

# Pathogens in Water

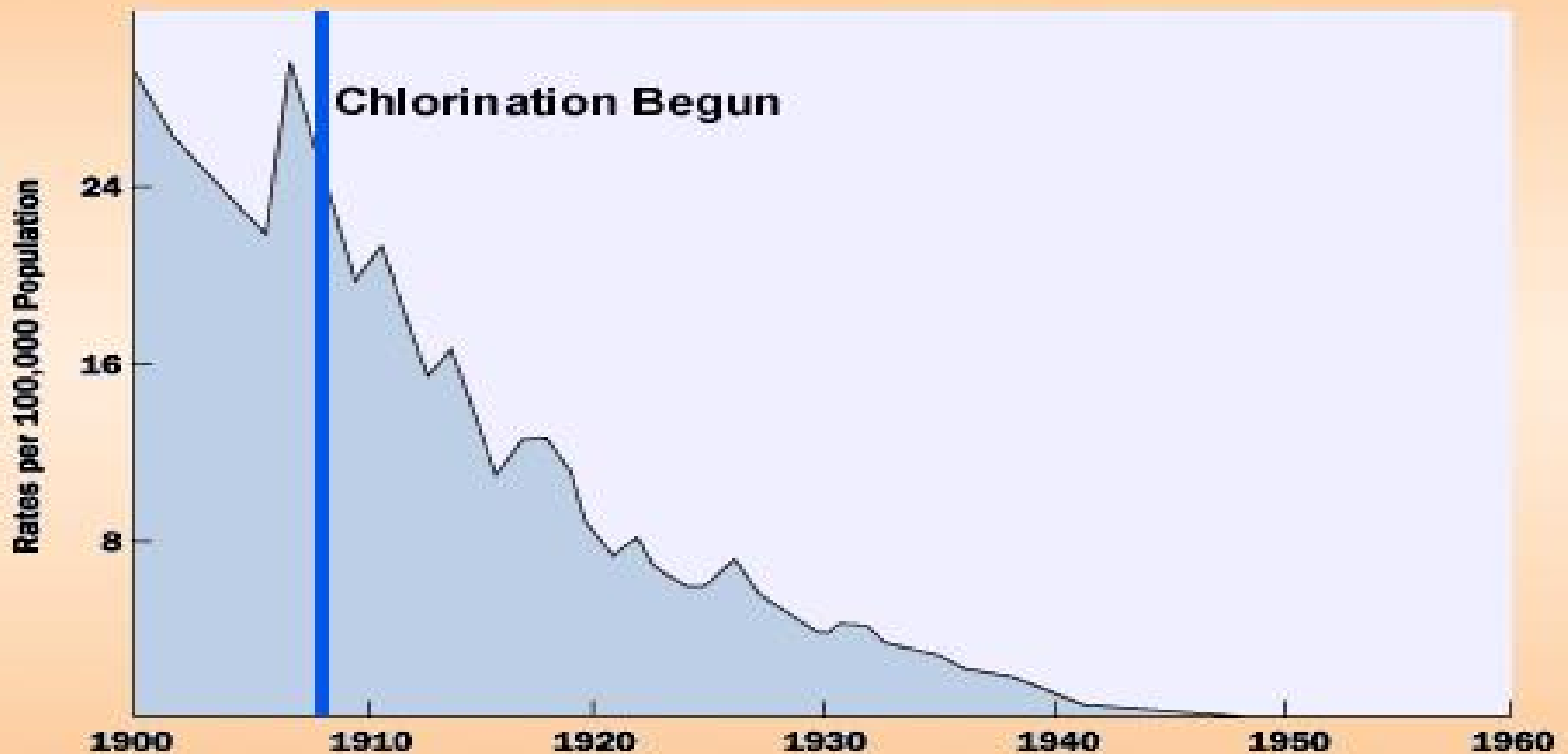
National Water Summit, Tuesday, 2nd October 2007

## Monitoring, Control and Technologies Available for Treatment

Prepared by;  
Paul O'Callaghan M.Sc.  
Dr. Hans Gethke

*Filtration of drinking water and use of chlorine  
“ - the most significant public health advance of the millennium.”*

## Death Rate for Typhoid Fever United States, 1900-1960



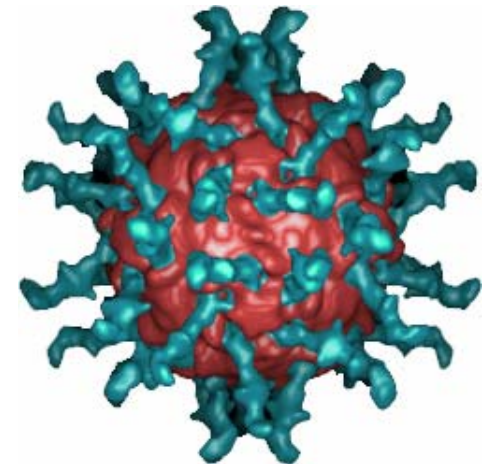
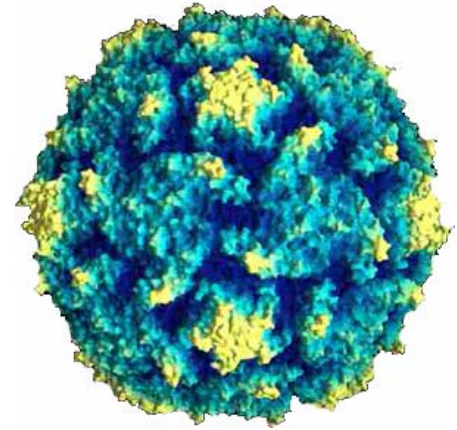
Source: U.S. Centers for Disease Control and Prevention, Summary of Notifiable Diseases, 1997.

