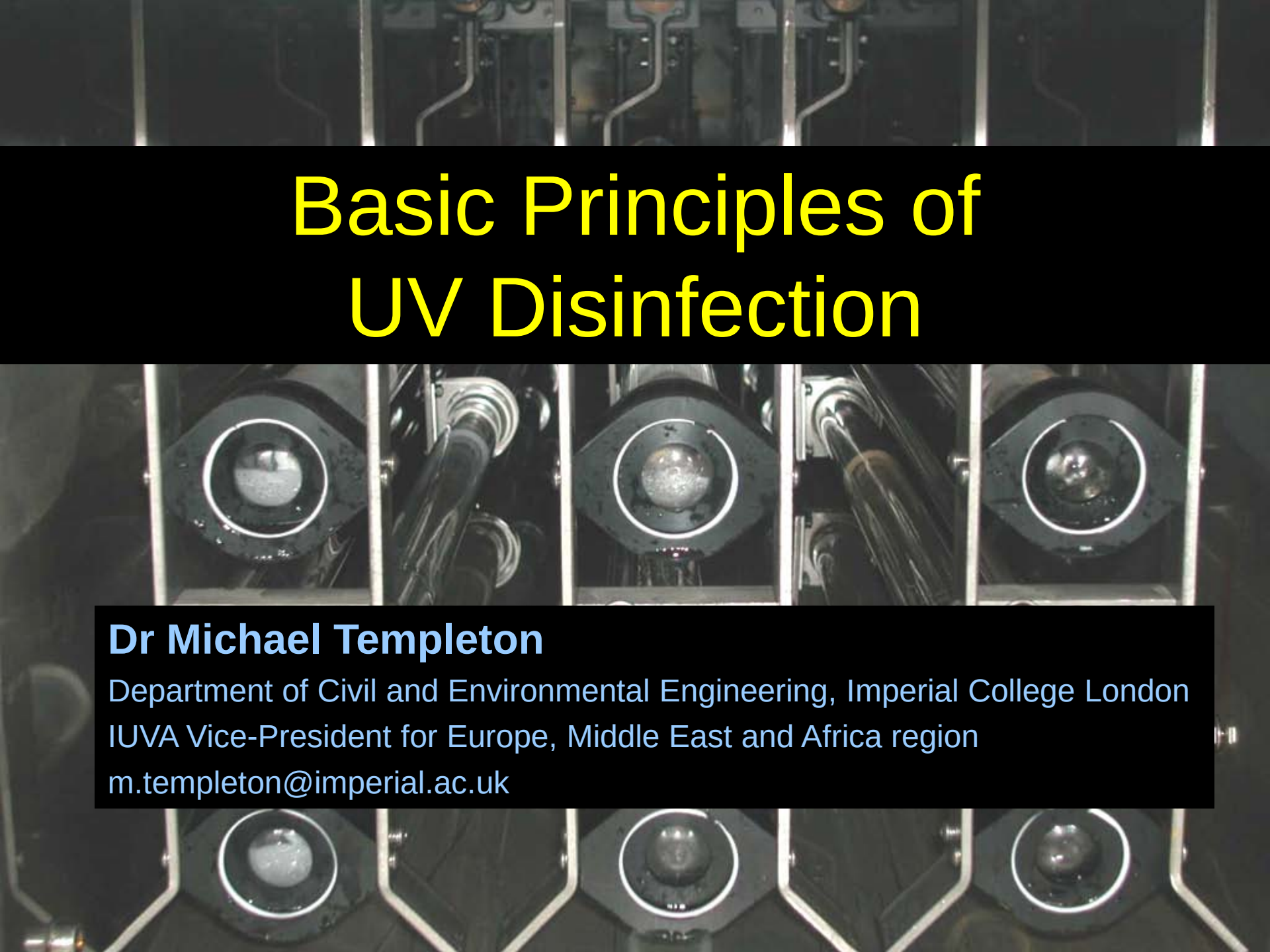

Basic Principles of UV Disinfection

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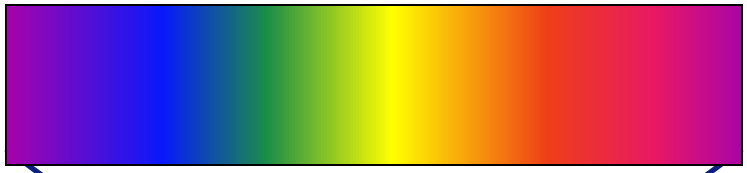
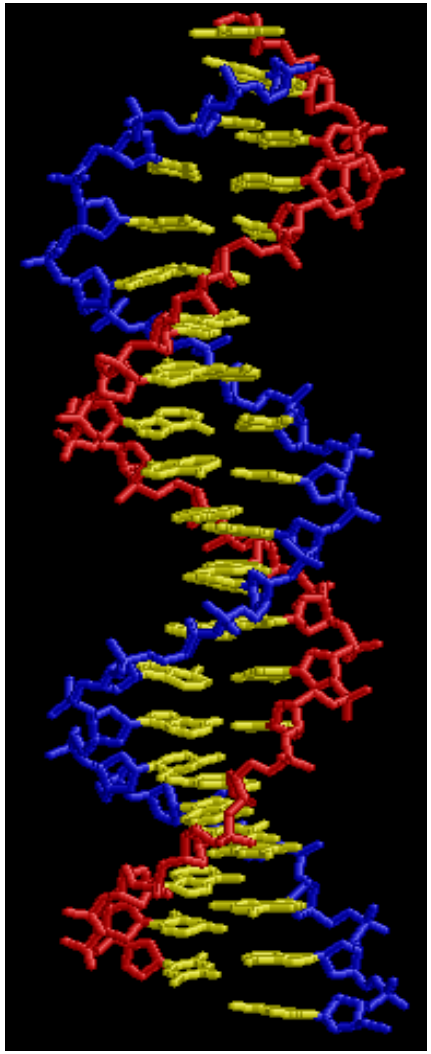


Gamma	Xrays	UV	Visible	Infrared	Microwave
Wavelength (nm)	1	10	340	760	10^6

vacuum UV	UVC	UVB	UVA
Wavelength (nm)	200	280	315

germicidal sunburn tan

Microbial Inactivation by UV Light



- In order to inactivate microorganisms, UV energy must be absorbed somehow
- DNA & RNA happens to absorb light in the UVC range emitted by UV lamps
- DNA & RNA are the master instructions for the cell
- UV damages these nucleic acids and prevents cell replication

