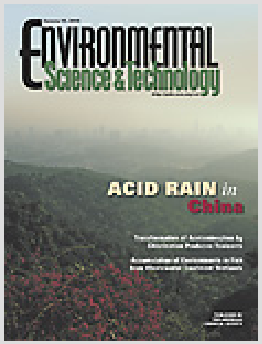


January 15, 2006
Vol. 40, Iss. 2

ES&T News

Vol. 40, Iss. 2
pp 413–414

Engineered wetlands may pose risks to wildlife

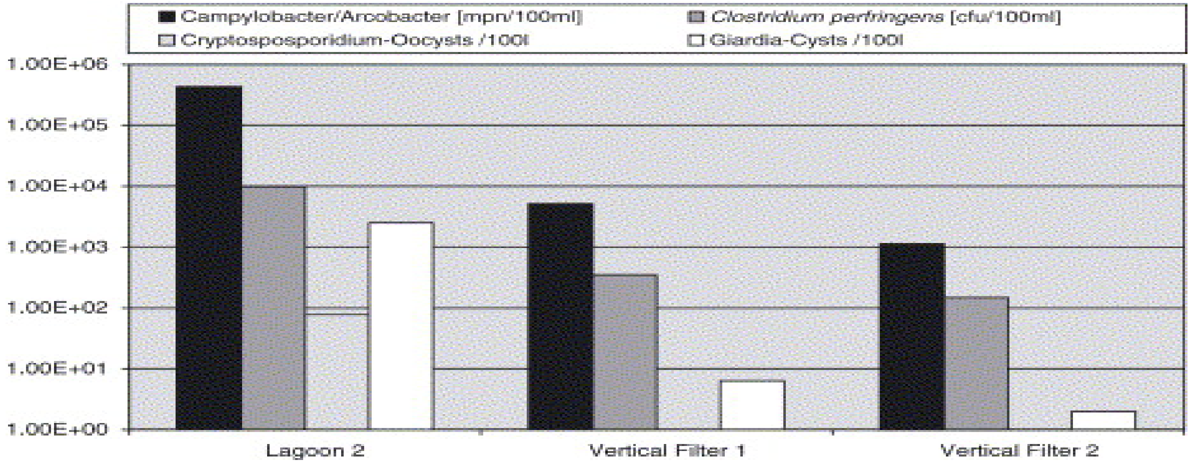
Havens for wildlife in the parched southwestern U.S., wetlands constructed to receive sewage treatment plant discharges also boast a sterling record for slashing nutrient levels, suspended solids, and biological oxygen demand in effluents. But after two decades of research on treatment wetlands, scientists have scarcely investigated whether pesticides and metals in sewage effluent pose a risk to wildlife. Research published in this issue of *ES&T* (pp 603–611) indicates for the first time a potential exposure pathway for a complex mix of the nearly 50 inorganic and organic contaminants found in a treatment wetland.

Larry Barber and his colleagues at the U.S. Geological Survey (USGS) analyzed water and fish tissue samples from the Tres Rios Demonstration Constructed Wetlands located near Phoenix, Ariz. The 10-acre site receives secondary sewage effluent from industrial, residential, and medical sources. Contaminants flowing through the site are eliminated through photodegradation, volatilization, biodegradation, sorption to sediments, and uptake by plants, says Barber.

John Thullen, USGS

Treatment wetlands outperform sewage treatment plants when it comes to removing contaminants, but scientists say that exposure to