# Presentation Structure

- Pathogens
  - Introduction to different types and classes
  - Some emerging pathogens of concern
  - Challenges in detection and monitoring
- Disinfection Technologies
  - **Membrane Filtration**
  - Ozone & Chlorination
  - **Ultraviolet Light**

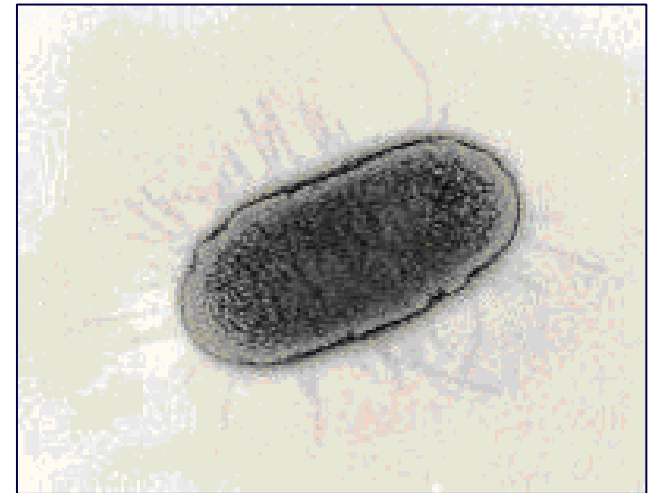
# Viruses

- Very small : 0.02 – 0.09  $\mu\text{m}$
- Difficult to detect
- Not routinely monitored
- Pathogens:
  - Polio
  - Hep A
  - Norwalk
  - Adenovirus
- Faecal coliforms are good indicators
- Chlorine is an effective disinfectant



# Bacteria

- Easy to carry out routine tests
- Routinely monitored
- Faecal coliform test a good indicator of bacterial contamination
  - Detected in 91% of cases where bacteria are cause of illness



# Protozoa

- *Greek for 'little animal'*
- Pathogens include
  - *Cryptosporidium*
  - *Giardia*
- 1976 : First discovered that *Cryptosporidium parvum* caused illness in humans



## Oocyst

- Resistant to Chlorine
- Can survive for months in cold damp environment
- 4-6μm in diameter

# Cryptosporidium Outbreak

## Milwaukee, Wisconsin, USA

- 1993 : Milwaukee, Wisconsin, USA
  - 400,000 people became ill
  - 4,300 were hospitalised
  - 50 people died
  - Single largest outbreak of illness since record keeping began.

# Detecting and Monitoring Protozoa

## 1. Complex Analysis Procedure

- Large volume filtered
- Utilizes Immunofluorescence & Molecular Biology Tools
- Genotyping required to determine sub-species