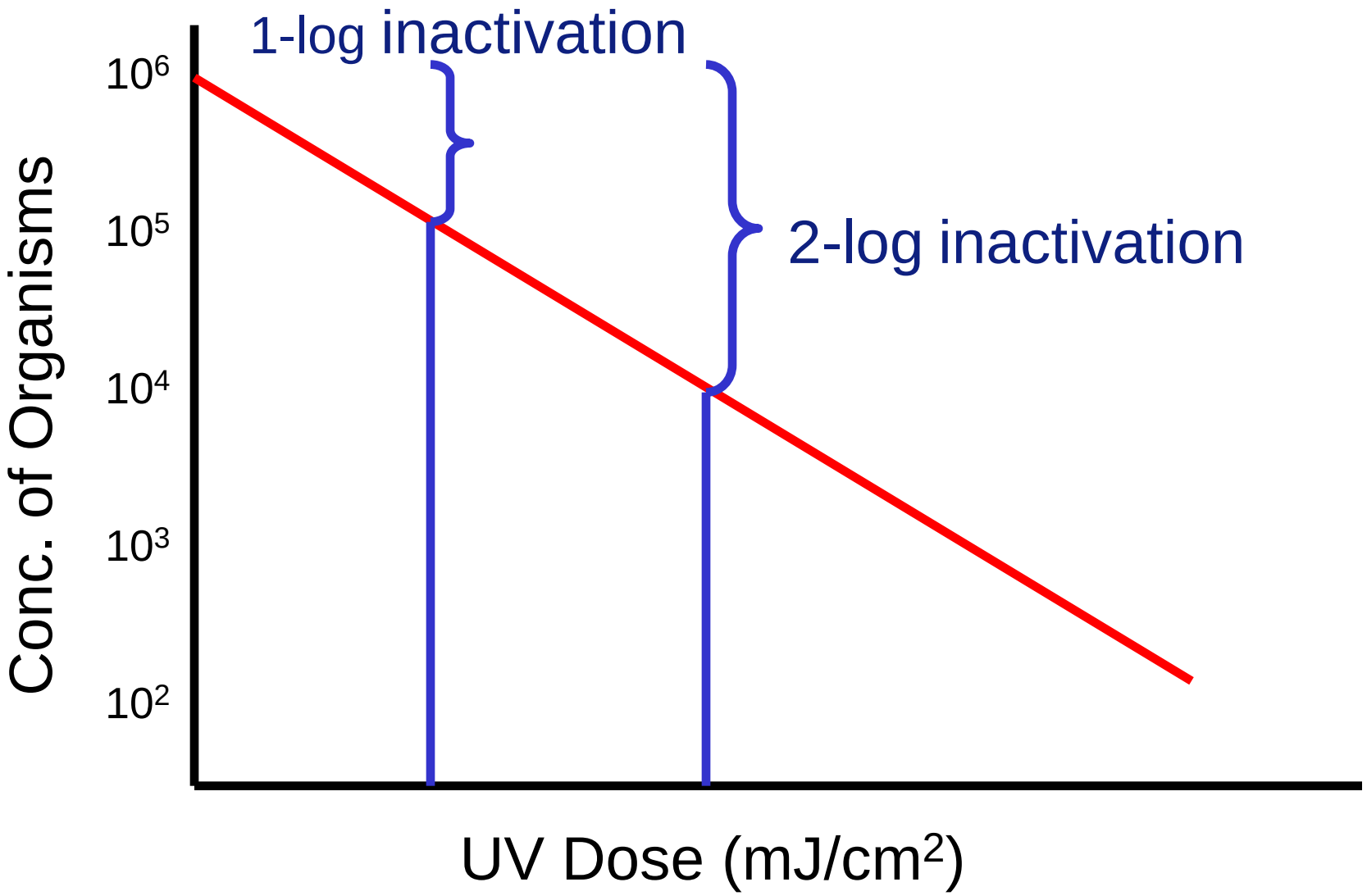
UV Dose Terminology

Dose = Intensity x Time

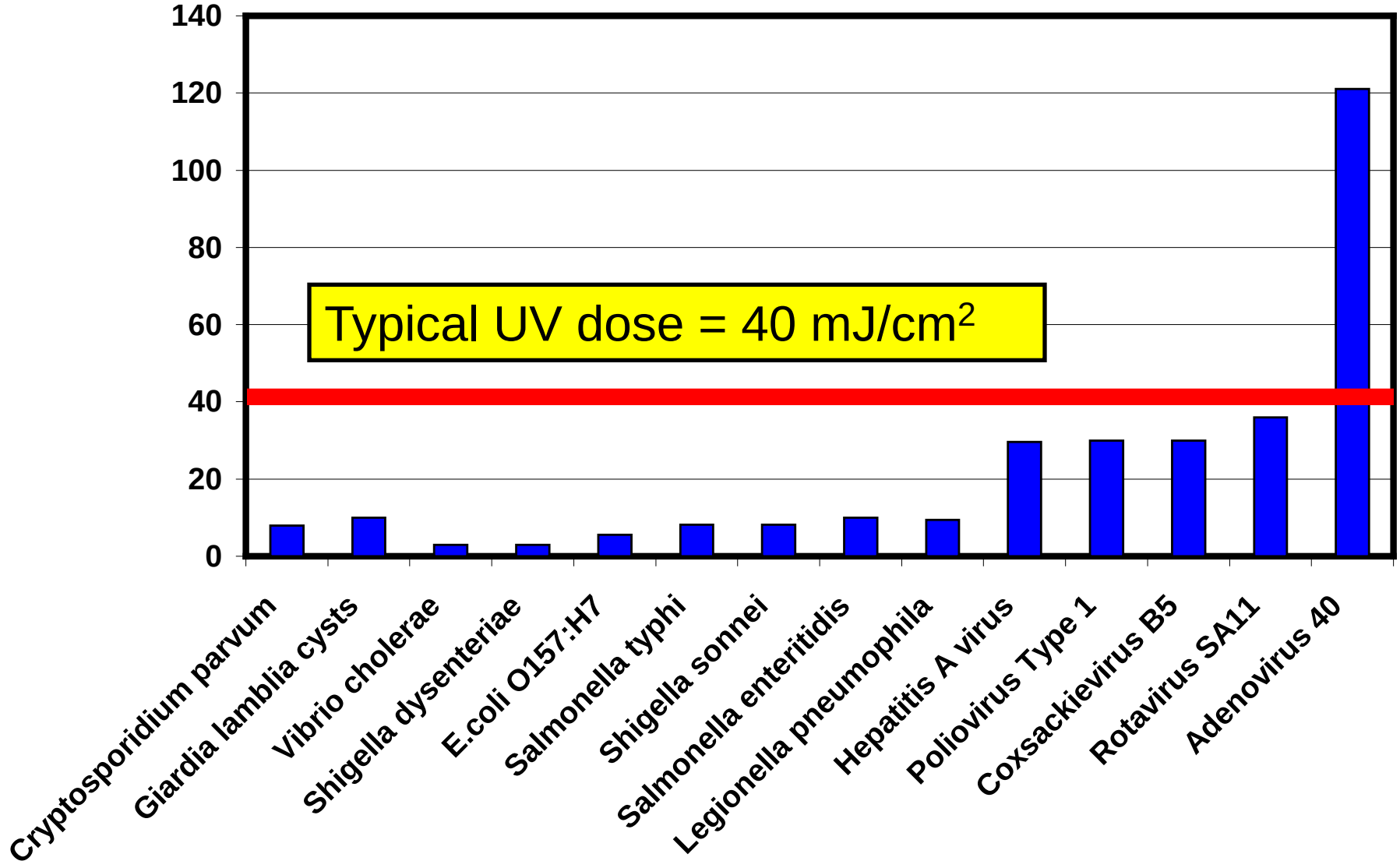
Fluence = Fluence rate x Time

- J/m^2, mJ/cm^2, $mW \cdot sec/cm^2$ are commonly used units
- 10 J/m^2 = 1 $mW \cdot sec/cm^2$ = 1 mJ/cm^2
- So, 400 J/m^2 is the same as 40 mJ/cm^2

