Disinfecting Montréal's wastewater:

Brief to the public hearings, April 9, 2008

Ronald Gehr, PhD, PEng

Associate Professor

Department of Civil Engineering

McGill

Outline of presentation

- **Introduction**
- **Context: Montréal and its effluent**
- **Review of UV information**
- **Review of ozone information**
- **Review of environmental aspects and ecotoxicology**
- **Summary and conclusions**

Introduction

- **Due to limited time, I will not review the many positive aspects of the Tripartite Report**
- **Aim of this submission is to provide convincing arguments why ozonation may not be an appropriate technology to disinfect Montréal's wastewater**
- **Unless otherwise stated, all the results presented herein were from tests done by my research group at McGill on Montréal's wastewater, and published in the peer-reviewed literature or conferences**

Characteristics of the Montréal Wastewater

Parameter	Mean/Typical	Range
Coagulant	20%Fe:80% Al	90%Fe:10%Al – 100% Al
SS (mg/L)	21	15 – 28
COD (mg/L)	100	67 – 132
UVT (%)	25	17 – 38
FC (CFU/100 mL) (geom.mean)	900,000	178,300 – 2,600,000

These three parameters:

- **SS (suspended solids)**
- **COD (chemical oxygen demand)**
- **UVT (ability of the wastewater to transmit UV light)**

are much worse for Montréal's wastewater than most other wastewaters which have biological treatment processes upstream

UV

Some pertinent points about UV (1)

- UV is excellent against bacteria, protozoa and some viruses
- UV is a mature technology for wastewater disinfection:
  - Approximately 125 plants in Québec
  - Over 6,000 plants worldwide
  - Over 380 Trojan UV 4000 systems (which was the alternative tested for Montréal) worldwide, including 10 in Québec

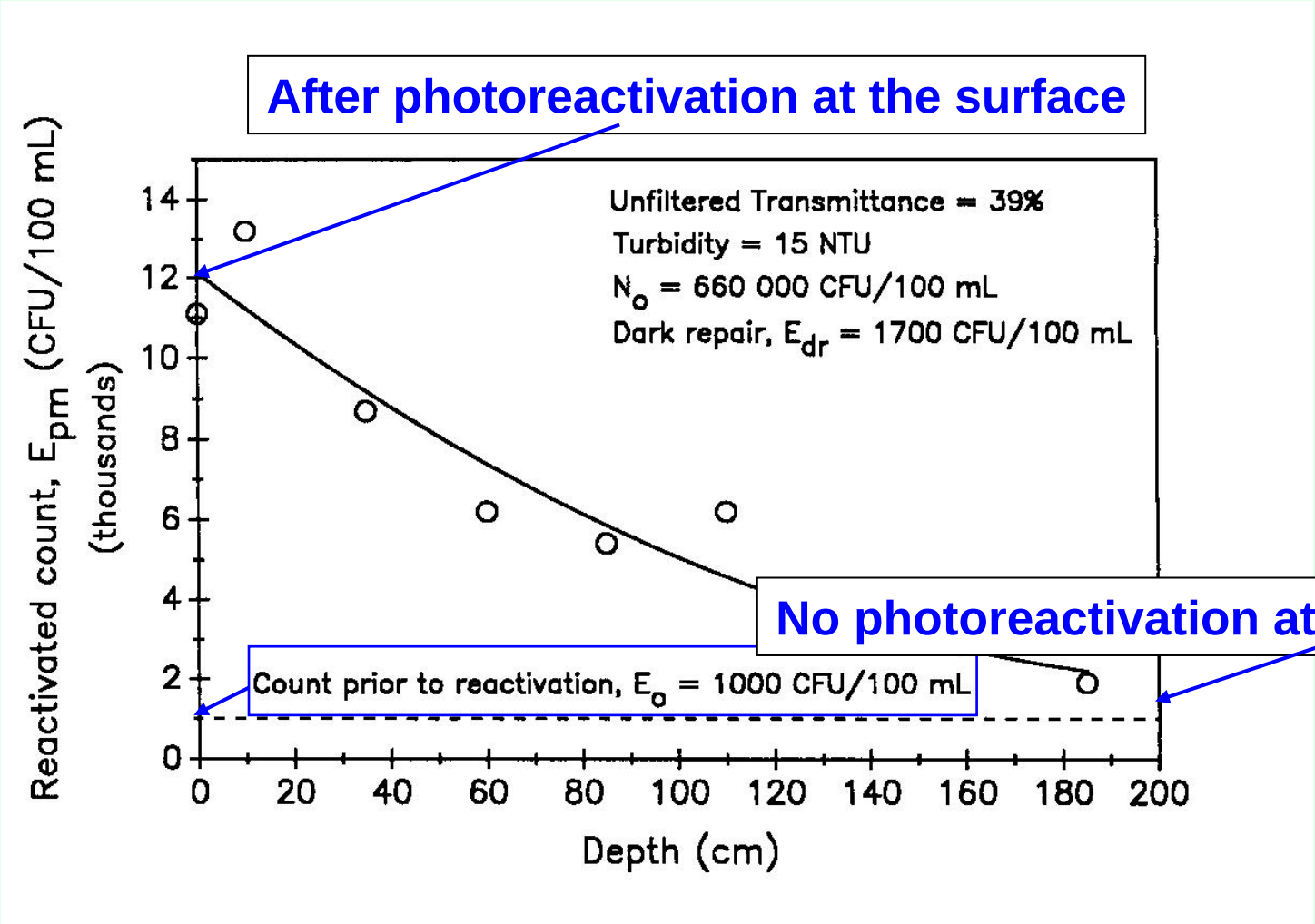
Some pertinent points about UV (2)

- No UV dose was given in the Tripartite report, only the number of lamps
- Doses for both UV and ozone are based on inactivation of fecal coliforms (FC)
- Because photoreactivation has been assumed to be 10 times, the target for Montréal is **900** CFU/100 mL FC (it is **9,000** for ozone)
- BUT photoreactivation will not be a problem for Montréal, for 3 important reasons:

Photoreactivation (1)

1. Photoreactivation would be serious only at the surface of the St Lawrence river….

Photoreactivation after UV



Photoreactivation (2)

1. Photoreactivation would be serious only at the surface of the river….
2. The UV 4000 system uses medium pressure lamps, for which photoreactivation is greatly reduced because of the wider range of wavelengths of UV light

Results from Oguma et al (2002) (and confirmed by others)

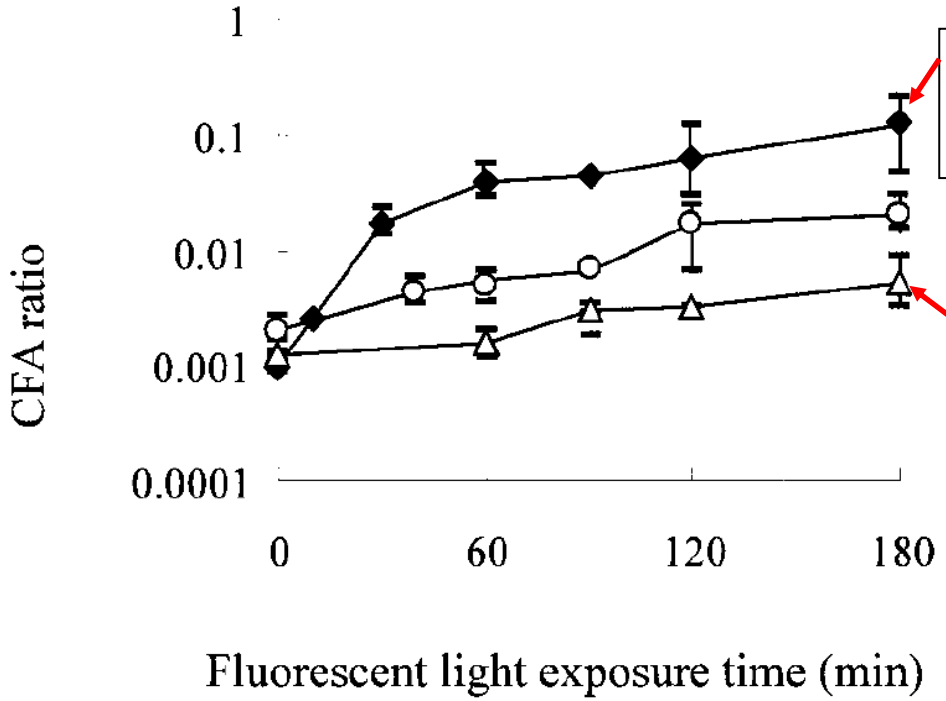


FIG. 8. CFA ratios after exposure to fluorescent light after LP UV (◆), MP UV (△), or MPF UV (○) inactivation. The symbols indicate the means from two or three independent experiments, and the bars indicate the maximum and minimum values.

Low pressure lamp – 10 times recovery

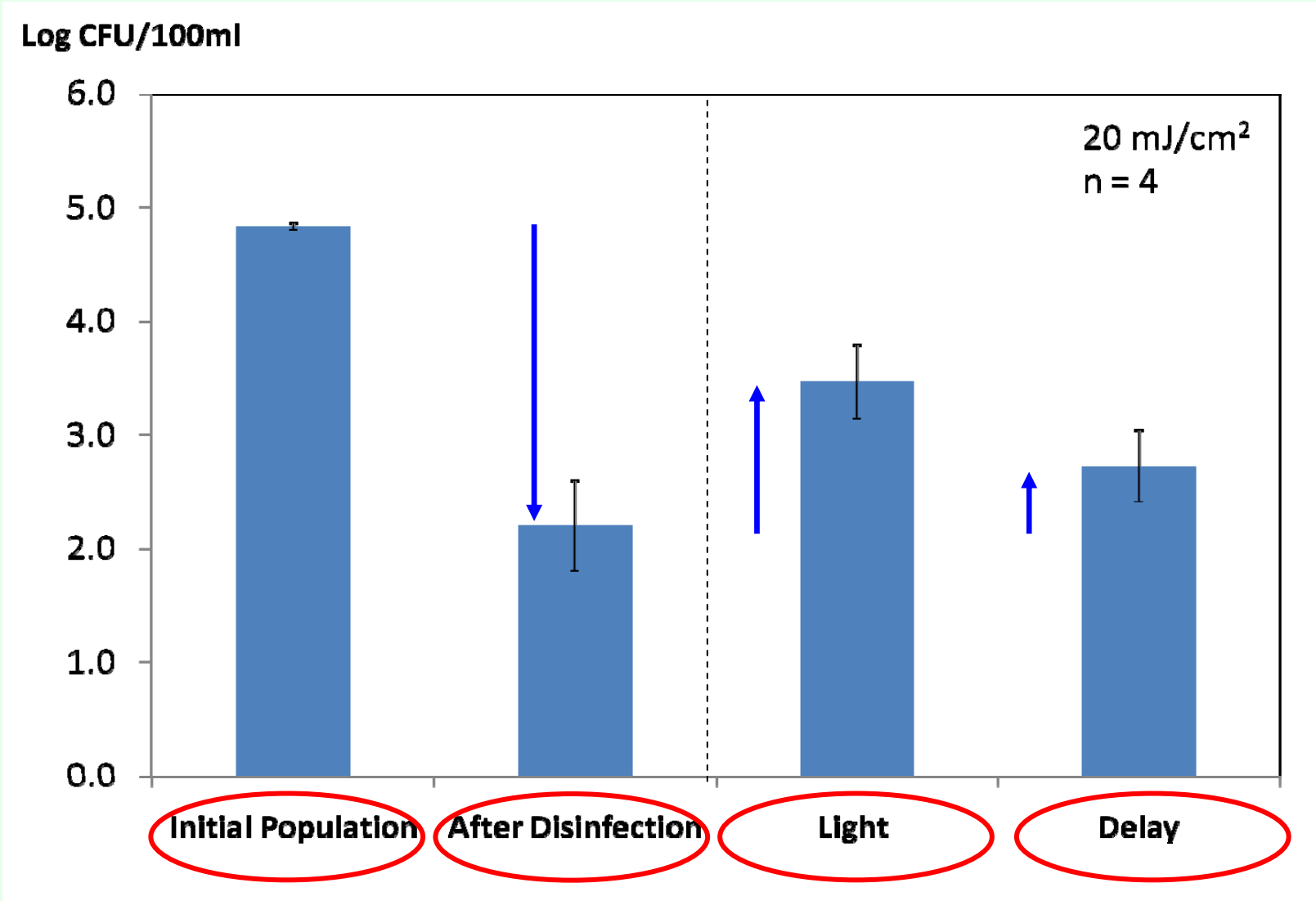
Medium pressure lamp – almost no recovery

APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Dec. 2002, p. 6029–6035

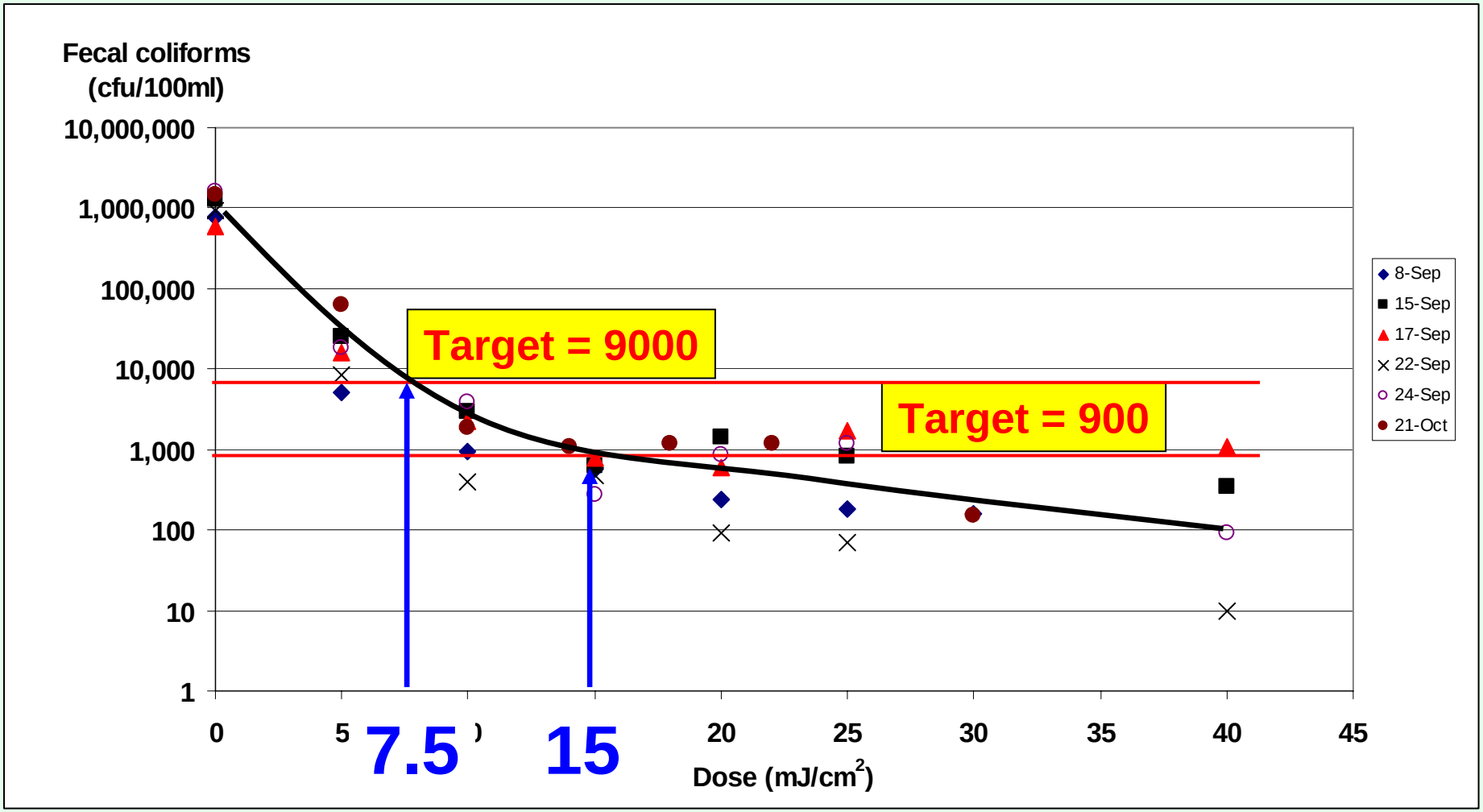
Photoreactivation (3)

1. Photoreactivation would be serious only at the surface of the river….
2. The UV 4000 system uses medium pressure lamps, for which photoreactivation is greatly reduced
3. After a delay of several hours (eg. in the outfall tunnel from the plant to the river) there is no photoreactivation

Effect of delay on photoreactivation



UV collimated beam curves (2004)