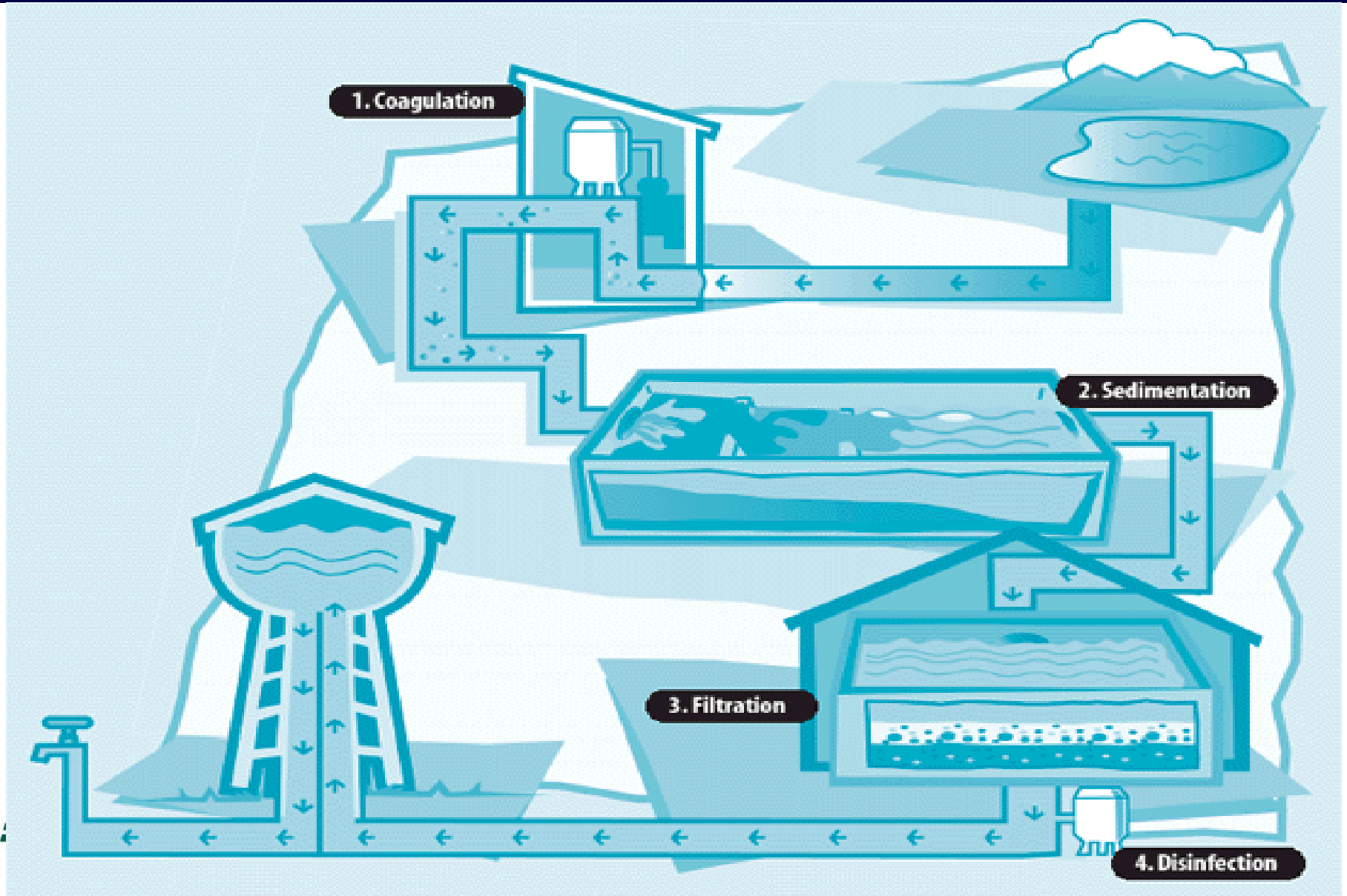
## 2. Not routinely monitored

- Very little historical data
- Test results may follow an outbreak

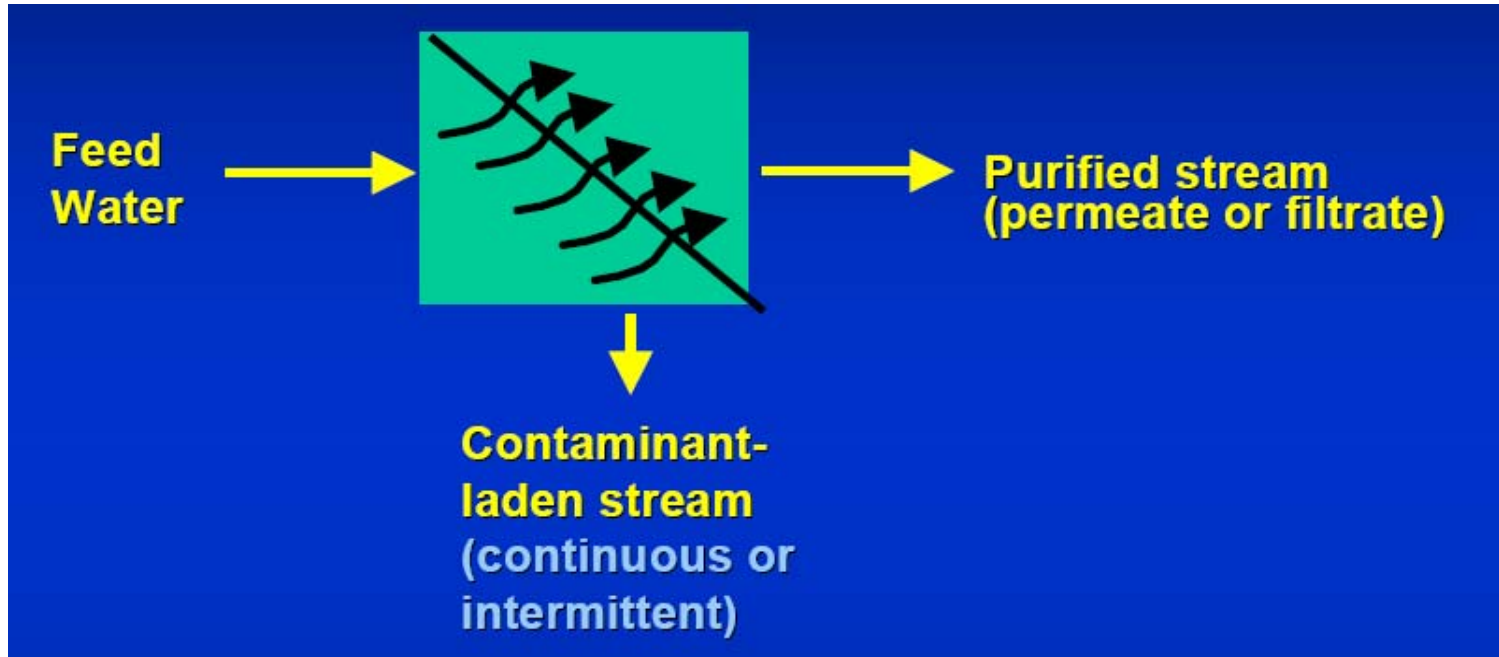
## 3. Traditional indicators not adequate

- In 51% cases of Protozoan illness in US, water tested negative for Faecal coliforms