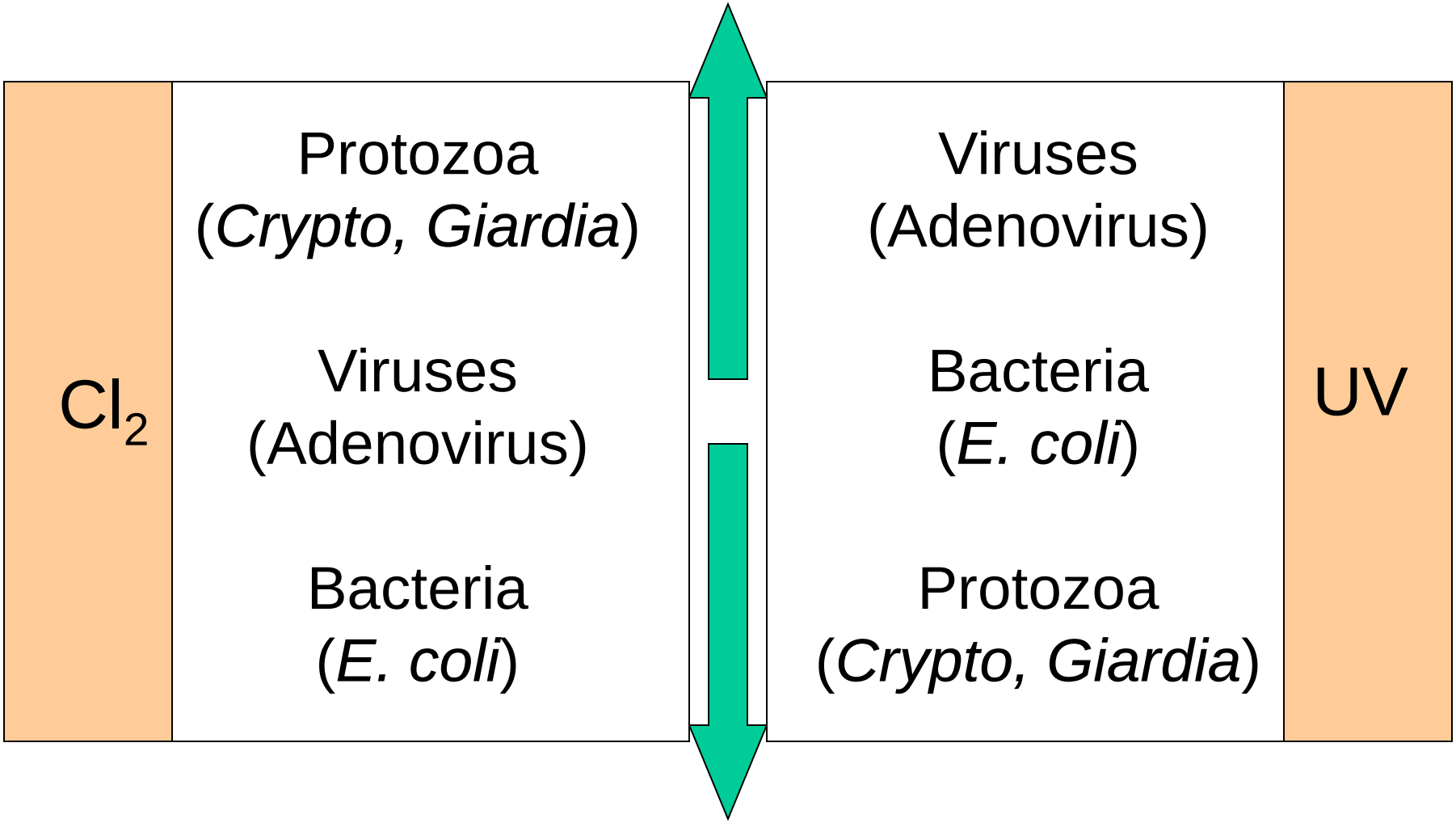
Log Inactivation



UV dose (mJ/cm^2) required for 4-log inactivation



Harder to inactivate

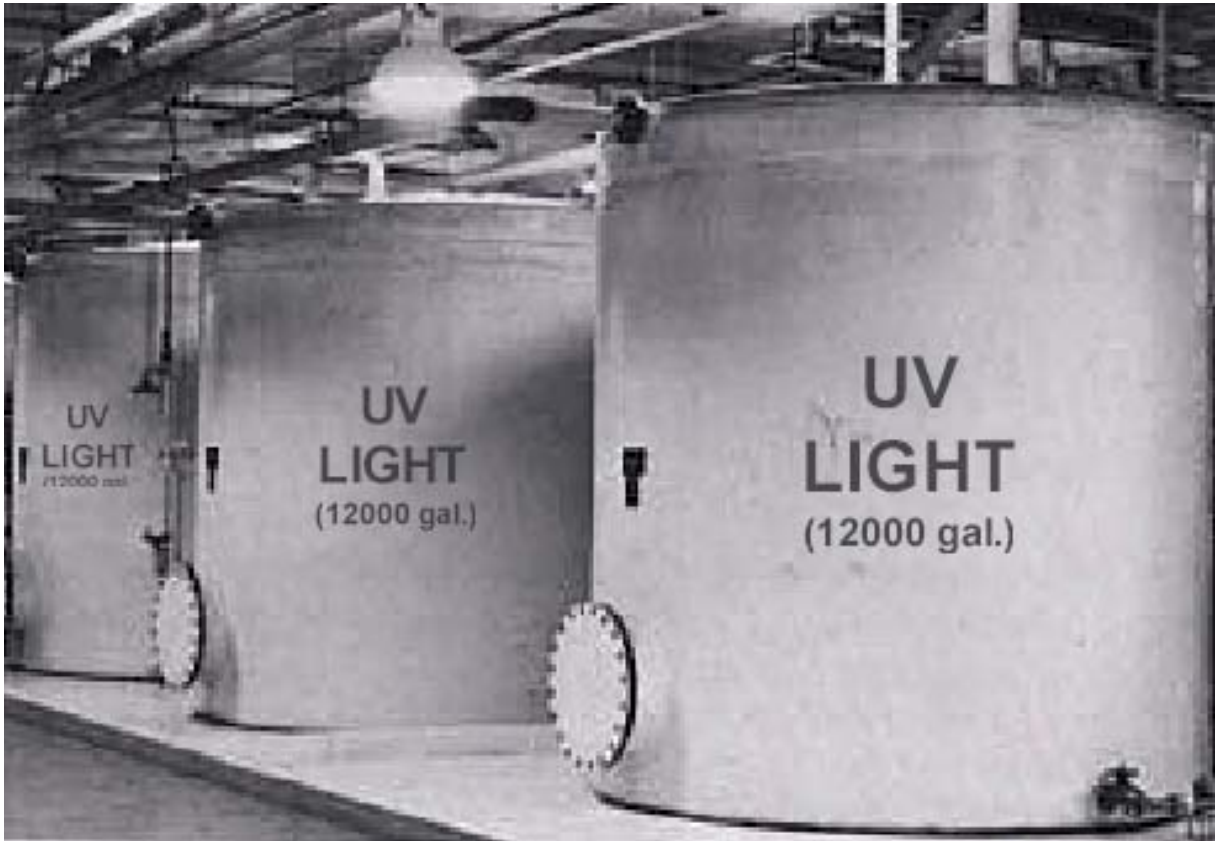


Easier to inactivate

A Note about DNA Repair

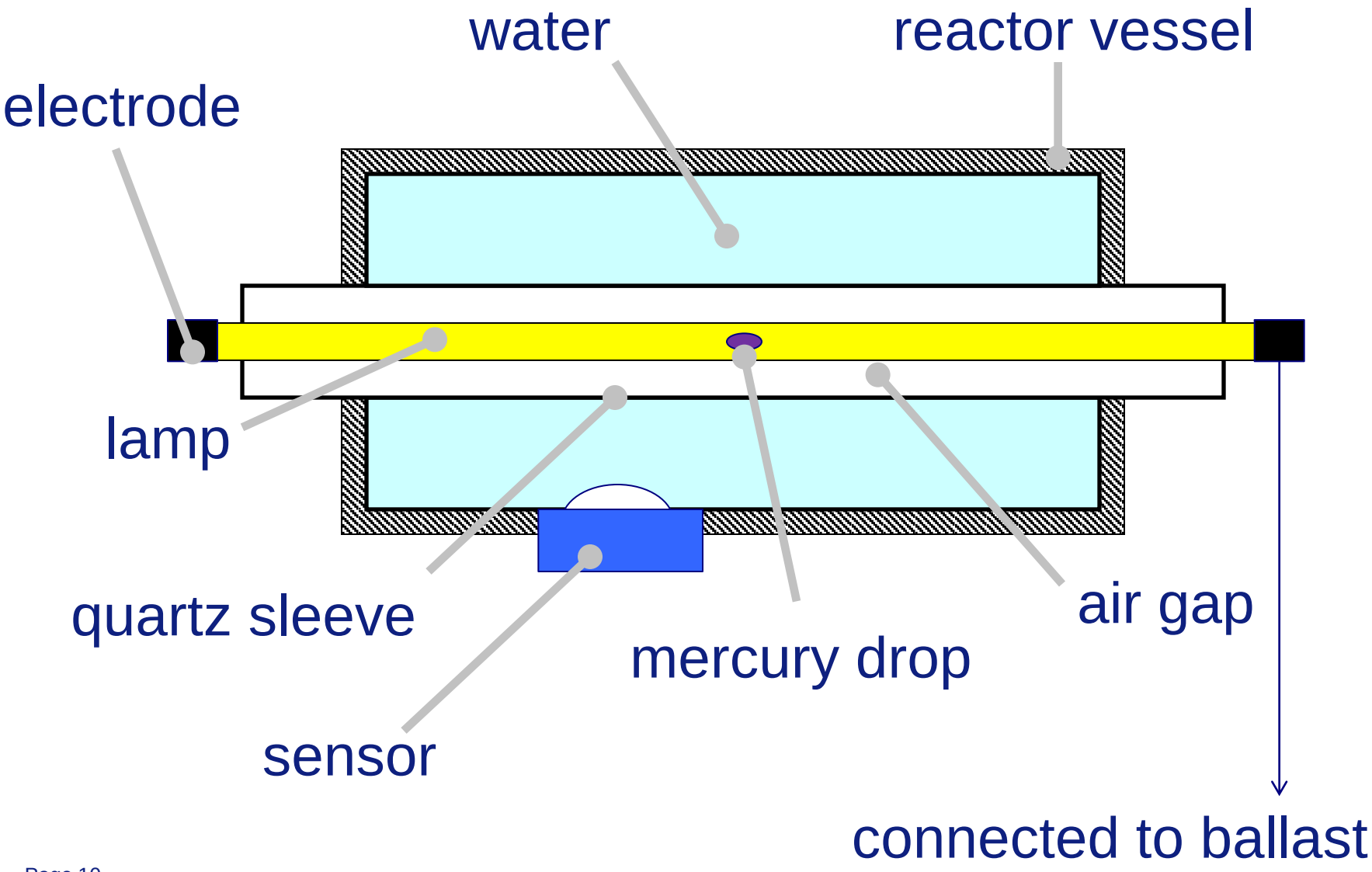
- ‘Light’ and ‘dark’ repair mechanisms exist, but likely not a drinking water concern
- If you apply enough UV, you destroy the ability to repair
- UV doses in the 40+ mJ/cm^2 range are thought to be easily high enough to prevent repair

Where Do You Get UV?