Indeed, the researchers found that the wetlands reduced contaminant



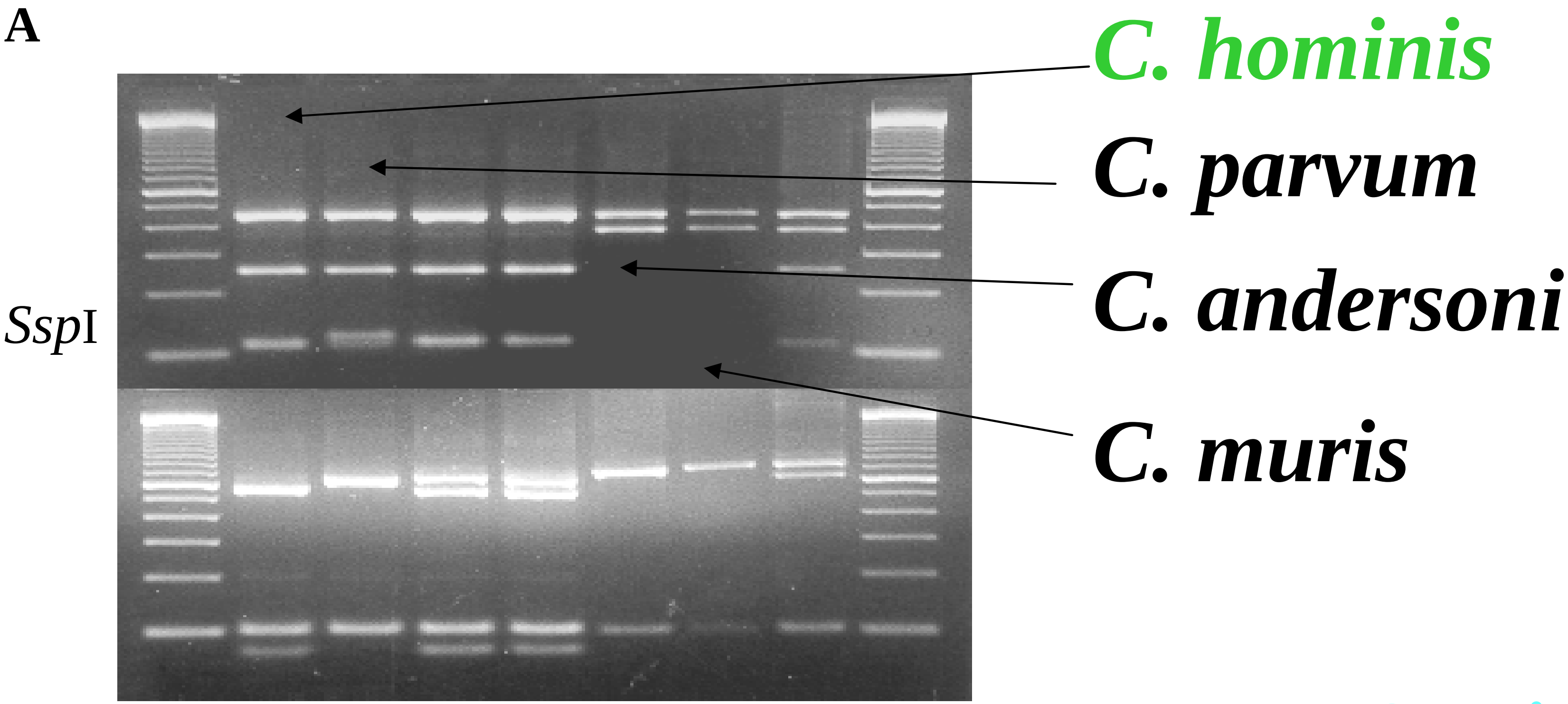
Ulrich et al. 2005. Water Res 39; 4849-58

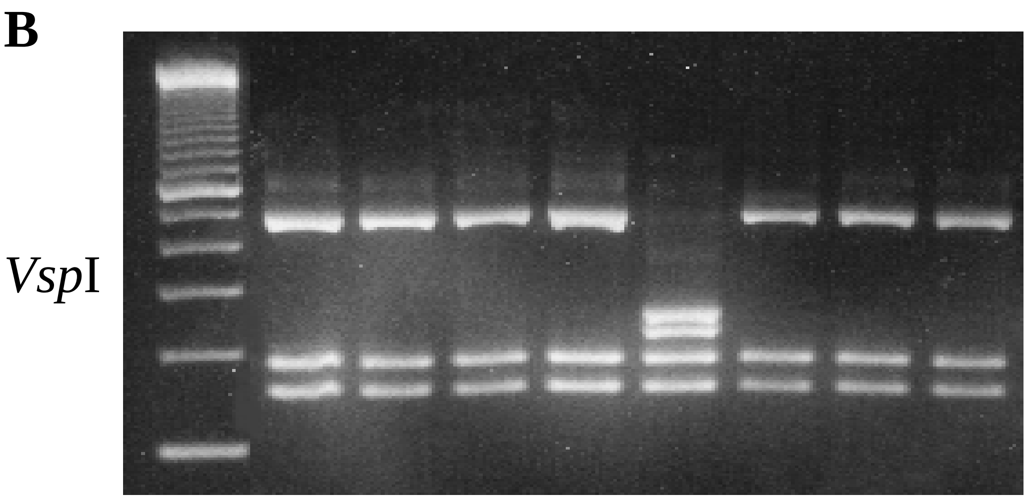
Microorganisms	Water			Sediment		
	Log reduction/(day $\log_{10}$ day^{-1})	R^2	*p*-value	Log reduction/(day $\log_{10}$ day^{-1})	R^2	*p*-value
Fecal coliform	−0.256	0.899	0.0001	−0.151	0.986	0.0001
S. typhimurium	−0.345	0.769	0.0019	−0.312	0.916	0.0001
Coliphage	−0.397	0.983	0.0001	−0.107	0.867	0.0008
PRD-1	−0.198	0.865	0.0008	−0.054	0.930	0.0001
Giardia	−0.029	0.490	0.187	−0.370	0.861	0.022