# Water Treatment Process



# Membrane Filtration Systems



- Physical Separation Process
- Removes Pathogens from water

# Membrane Systems : Classification

## Microfiltration

0.1 – 10 $\mu$ m



## Ultrafiltration :

0.01 $\mu$ m – 0.1  $\mu$ m



## Nanofiltration

0.001 – 0.01 $\mu$ m



## Reverse Osmosis

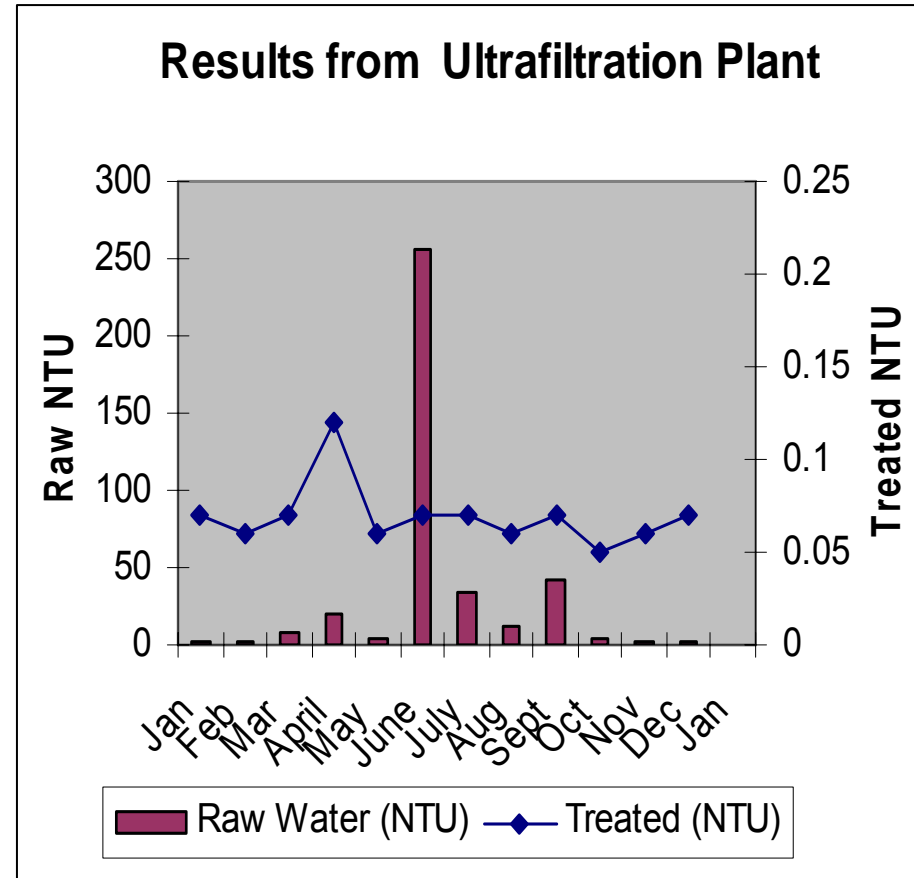
< 0.001 $\mu$ m



# Membranes - Final Water Quality Independent of Influent Quality



*Hollow Fibre Module*



# Membranes : Specifying a Membrane System

## 1. Membrane Flux

- How much water you can treat for a given pressure

## 2. Membrane Material

- Organic Polymer : e.g. PVDF, Polysulfone
- Ceramic Materials : e.g. Titanium Dioxide
- Varying resistance to pH, Fouling  
Oxidising chemicals and Temperature.