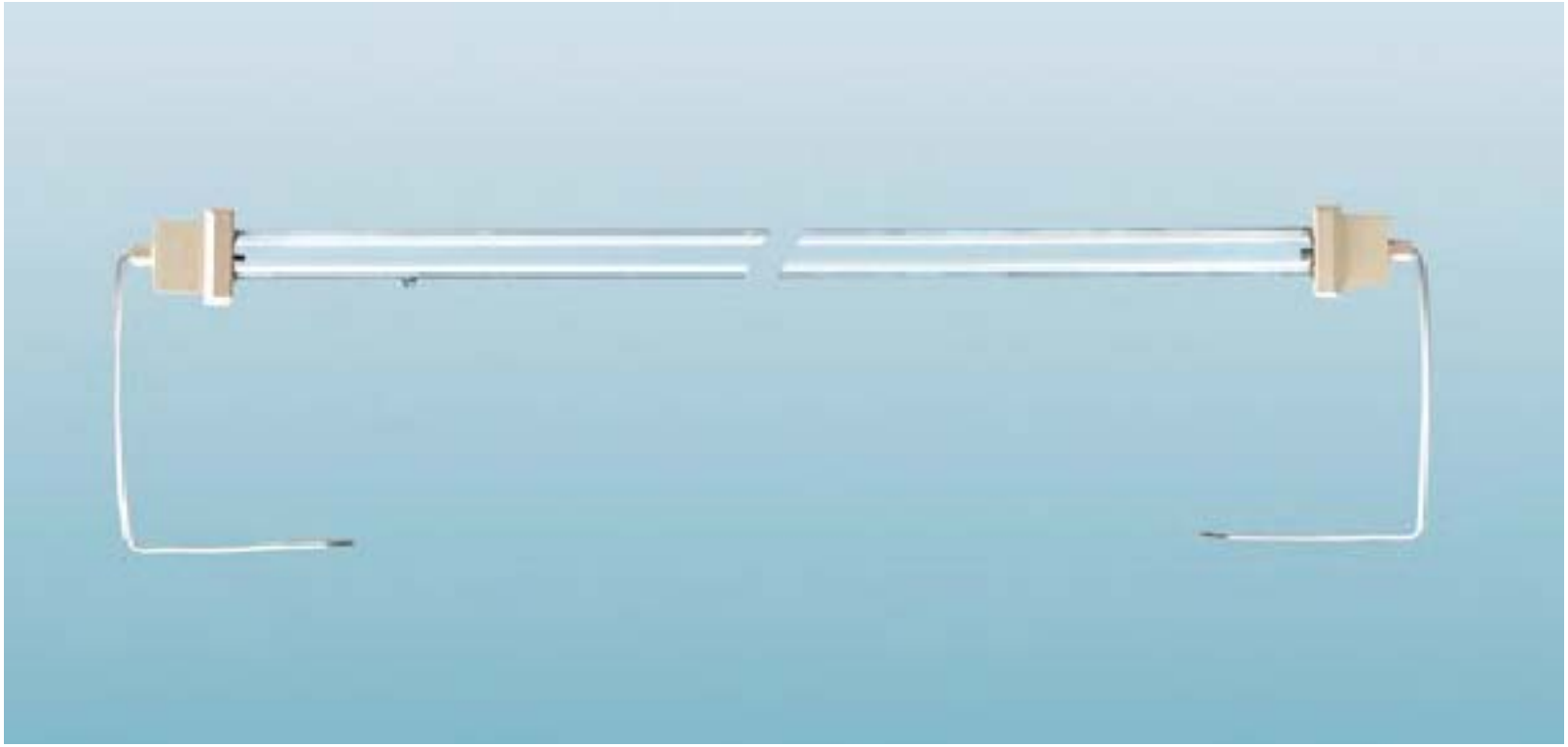


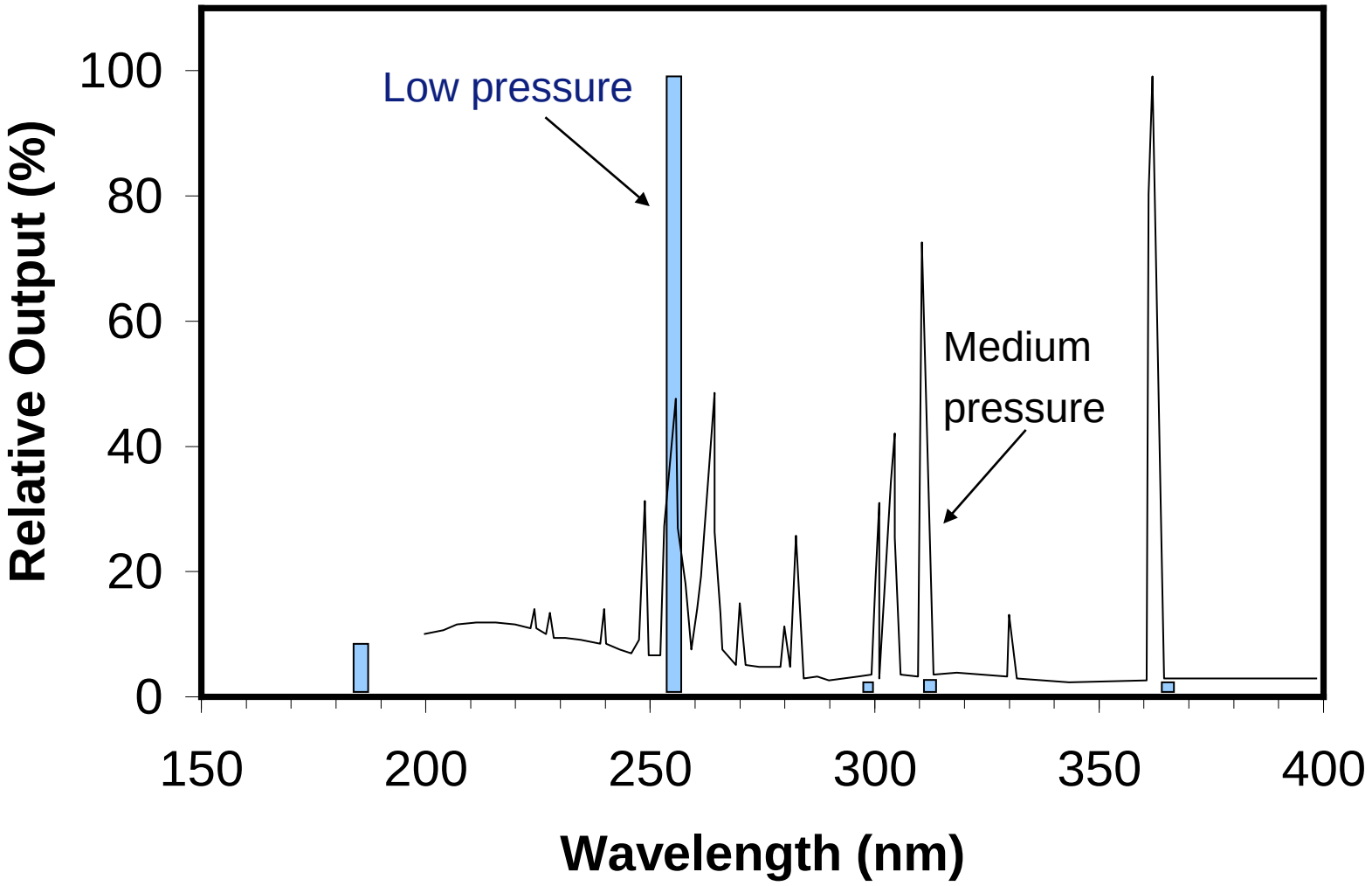
Humour Credit: Ron Hofmann

UV Reactors

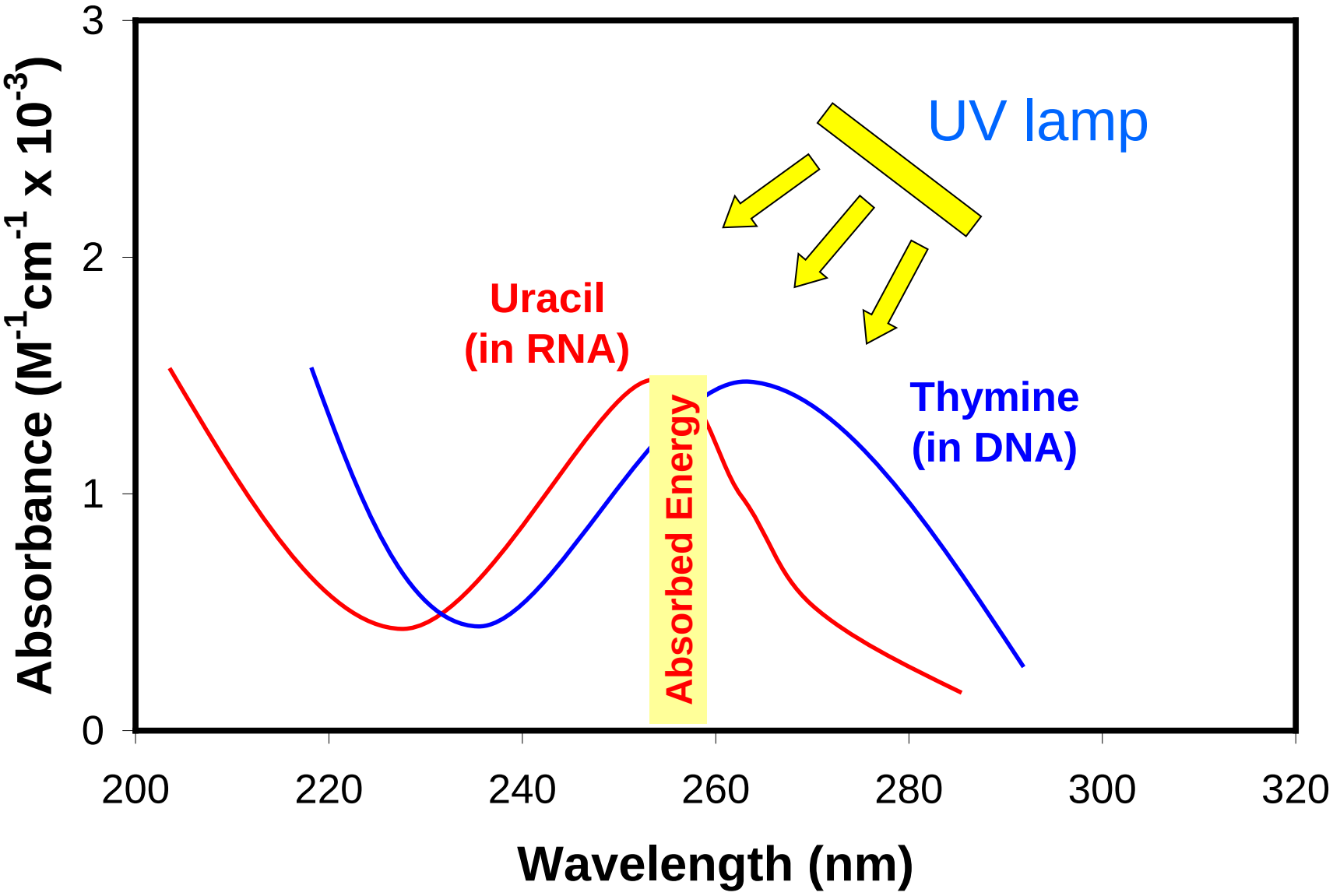


UV Lamps

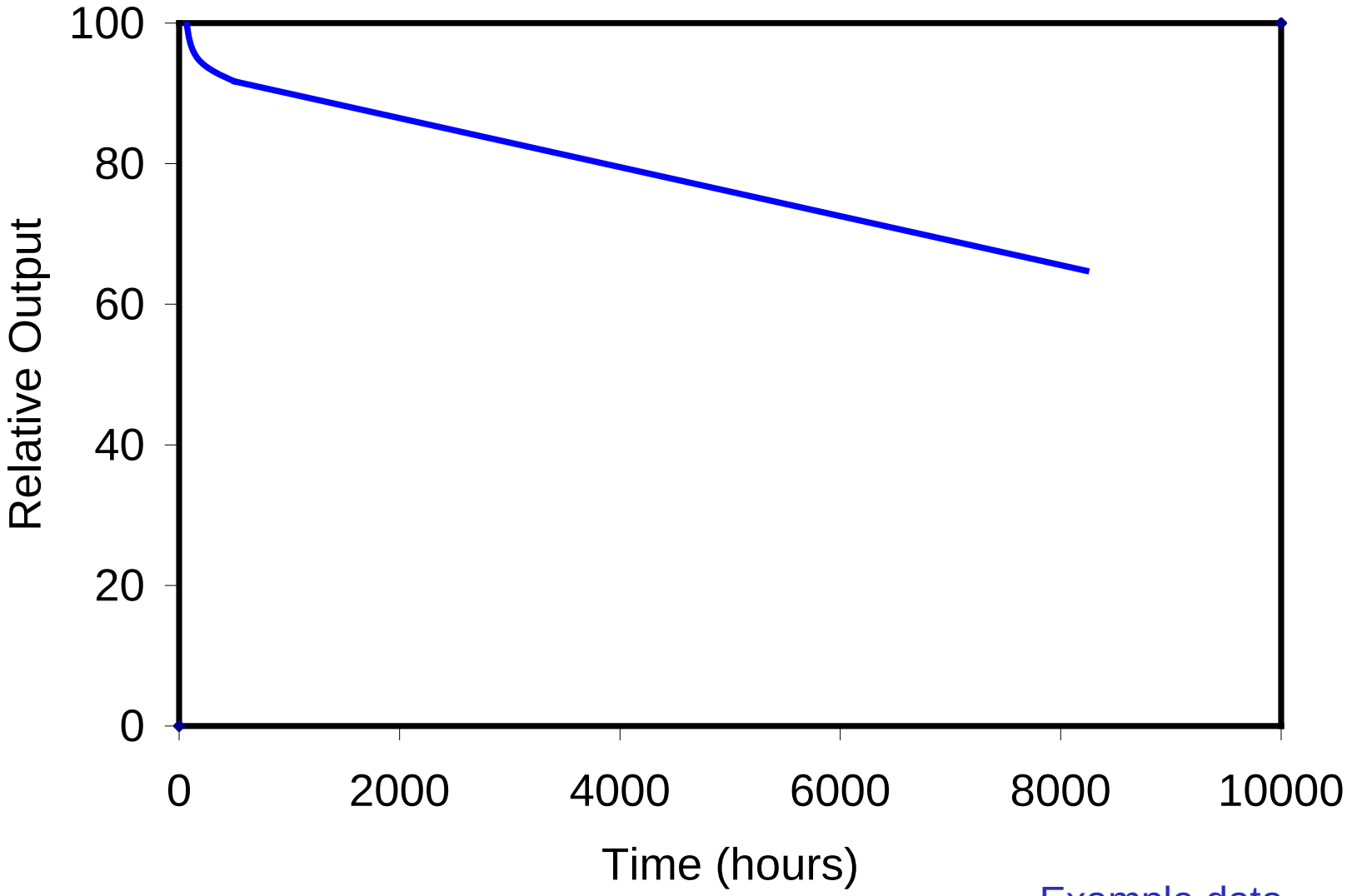