Organism	Potable water supplied wetland		Wastewater supplied wetland[a]		
	Influent	Effluent	Influent	Effluent	Percent reduction
Total coliform (CFU/100 mL)	< 1.0	1.3 × 102	1.7 × 104	1.1 × 102	98.8
Fecal coliform (CFU/100mL)	< 1.0	22.3	7.4 × 103	45.0	98.2
Coliphage (PFU/mL)	< 1.0	< 1.0	2.5 × 102	4.7	95.2
Giardia[b]	< 1.0	< 1.0	14.1	0.7	87.8
Cryptosporidium[c]	< 1.0	< 1.0	< 12.6	2.7	64.2

Thurston et al. 2001. Water Res 35; 1547-51

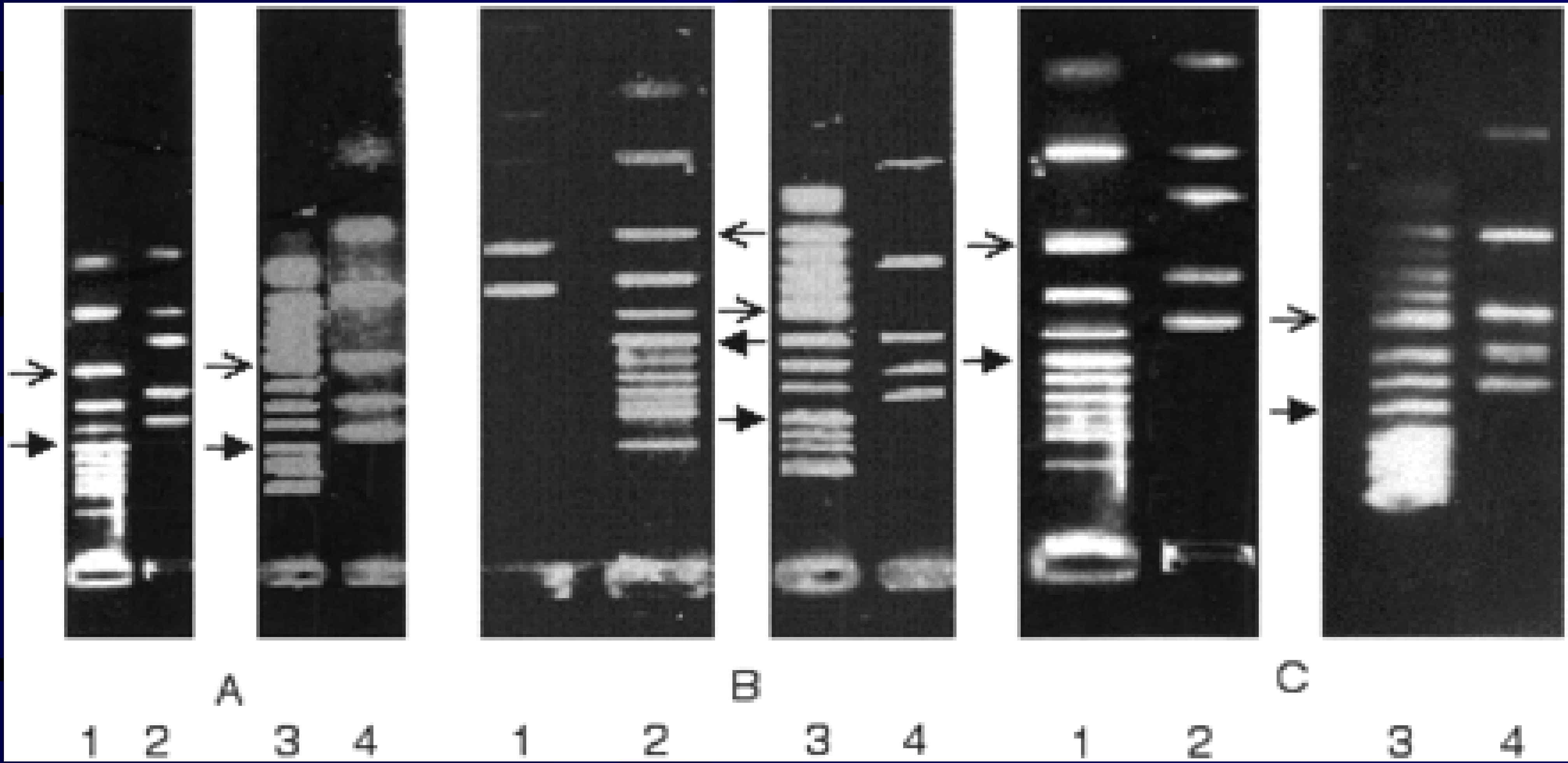
Identification of *Cryptosporidium*; PCR, RFLP