## 3. Pore Size

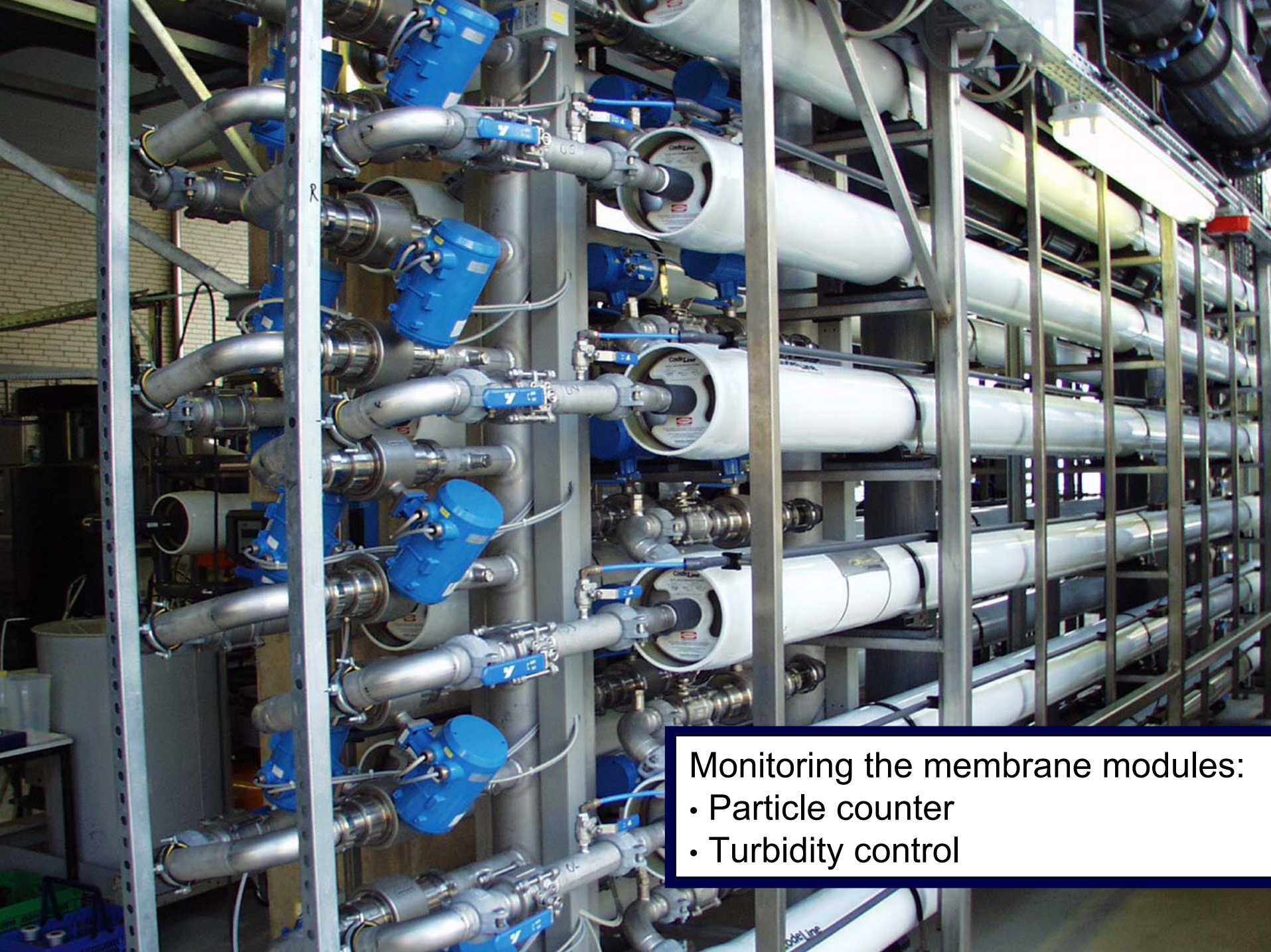
## 4. Membrane Type

- Inside-out/ Outside-in
- Spiral wound, Tubular, Hollow Fibre, Plate
- Cross-flow / Dead-end flow



# Membranes : Factors Affecting Effectiveness

- Membrane Integrity
  - On-line Particulate and Turbidity meters important
  - Air pressure testing
  - Sonic leak detection
- Fouling
  - Gradual decrease in flux / increase in pressure
  - Result of Particulates, Organic Fouling and Biofouling
  - Controlled by back-washing & chemical cleaning
- Resistance of membranes to
  - pH
  - Oxidising Agents
  - Temperature

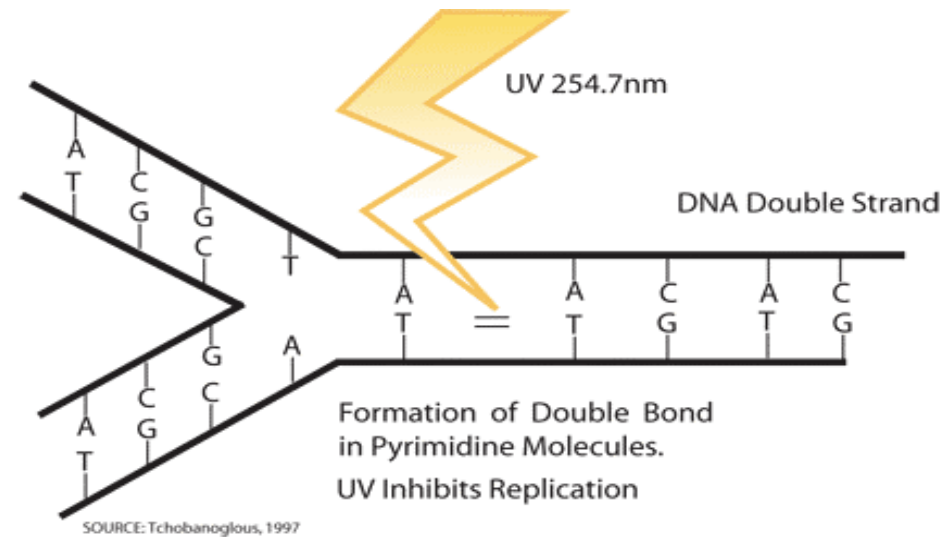


Monitoring the membrane modules:

- Particle counter
- Turbidity control

# Ultraviolet Light

- Inactivates organisms
- Does not destroy organisms
- Absorbed by DNA and RNA
- Inhibits the ability of micro-organisms to replicate
- Most effective wavelength is at 265nm