Note: The y-axis scale is different for LP and MP lamps on this graph. MP lamps emit MUCH MORE energy than LP lamps.

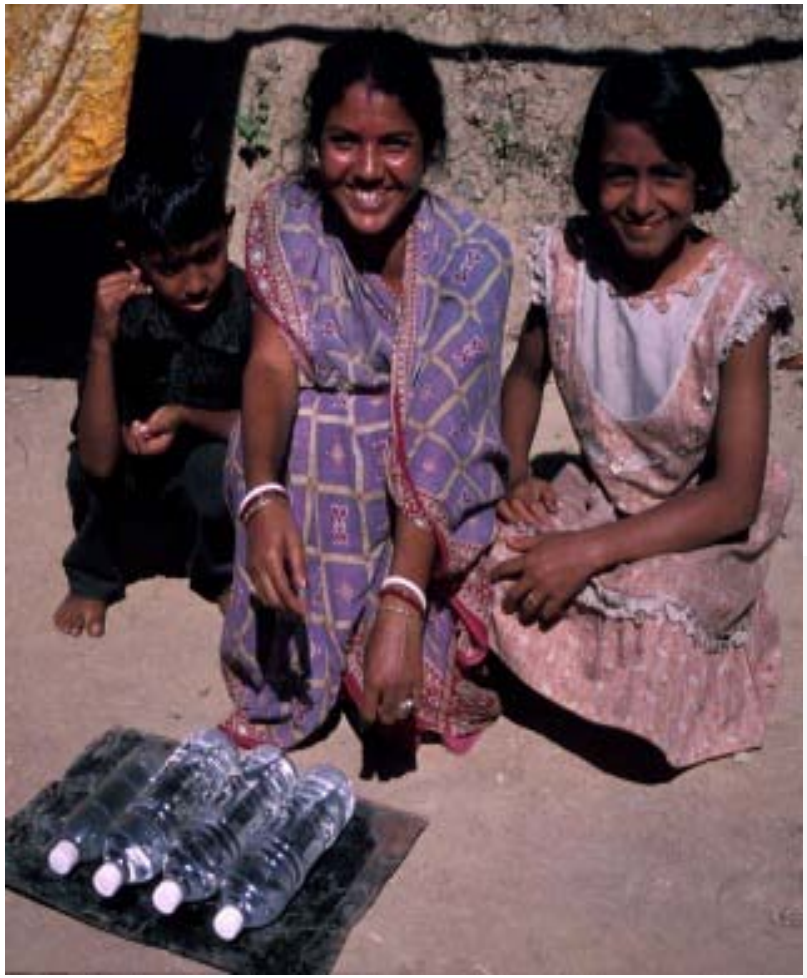

UV lamp
Uracil
(in RNA)
Thymine
(in DNA)
Absorbed Energy
Absorbance (M-1cm-1 x 10-3)
Wavelength (nm)
0
1
2
3
200
220
240
260
280
300
320