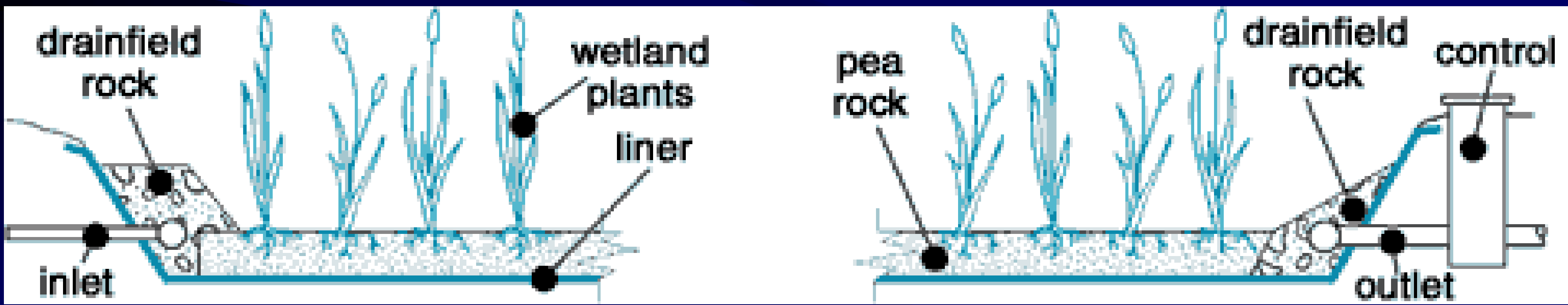




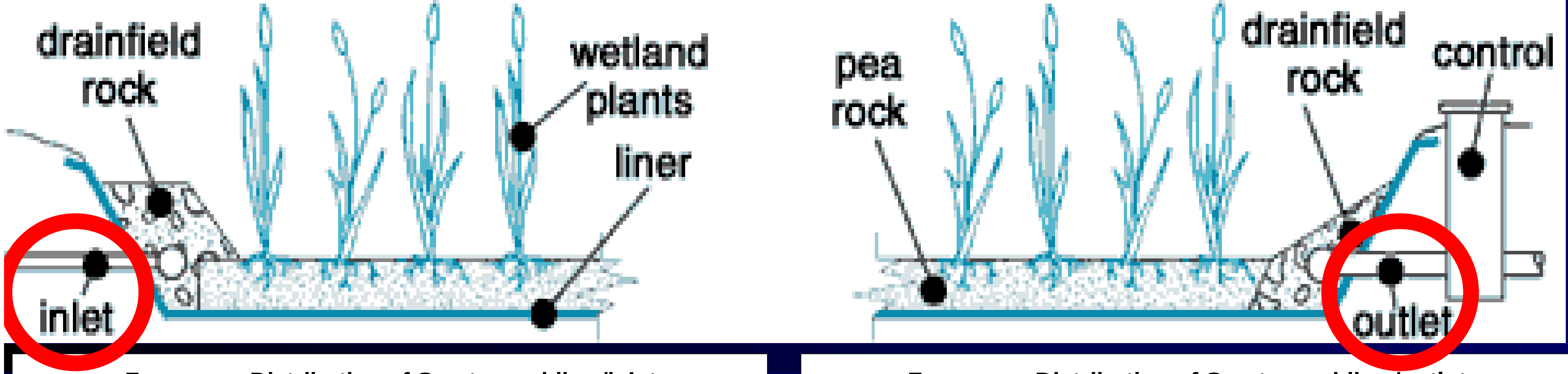
Species

Genotype

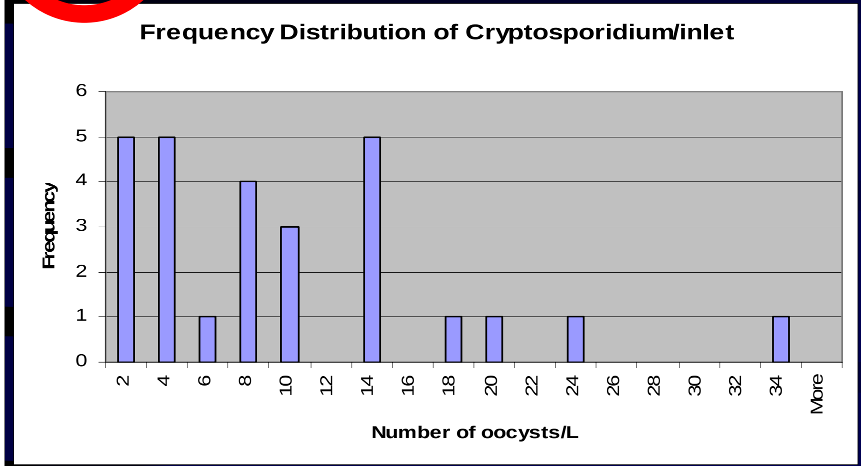

A
B
C
1 2 3 4 1 2 3 4 1 2 3 4