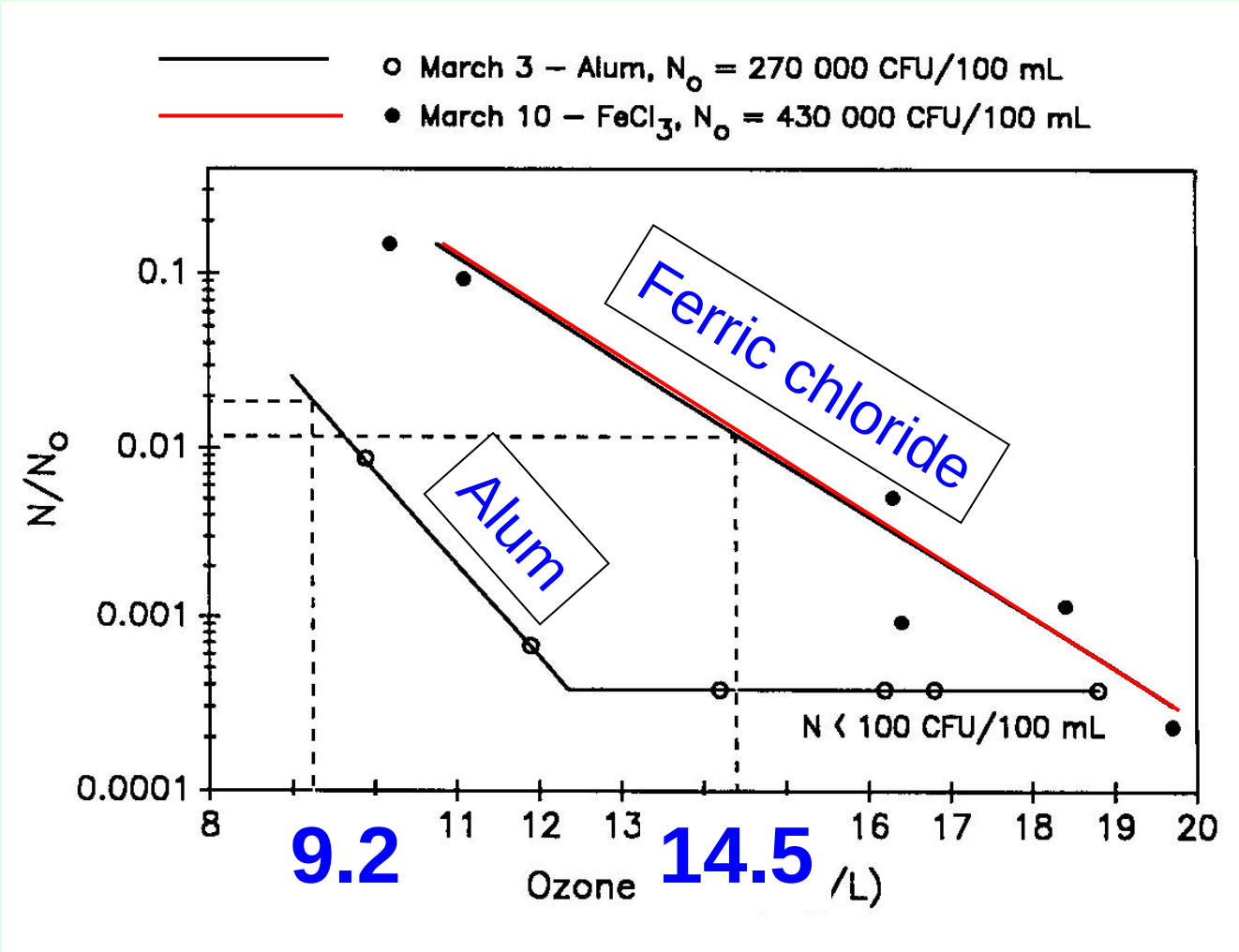
Without photoreactivation, we require a UV dose up to 50% less, which could reduce the cost for UV disinfection by as much as $100m over the life of the project

Ozone

Pertinent facts about ozone (1)

1. There is a high ozone demand in wastewater effluents, caused especially by COD, iron coagulants (i.e. ferric chloride), and other compounds

$FeCl_3$ vs alum for ozonation



Pertinent facts about ozone (2)

1. There is a high ozone demand in wastewater effluents, caused especially by COD, iron coagulants, and other compounds
2. There are very few wastewater treatment plants using ozone for disinfection

Key points from the WERF report (2007)

- Of 43 wastewater facilities using ozone in 1989 in the USA, only 5 major treatment plants were still using ozone in 2006
- Currently there are only 7 ozone plants in North America (none in Canada) for wastewater, with a median flow of 0.44 m^3/s (Montréal is 40 m^3/s)
- All of these ozone plants use secondary biological treatment upstream (Montréal uses primary physicochemical treatment)