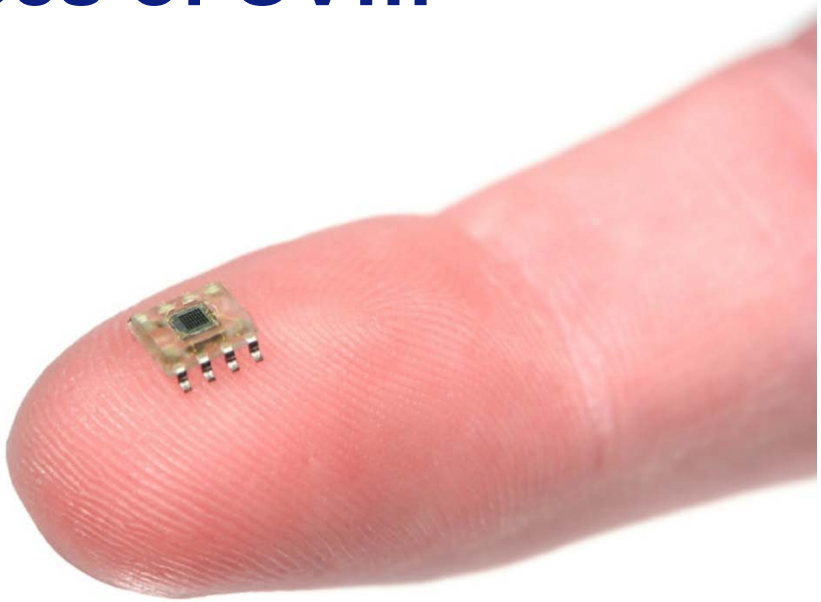
Lamps Age and Need Replacing!



Example data

Other Sources of UV…





UV Disinfection Benefits

- *Cryptosporidium* and other pathogens inactivated at relatively low, economical UV doses
- No formation of regulated disinfection by-products at typically applied UV doses for disinfection
- Small space requirements (no contact tank)
- Competitive costs versus alternatives (*e.g.* ozone, membrane filtration)

UV Disinfection Limitations

- No taste and odour control (on its own…)
- Does not remove colour (on its own…)
- No iron, manganese oxidation
- No residual disinfecting capabilities

Design and operation of UV reactors must take into account relevant water quality factors and include a dose validation/monitoring strategy

Water Quality Considerations

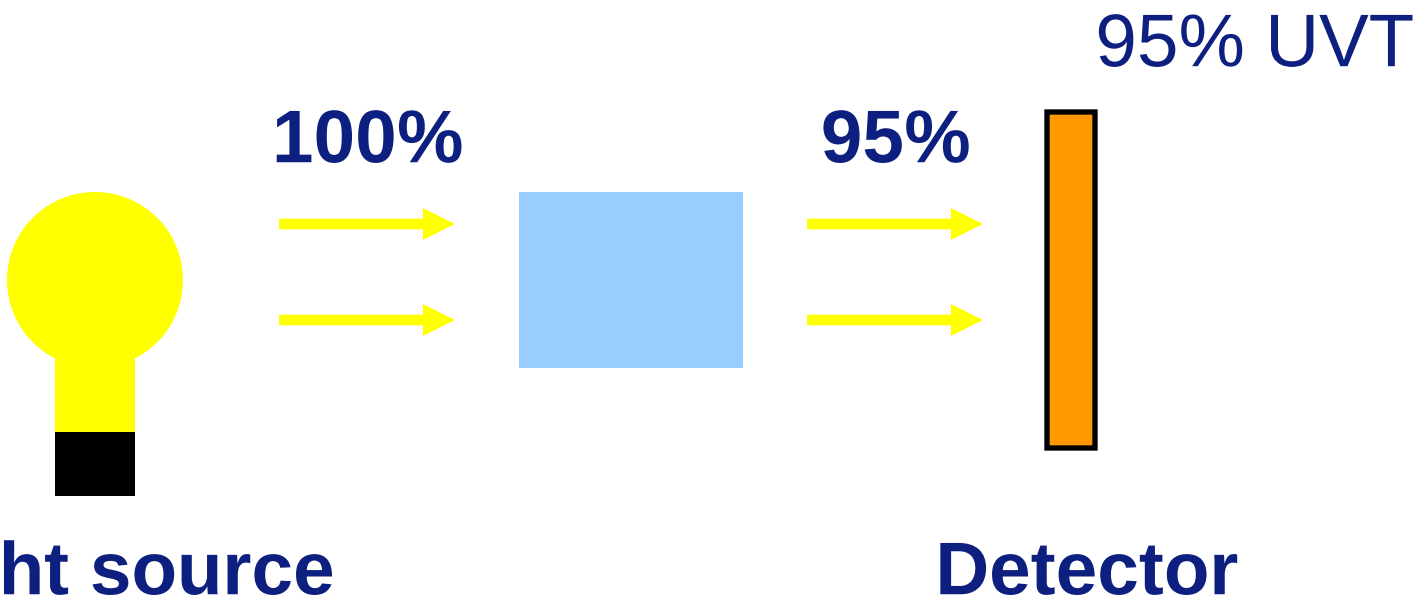
Relevant water quality parameters:

- UV Transmittance (UVT)
- Fouling
- Turbidity

Note: pH, temperature have no major direct impact on UV performance

UV Transmittance (UVT)

- Definition of %UVT: Percent of light emitted (254 nm) that passes through 1 cm of water



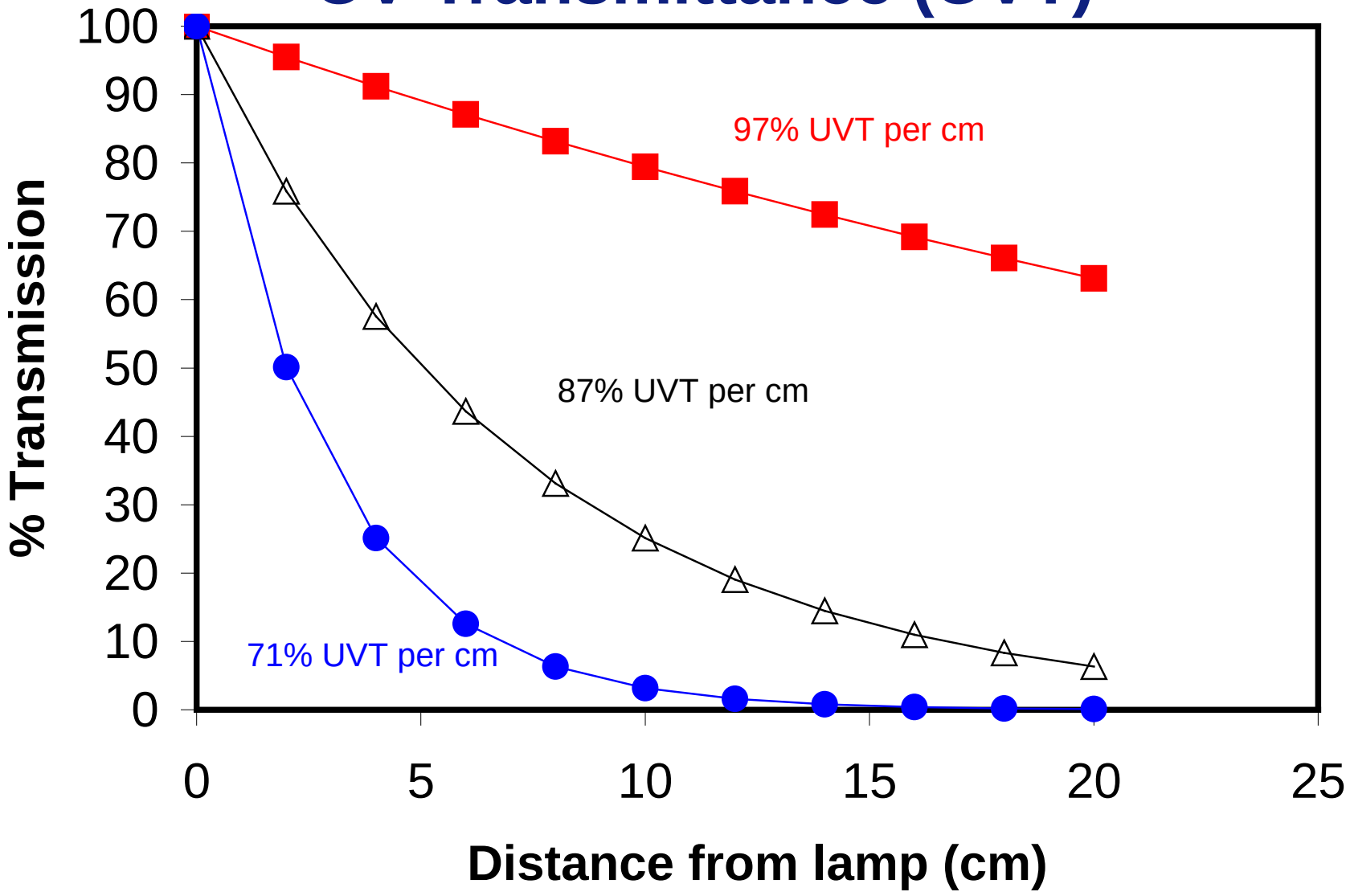
UV Transmittance (UVT)