# Ultraviolet Light: Specifying a UV System

## Specification :

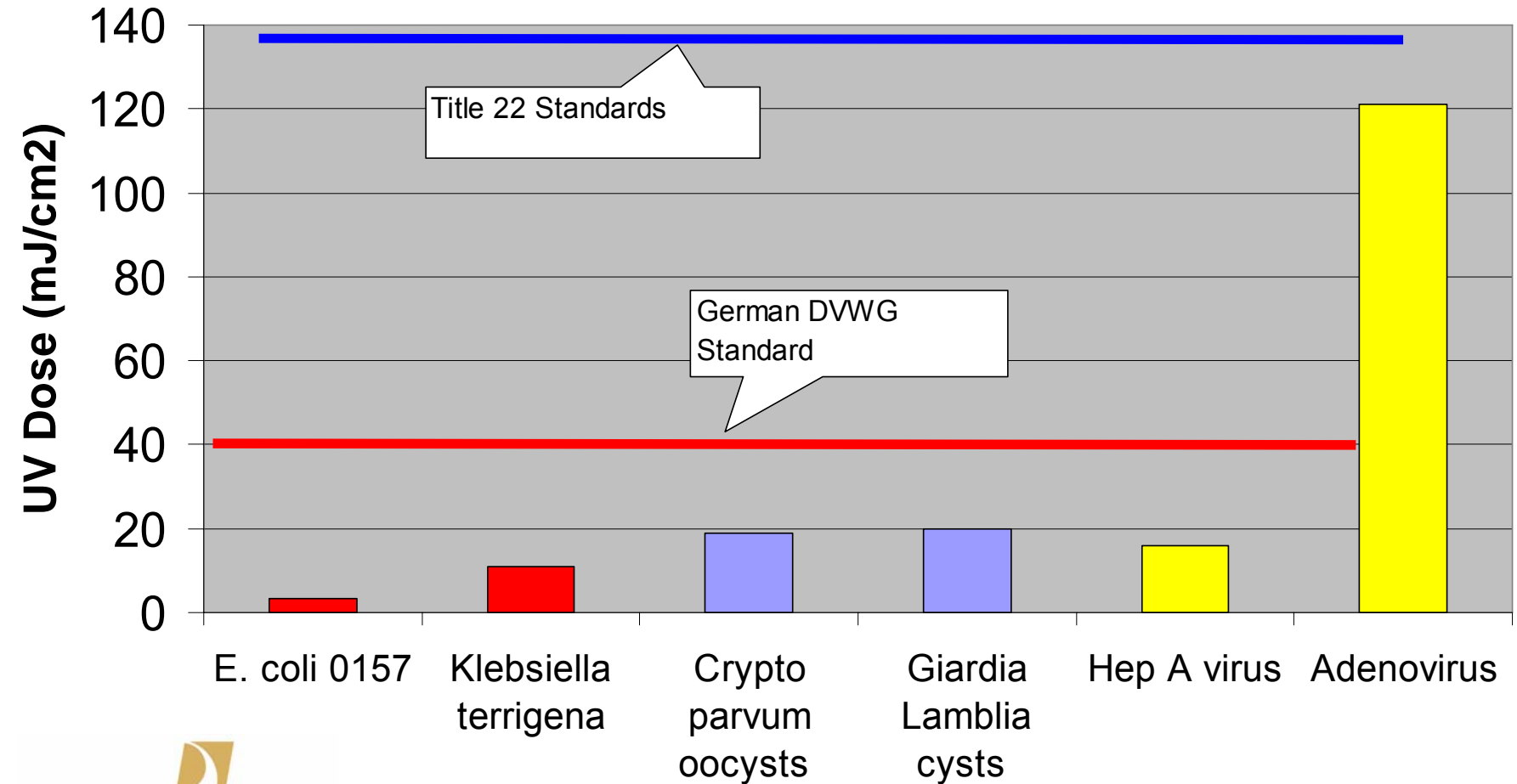
1. Independent validation essential
2. What is the UV Transmittance of the water being treated:
  - *10% decrease in UVT can double size of system!*
3. What Log reduction / % Removal are you going for?
4. What organisms are you targeting?

# Ultraviolet Light: Factors Affecting Effectiveness

1. UV Transmissivity (UVT)
  - Turbidity
  - Total Suspended Solids
  - Iron
  - Dissolved organic material, 'exotics'.
2. Lamp fouling
3. Lamp Failure
  - Starts and stops can void warranty.
4. Temperature
  - Output is less in cold water

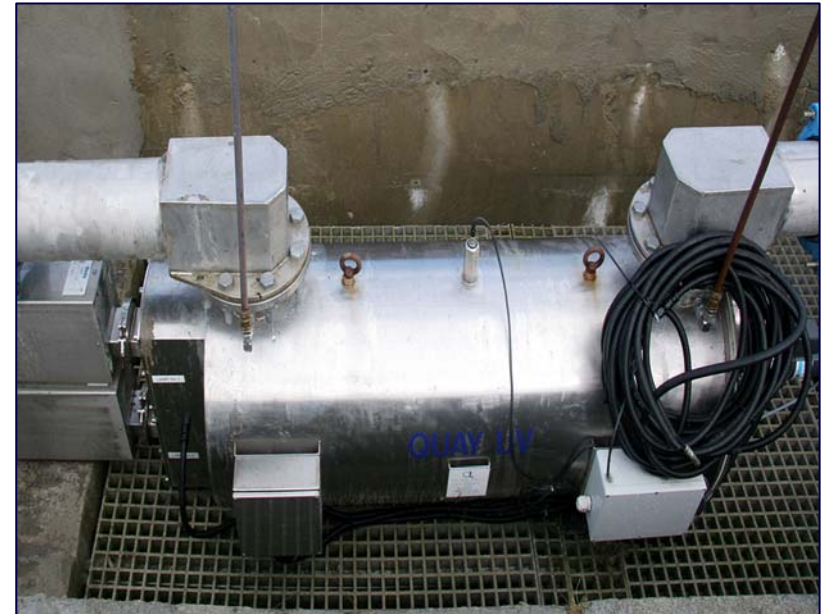
# What UV Dose is required to inactivate Cryptosporidium?

*UV Dose Rates Required for a 4 log reduction (99.99%)*



# Microwave UV, Doonbeg WWTP, Co. Clare

- Uses Microwave Energy to generate UV
- First of its type in Ireland
- Size of the plant :1,500p.e.



# UV Installation at Terryland WTP, Galway

- UV Plant installed July 2007
- Medium Pressure system
- 2,500 m<sup>3</sup>/hour
- Design dose = 40 mJ/cm<sup>2</sup> @ 85% UVT.
- 4.1 NTU Maximum.