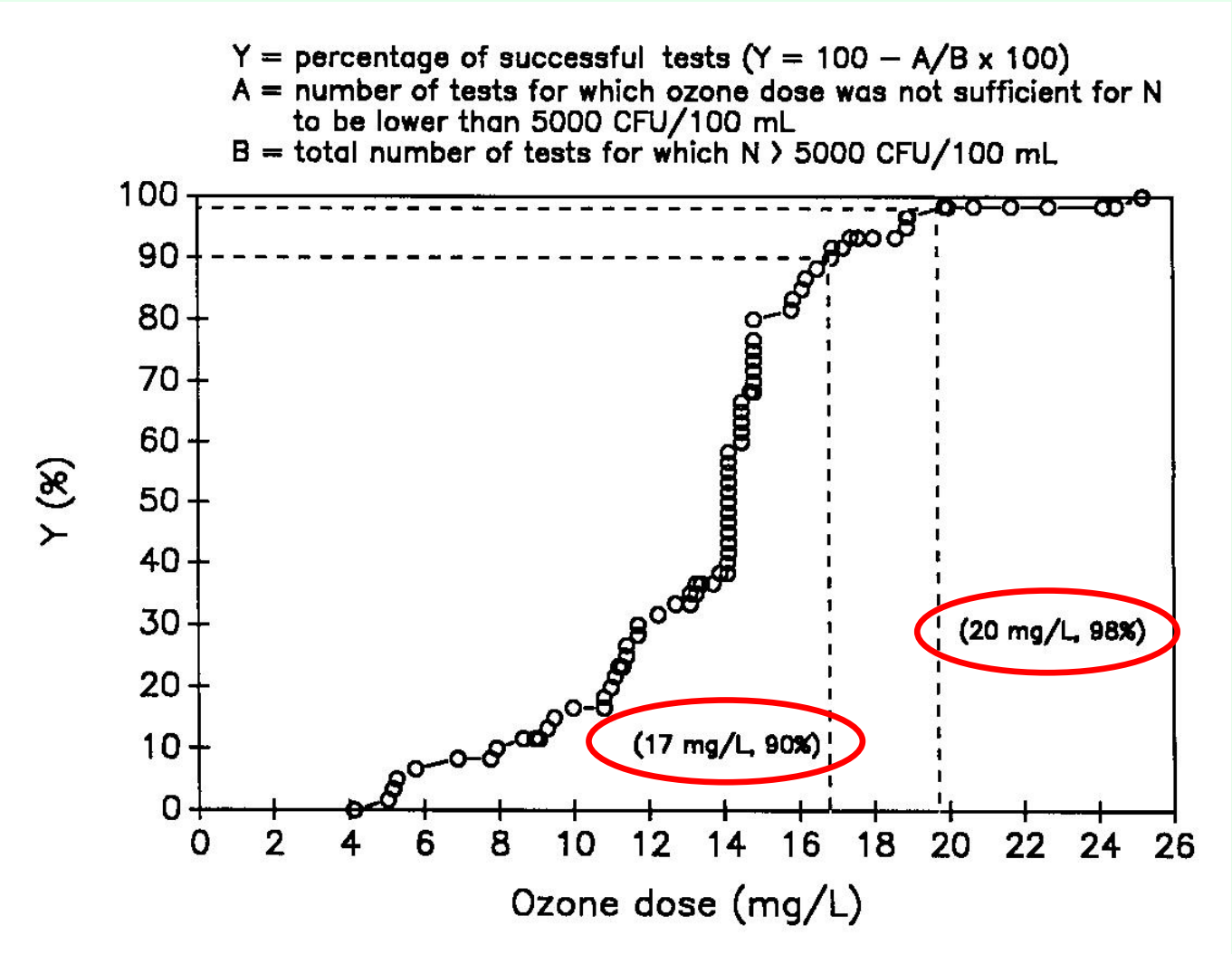
Pertinent facts about ozone (3)

1. There is a high ozone demand in wastewater effluents, caused especially by COD, iron coagulants, and other compounds
2. There are very few wastewater treatment plants using ozone for disinfection
3. Ozone increases the biodegradability (hence the BOD) of the wastewater, which could lead to biofilm growth on the tunnel and eventual release of more bacteria

Pertinent facts about ozone (4)

- Note that the target for Montréal's effluent is **9,000** CFU/100 mL (fecal coliforms), 10 times higher than for UV
- The ozone dose given in the Tripartite report is 16.5 mg/L, but performance is highly dependent on variations in wastewater quality
- Ozone requires either a very large oxygen production plant nearby, and/or transport of large quantities of liquid oxygen, with attendant safety/security/reliability risks

Ozone: Probability plot (1993)



Environmental and ecotoxicology aspects

Fish

- The effect of UV on fish was most surprising
- This has not been reported anywhere in the literature, nor to my knowledge has it been seen at any of the Québec plants, including La Pinière (which also uses primary physicochemical treatment)
- The effect of dilution was measured as equivalent to 300 m from the discharge; this is irrelevant as the fish will avoid the plume
- If the effect on fish is due to industrial discharges, these should be regulated

Viruses, protozoa, pharmaceuticals

- Ozone is excellent against most viruses but is ineffective against protozoa (*Giardia*, *Cryptosporidium*)
- Current levels of most pharmaceuticals are very low (likely not harmful), and ozone is effective against only some

Summary and conclusions

Summary and conclusions (1)

- The two processes (ozone and UV) should be judged according to the same target level (9,000 CFU/100 mL of fecal coliforms)
- The difference in project costs over 20 years, even at the more stringent target for UV, is significant:
  - UV $254.6 m
  - Ozone
    - Option 1: $289.9 m (**14% higher**)
    - Option 2: $318.6 m (**25% higher**)
- At more realistic UV doses, UV cost could be reduced from $254 m to $150 m or lower

Summary and conclusions (2)

- If Montréal would use ozone, the plant would be the largest in the world for wastewater disinfection by a significant margin, and there is still great uncertainty in its application
- Technology chosen for disinfection should not be expected to solve other problems such as genotoxicity, sex changes of fish, tensioactive products, and pharmaceuticals
- The better solution for these is reduction at source (i.e. industrial discharges into Montréal's sewers must be regulated). Industrial source control can also assist both UV and ozone disinfection

Acknowledgements

- Daina Brumelis, laboratory manager
- NSERC
- Pierre Payment
- Numerous students
- City of Montréal and staff at the Wastewater Treatment Plant