- Arguably the most important water quality parameter
- Clean source water: > 90% UVT
- Wastewaters: often 30% to 50%
- Can vary seasonally for surface waters; often more stable for groundwaters

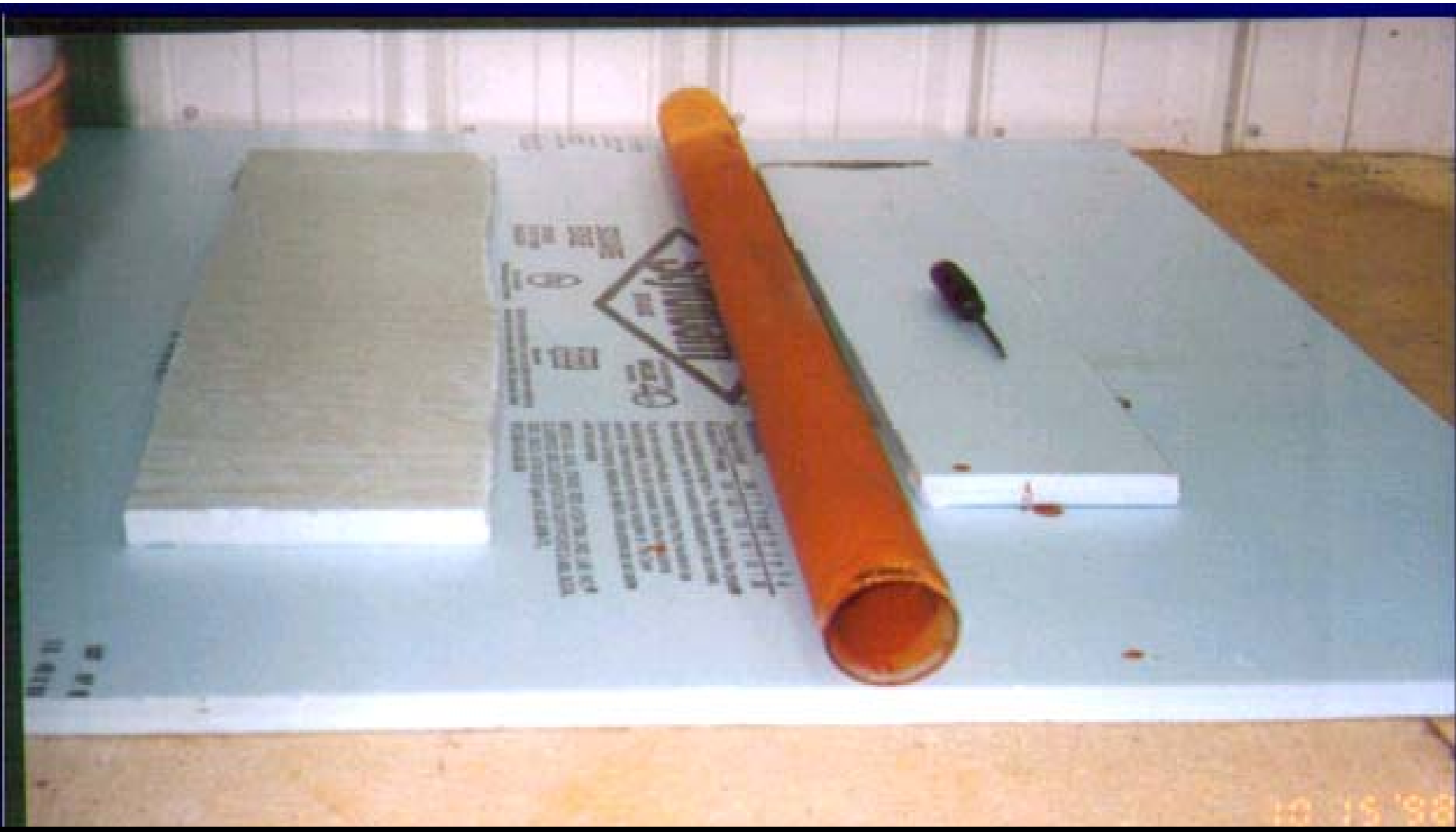
UV Transmittance (UVT)

- UVT affected by dissolved and particulate matter; best to apply UV post-filter in a conventional treatment works
- Can always design a powerful enough UV system to handle any UVT
- UV reactor design should consider lowest expected UVT
- Rough rule of thumb: For every 5% decrease in UVT, 50% reduction in UV dose (*i.e.* Need to build 2X the UV system!)

UV Transmittance (UVT)



Fouling



From Jim Malley, IUVA website

Fouling

- Caused by minerals that accumulate on quartz sleeve (*i.e.* hard waters have greater fouling potential)
- Blocks the light
- Will occur in any water
- Hardness < 100 mg/L as $CaCO_3$ = “slow” fouling
- Iron can be a problem (*e.g.* 0.5 mg/L iron may require chemical cleaning every few days)
- Good news: Can always be controlled using existing lamp cleaning technology (mechanical/chemical)
- (Clean the sensors too…)

Turbidity

- No direct correlation with UV effectiveness in the drinking water context
- Turbidity = scattering. Scattered light can still disinfect
- Turbidity = particle enmeshed organisms
- To forbid UV for turbid waters implies another disinfectant works better with turbidity
  - No good data substantiating this
- Turbid waters may be most in need of multi-barrier disinfection (e.g. some form of filtration before UV)
- Turbidity does affect UVT, which should be accounted for in the design (by measuring UVT)

UV Basics: ‘Take-Home Messages’

- UV is a very effective disinfectant, but not a panacea
- UV handles protozoa and bacteria easily at typically applied doses; some viruses may require higher doses
- UV is not an ‘install and forget’ technology
- Water quality matters
- Pre- and post-treatment may be necessary