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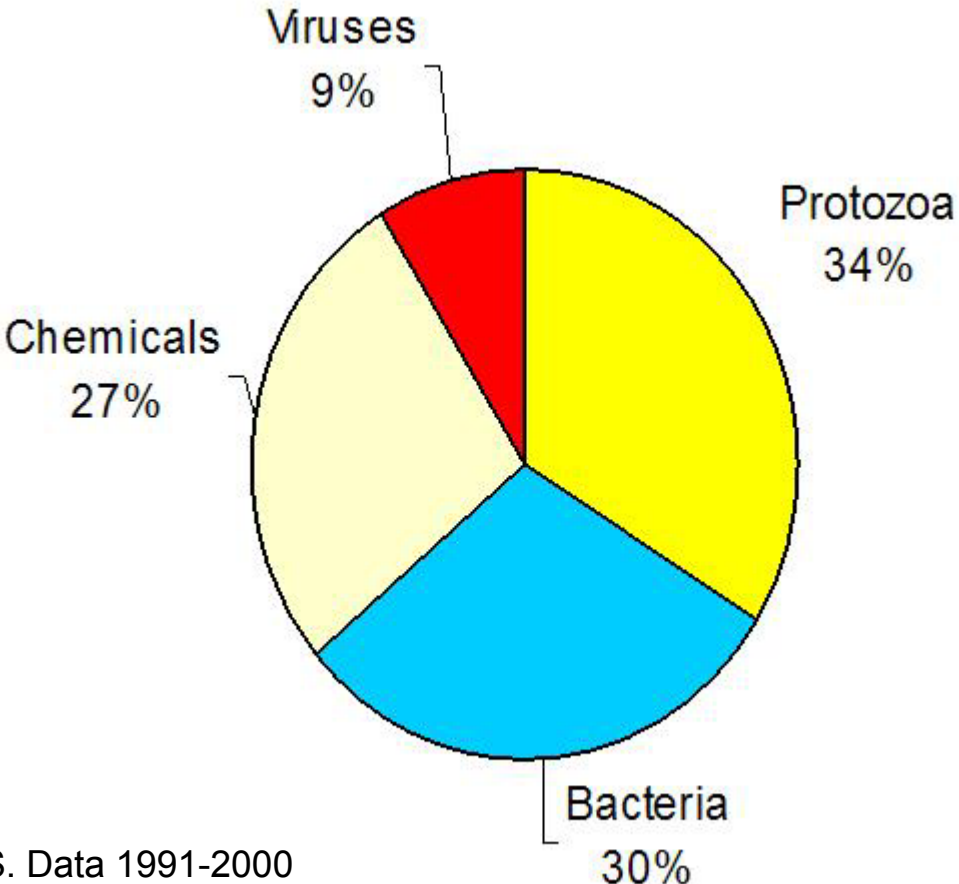


# Concluding Remarks

## ***“Working towards a sustainable future for Ireland’s water needs”***

- New challenges in drinking water treatment require new management techniques
- Treatment and disinfection is one part of the multi-barrier approach
- New technologies available require understanding of new concepts and terminology
- Specification important to get the product that best meets your requirements

# Breakdown of Causes of Waterborne Illness\*



Viruses	
Norovirus	6%
Hep A	2%
Others	1%

Protozoa	
Cryptosporidium	12.6%
Giardia	21.4%

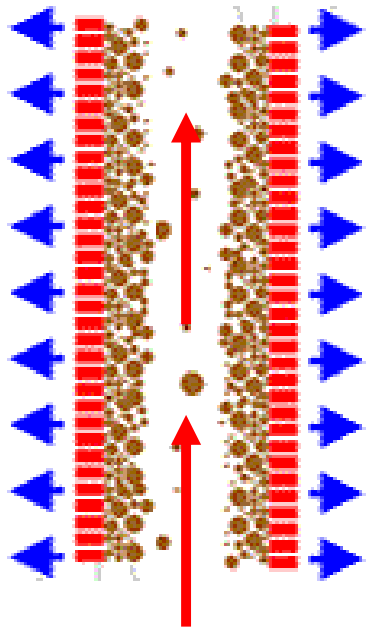
Bacteria	
E.coli	9.6%
Shigella	8.7%
Campylobacter	5.7%
others	6%