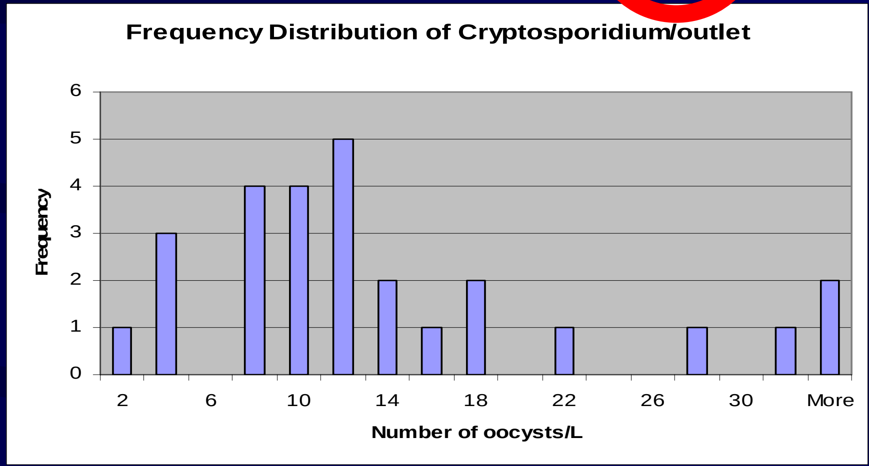

drainfield rock
wetland plants
liner
inlet
pea rock
drainfield rock
control
outlet

1 2 3 4



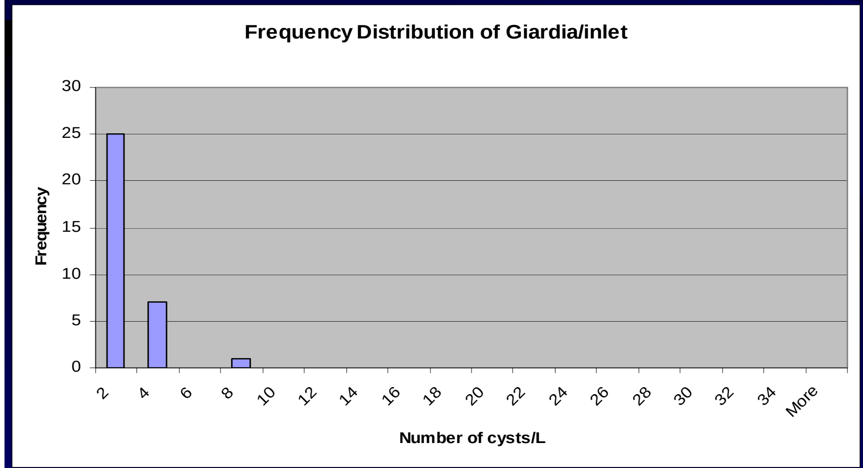
outlet/inlet (%)