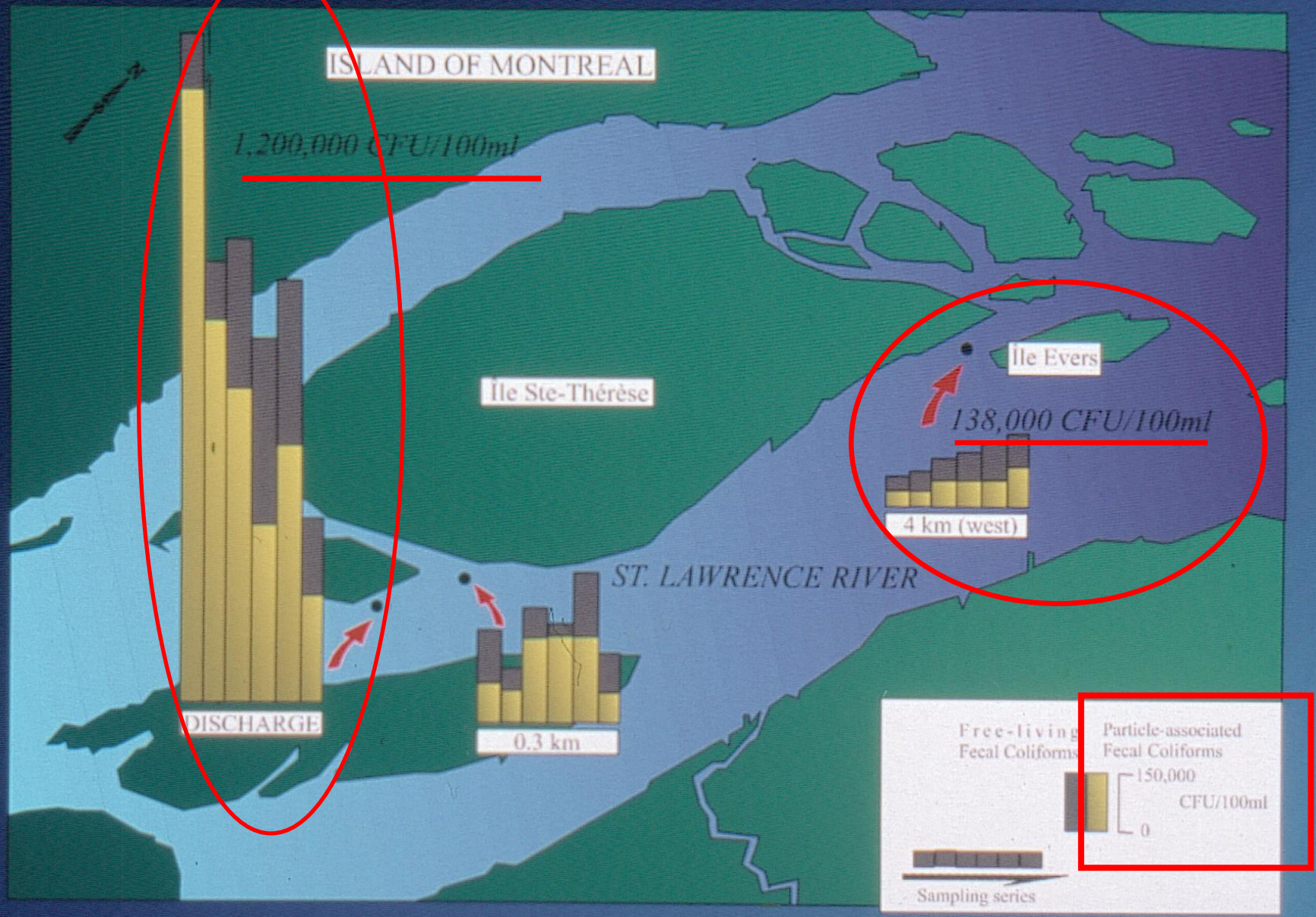
Thanks for listening!

Any questions?

Additional slides (not for presentation)

References

- Martin, N. and Gehr, R. Reduction of photoreactivation with the combined UV/peracetic acid process or by delayed exposure to visible light. Water Environment Research. 79, 9, 991-999 (2007).
- Payment, P. and Gehr, R.: Impact de la Désinfection des Eaux Traitées de la Station d'Épuration de la Ville de Montréal sur la Qualité des Eaux Vocation Récréative en Aval du Rejet. Vecteur Environnement, 37, 1, 54 - 64 (2004).
- Gehr, R., Wagner, M., Veerasubramanian, P. and Payment, P: Disinfection Efficiency of Peracetic Acid, UV and Ozone after Enhanced Primary Treatment of Municipal Wastewater. Water Research, 37, 19, 4573-4586 (2003).
- Brown, H. and Gehr, R: A Novel Approach for Evaluation of UV Dose Requirements Prior to Upgrading Wastewater Treatment Plants. Proc. Disinfection '98, WEF, Baltimore, April 19-22, 1998.
- Gehr, R. and Nicell, J: Pilot Studies and Assessment of Downstream Effects of UV and Ozone Disinfection of a Physicochemical Wastewater. Water Quality Research Journal of Canada, 31, 2, 263-281 (1996).
- Absi, F; Gamache, F; Gehr, R; Liechti, P. and Nicell, J: Pilot Plant Investigation of Ozone Disinfection of Physico chemically Treated Municipal Wastewater. Proceedings of the 11th World Ozone Congress, San Francisco, pp S 7 33 42, August 29 September 3, 1993.
- Gehr, R; Comair, C.B. and Cairns, W.L: UV Disinfection of Wastewater by Medium Pressure Lamps. Proceedings of the Joint CSCE ASCE National Conference on Environmental Engineering, Montreal, pp 1,929 1,936, July 12 14, 1993.
- Cairns, W.L; Sakamoto, G; Comair, C.B. and Gehr, R: Assessing UV Disinfection of a Physico chemical Effluent by Medium Pressure Lamps Using a Collimated Beam and Pilot Plant. Proceedings of the WEF Specialty Conference: Planning, Design and Operation of Effluent Disinfection Systems, Whippany, NJ, pp 433 444, May 23 26, 1993.

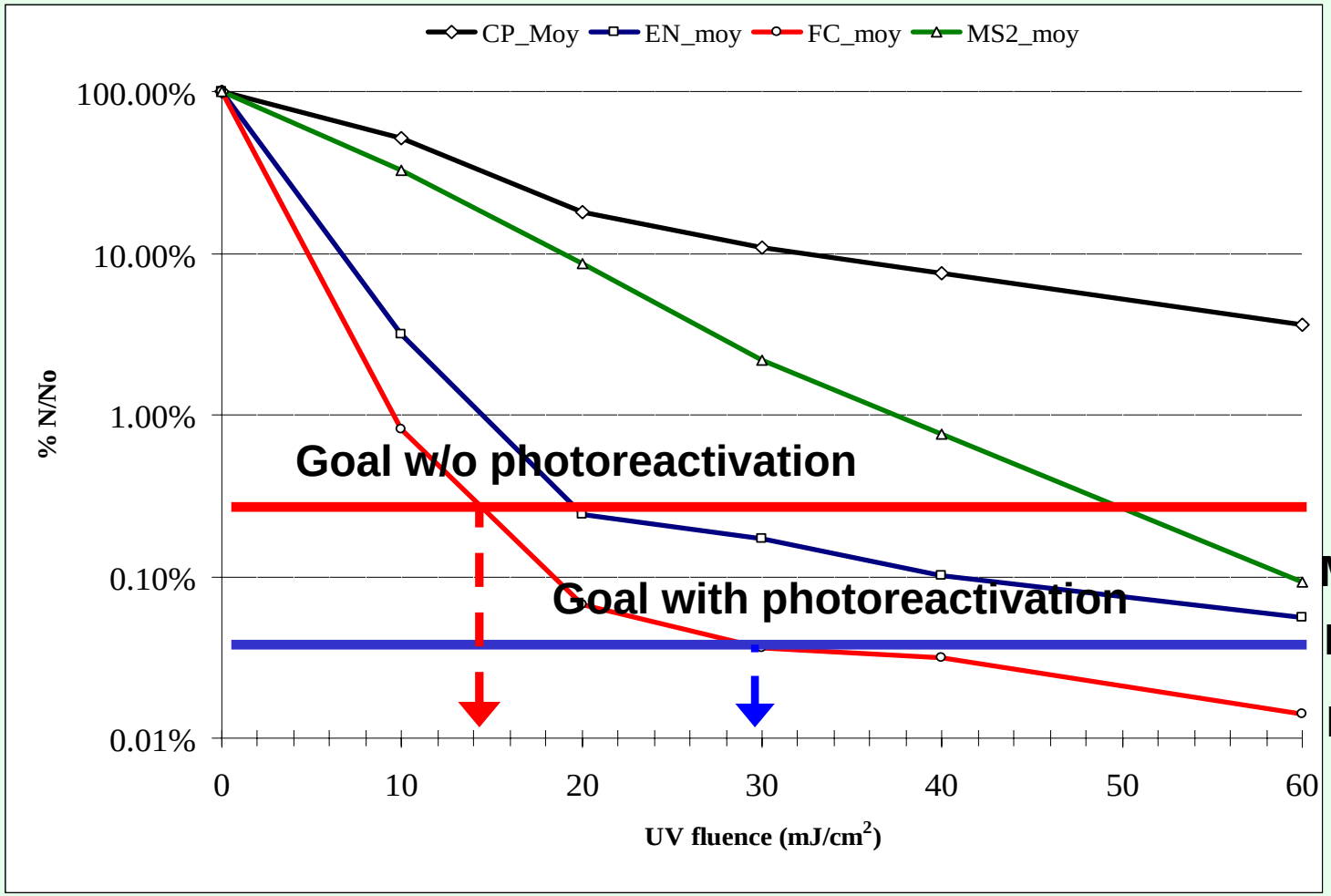


Fecal coliform distributions

Assumptions in the risk analysis

- Risk is based on recreational usage, such as sailing, water skiing, etc, but NOT swimming
- Ingestion is 100 mL per immersion; 10 immersions per season
- Although Quebec standards refer to *Enterococci*, risk is based on viruses
- Dilution factor runs from 19 @ 1 km to 64 @ 4.2 km downstream of WWTP
- Natural die-off is insignificant

% inactivation by UV (2001)