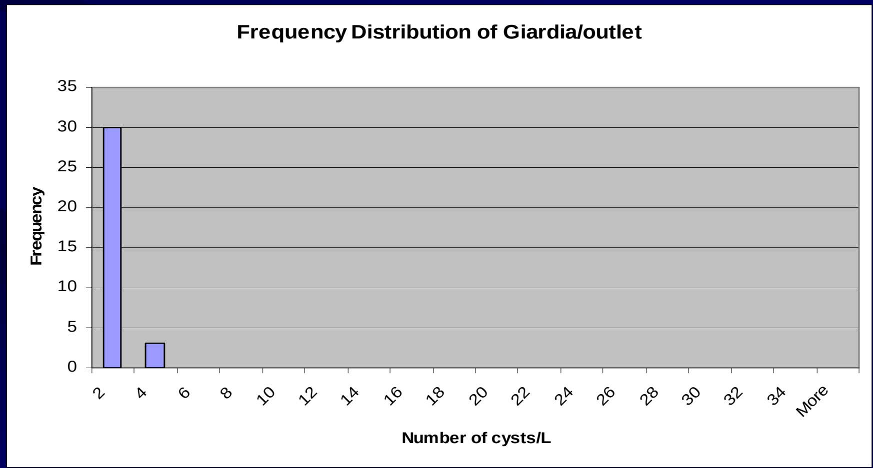




65%

Cryptosporidium



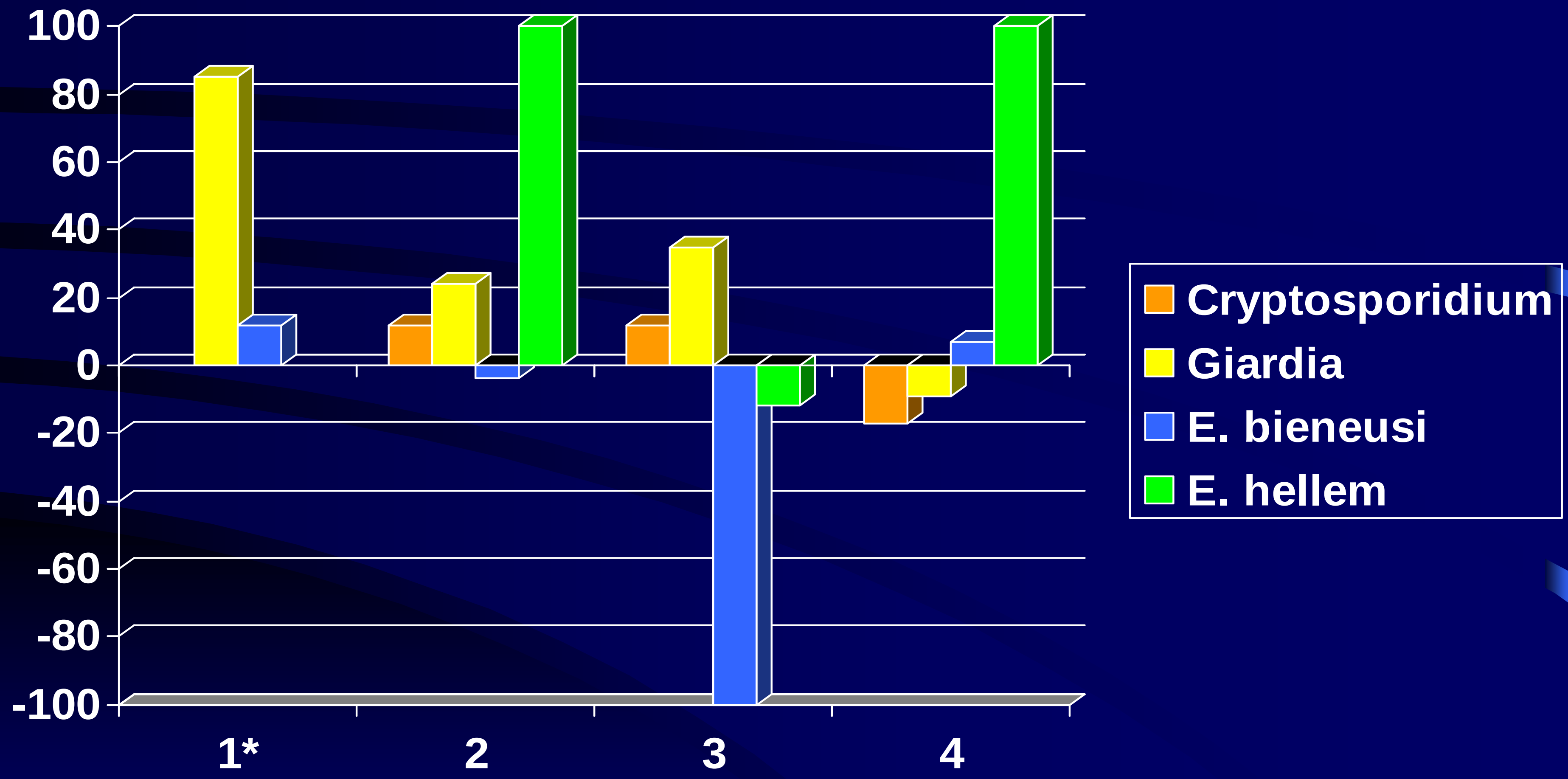