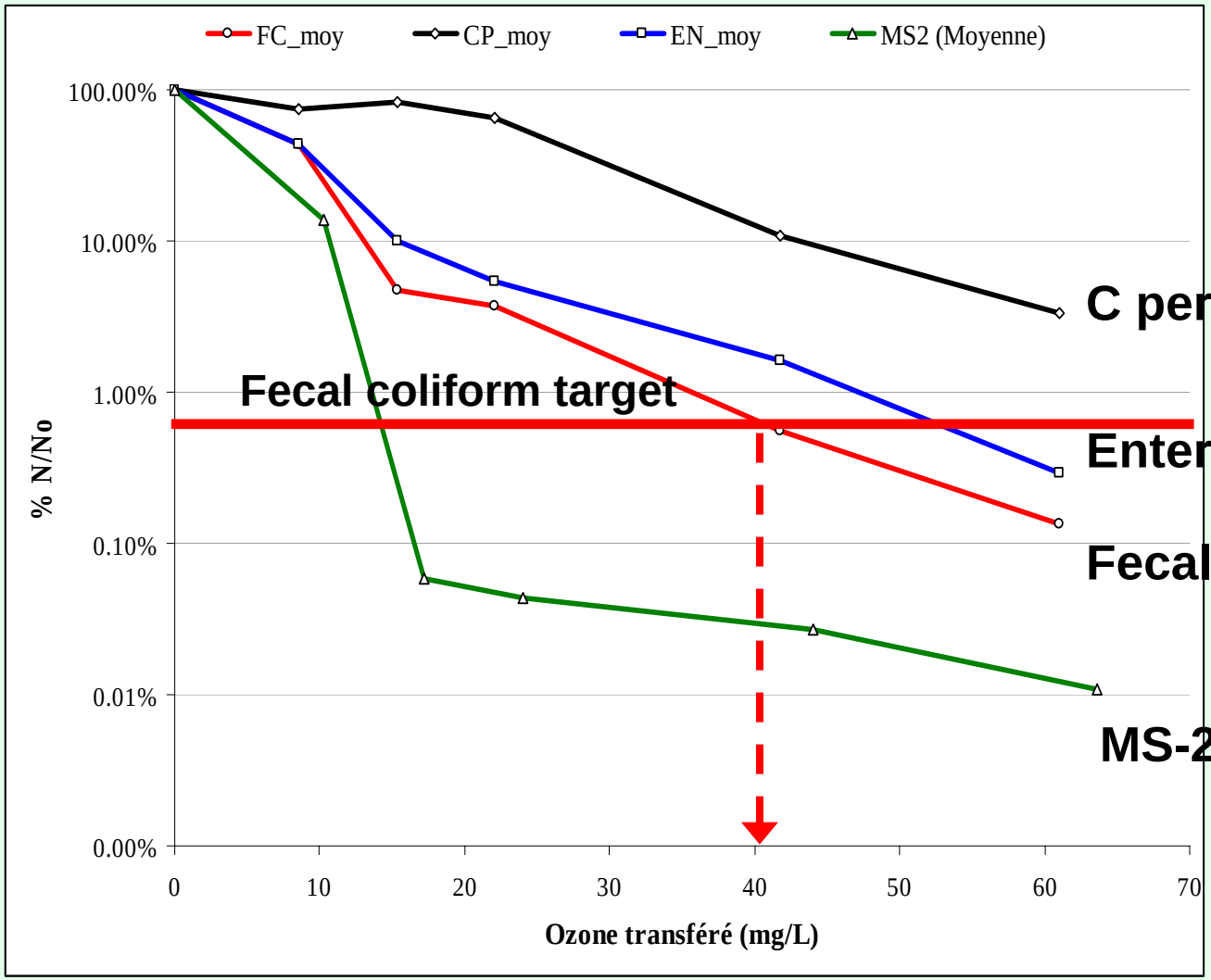
C. perfringens

MS-2 coliphage

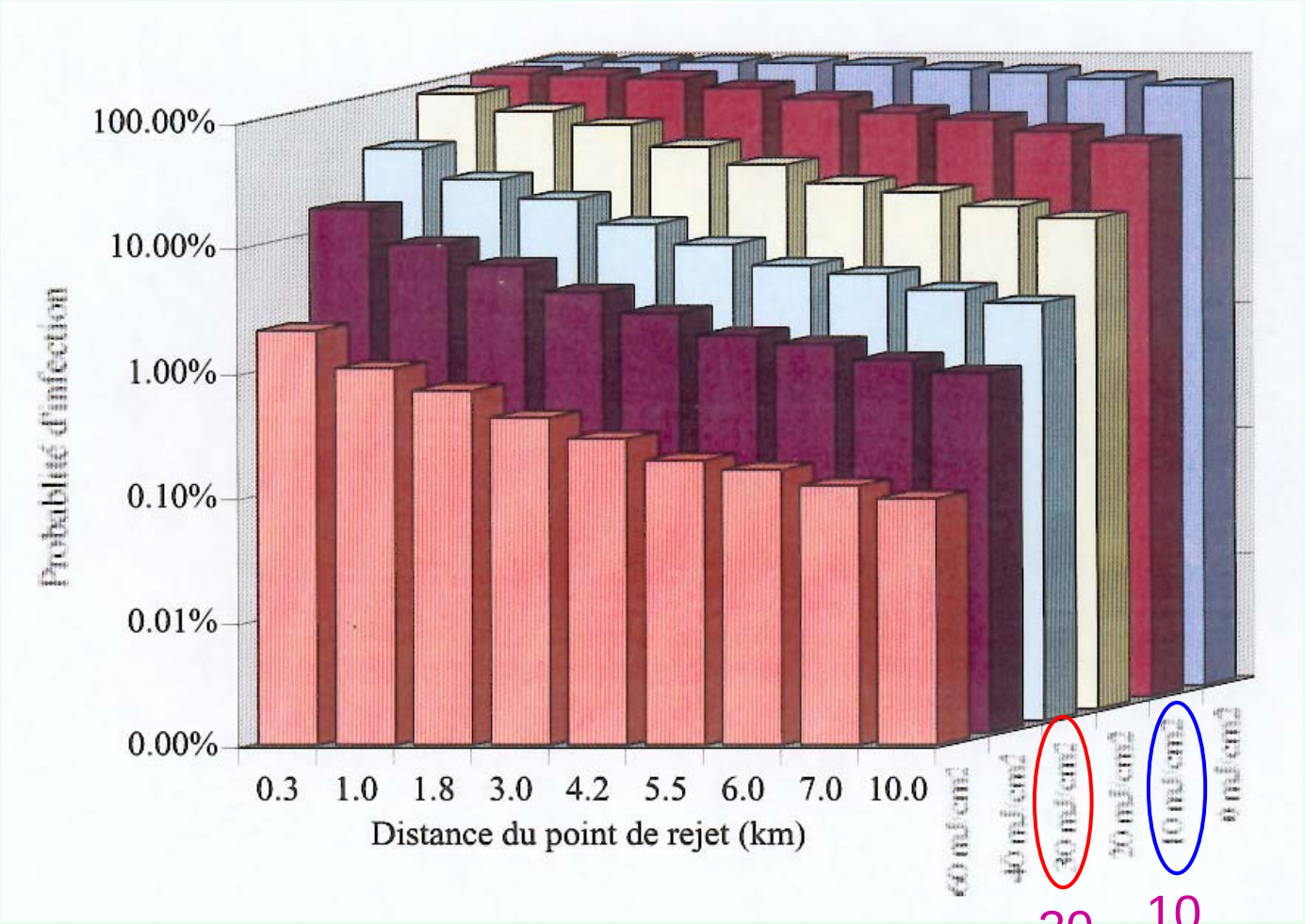
Enterococci

Fecal coliforms

Inactivation by ozone (Batch, 2001)



Risk of viral infection in August due to recreational exposure. UV disinfection.



Risk of viral infection in August due to recreational exposure. Ozone disinfection.