85%

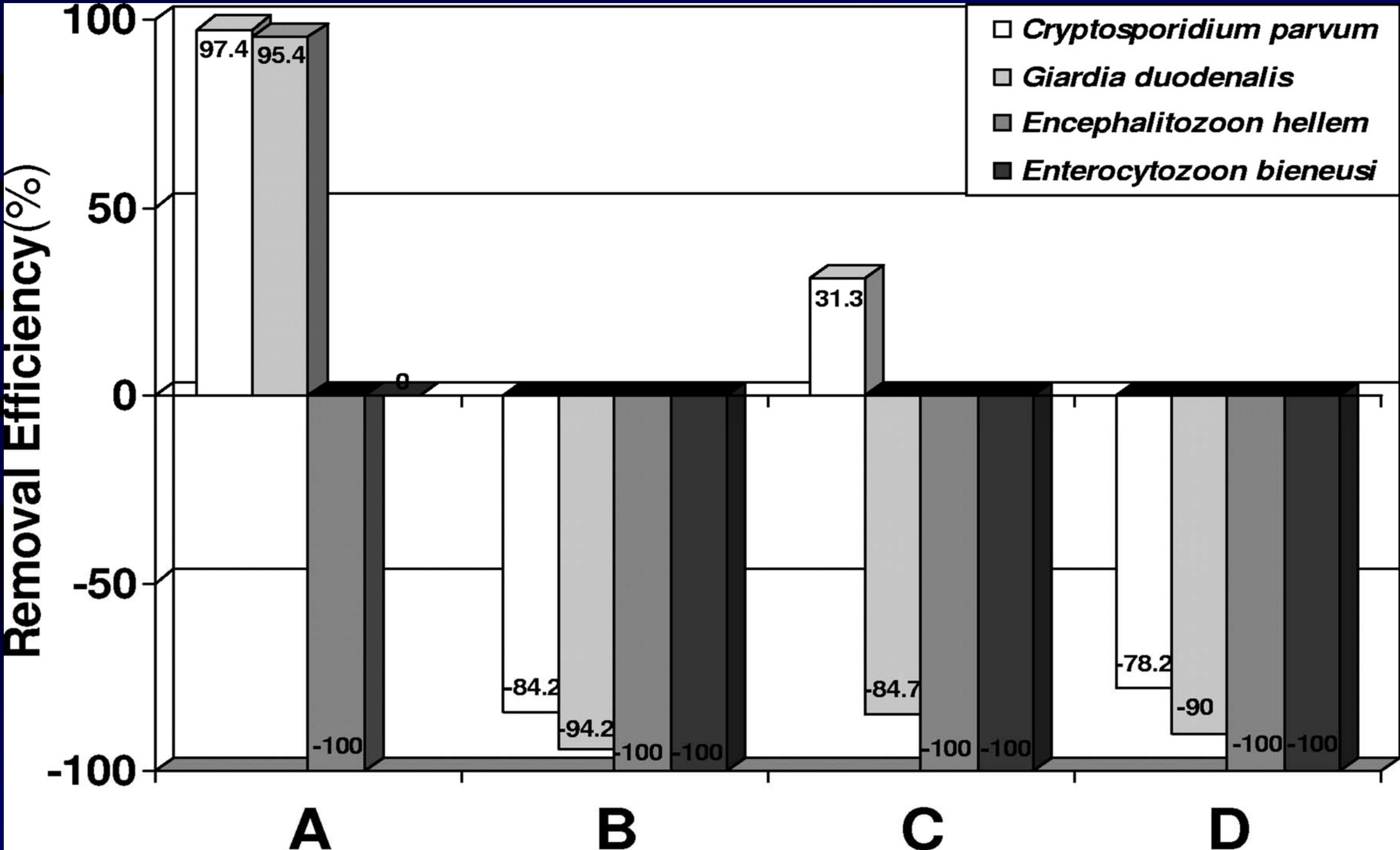
Giardia (Assemblage A)

Giardia (Assemblage A, E, and C)

Pathogen removal relative index (inlet - outlet)%



Graczyk et al. 2009. *Applied Environmental Microbiology* 75 (13) 4531-4538



```
Cryptosporidium felis                  AAGCTCGTAG TTGGATTTCT GTTAATACCT TATATATAAT ATTTTTTTTT AAATATTATT   60
Cryptosporidium sp. (canine)           .......... .......... .......AT. .......... ....------ -..C..AT..   53
Cryptosporidium parvum genotype 1      .......... .......... .......AT. ......A... .....----G .TGA..AT..   56
C. parvum genotype 2                   .......... .......... .......AT. ......A... .....----G .TGA..AT..   56

C. felis                               ATGTAAGATT AACATAATTC ATATTTTTTA AGACTGAATT TTT----AGT TTTGATAATA  116
Cryptosporidium sp. (canine)           ..A...T... .......... .....----- --...ATT.A .-------.. -------...   93
C. parvum genotype 1                   ..A...T... .......... .....----- --...ATT.. ...TTTT... -------...  102
C. parvum genotype 2                   ..A...T... .......... .....----- --...AT..A ...T---... -------...   99

C. felis                               TGAAATTTTA CTTTGAGAAA ATTAGAGTGC TTAAAGCAGG CTTTTGCCTT GAATACTCCA  176
Cryptosporidium sp. (canine)           .....C.... .......... .......... .......... .......... .......AG.  153
C. parvum genotype 1                   .......... .......... .......... .......... .A.A...... ..........  162
C. parvum genotype 2                   .......... .......... .......... .......... .A.A...... ..........  159

C. felis                               GCATGGAATA ATAATA--AA AGATTTTTAT CTTTTTTTTA TTGGTTCTAA GATAAAAATA  236
Cryptosporidium sp. (canine)           ......---. ......TT.. .......... ....C..--. .......... ....G.....  208
C. parvum genotype 1                   ......---. ......TT.. .......... .......--. .......... .....G....  217
C. parvum genotype 2                   ......---. ......TT.. .......... ....C..--. .......... .....G....  214

C. felis                               ATGATTAATA GGGACAGTTG GGGGCATTTG TATTTAACAG TCAGAGGTGA TATTCTTAGA  294
Cryptosporidium sp. (canine)           .......... .......... .......... .......... .T........ A.........  268
C. parvum genotype 1                   .......... .......... .......... .......... .......... A.........  277
C. parvum genotype 2                   .......... .......... .......... .......... .......... A.........  274
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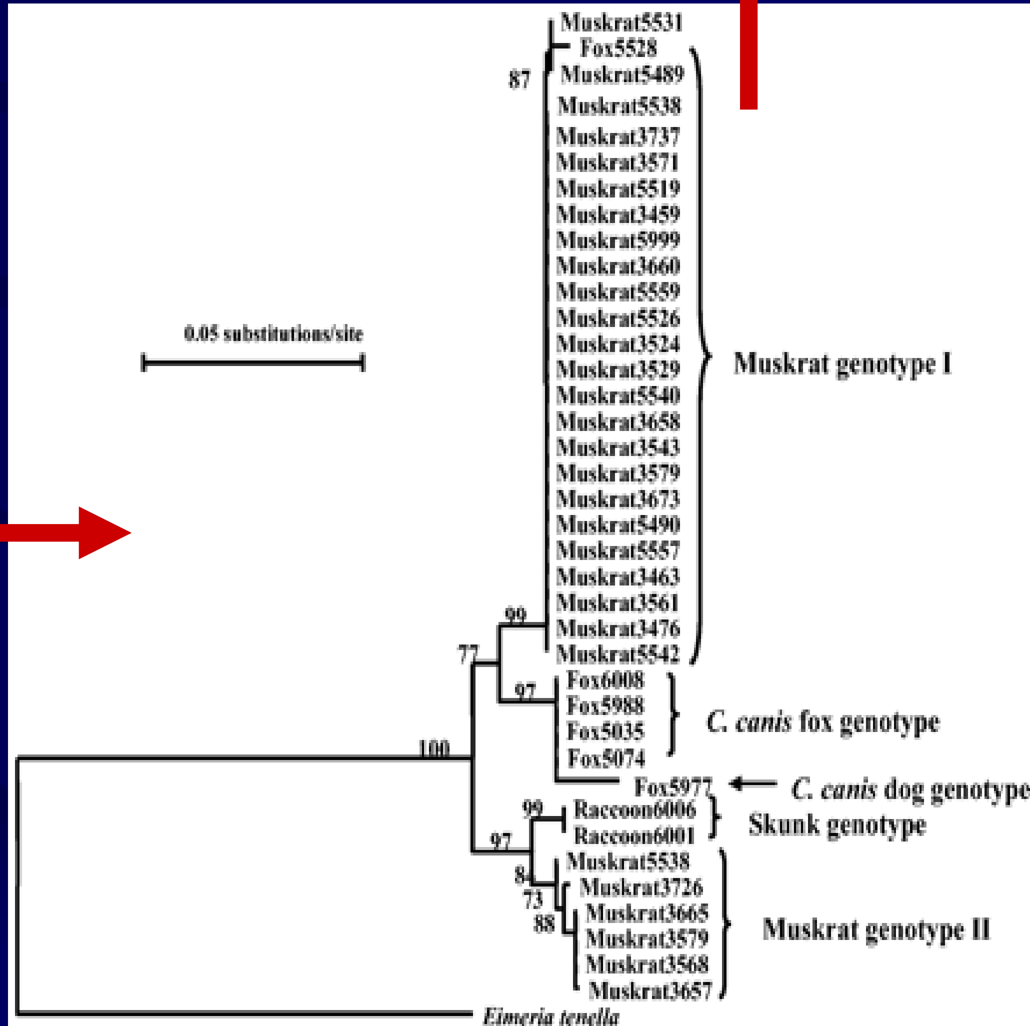

Conclusions

- ✓ Wastewater discharges are worldwide risk factors for the introduction of human protozoan enteropathogens into surface waters

- ✓ Demand for high quality drinking and recreational waters rises exponentially due to global demographic growth, reinforcing an urgent need for microbiologically safe reclaimed waters

- ✓ Pathogen source-tracking research in engineered wetlands is deficient, due to the lack of available molecular technology in the past

- ✓ Current technology allows for multiplexed species-specific identification, enumeration, viability assessment, and source-tracking of human protozoan pathogens

- ✓ Public health in developing and developed regions of the world will benefit from changing the conceptual research framework for constructed wetlands from "pathogen removal" to "pathogen source-tracking" efforts. "Removal" assumes that "survived pathogens" originate from pathogens delivered to that wetland from the sewage treatment process, while "source tracking" evaluates the complexity of pathogen ecological interactions

- ✓ Improvements in reclaimed water quality by lowering fecal coliform counts is not a sound solution for human protozoan enteropathogens

Acknowledgements

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