\* U.S. Data 1991-2000

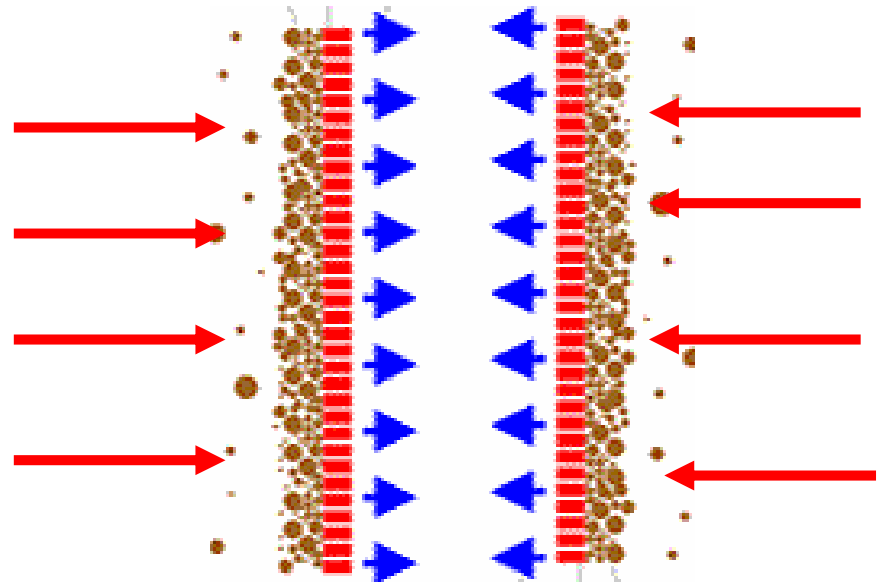
# Comparison of Treatment Processes

Process	Microorganism					
	Non-attached suspended			Attached to particles from Faecal sources		
	bacteria	viruses	parasites	bacteria	viruses	parasites
<b>Filtration</b>	+	+	+	+	+	+
<b>Disinfection</b>						
Chlorine	+	+	-	-	-	-
Chlorine dioxide	+	+	-	-	-	-
Ozone	+	+	+	-	-	-
UV	+	+	+	-	-	-
<b>Thermal (&gt;90 C)</b>	+	+	+	+	+	+

# Membrane Flow : In-side-out & Outside-In



*Inside - Out*



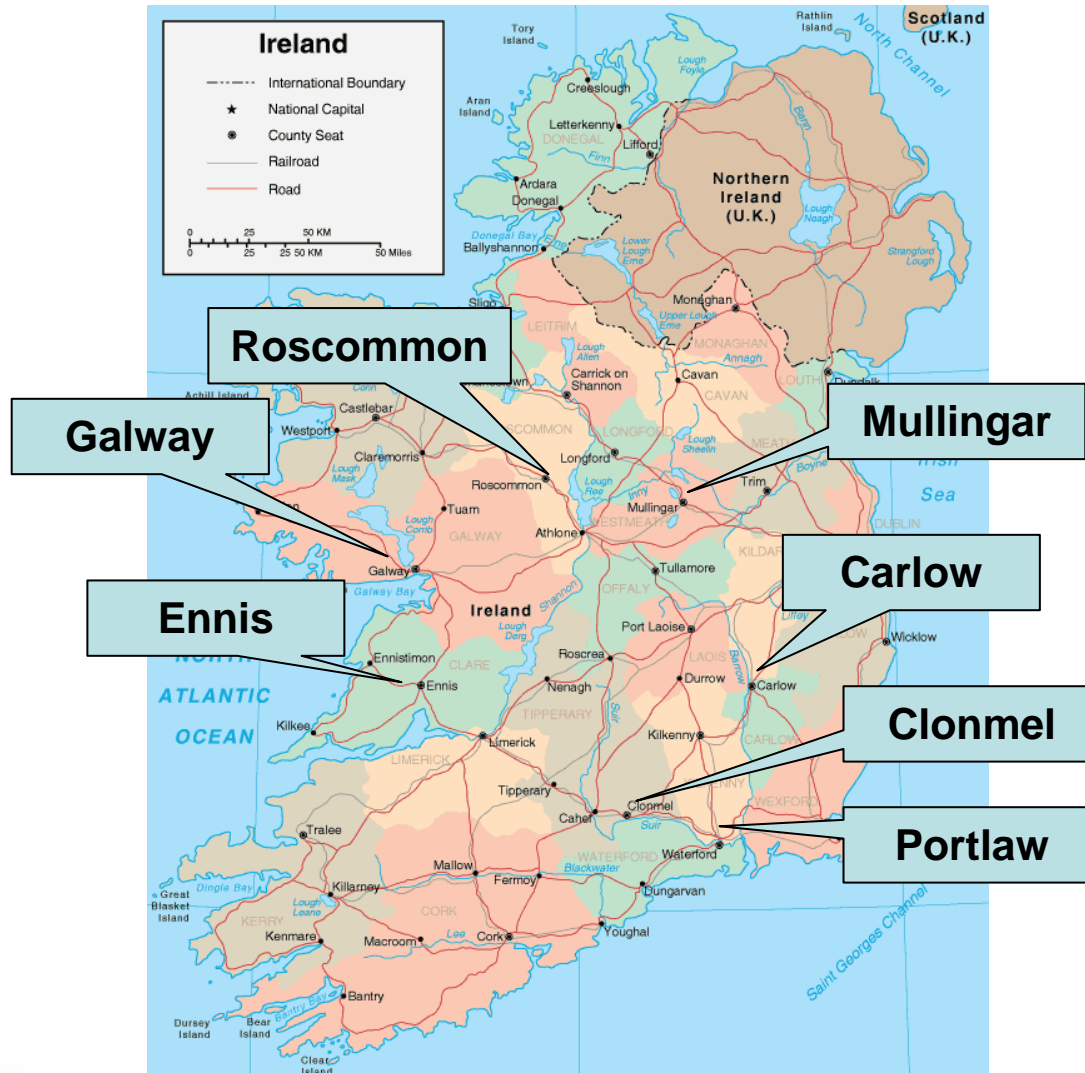
*Outside - In*

# Ultraviolet Light : Types of Systems Available



- Medium Pressure
  - Electrode lamp
  - Higher energy output
  - Polychromatic
- Low Pressure
  - Electrode lamp /Microwave lamp
  - Lower energy output
  - Monochromatic output at 265nm

# Cryptosporidium Incidents Linked To Water Supply In Ireland



# Chlorine Dioxide

- **More stable than other forms of chlorine**
- **Disintegrates biofilms in distribution systems**
- **No production of chlorinated by-products**
- **No change of odour and flavour characteristics**

# Ozone

- A strong oxidizing agent
- Effective against Cryptosporidium and Giardia
- Can be generated on-site
- Removes colour, taste and odour
- Useful for emerging contaminants

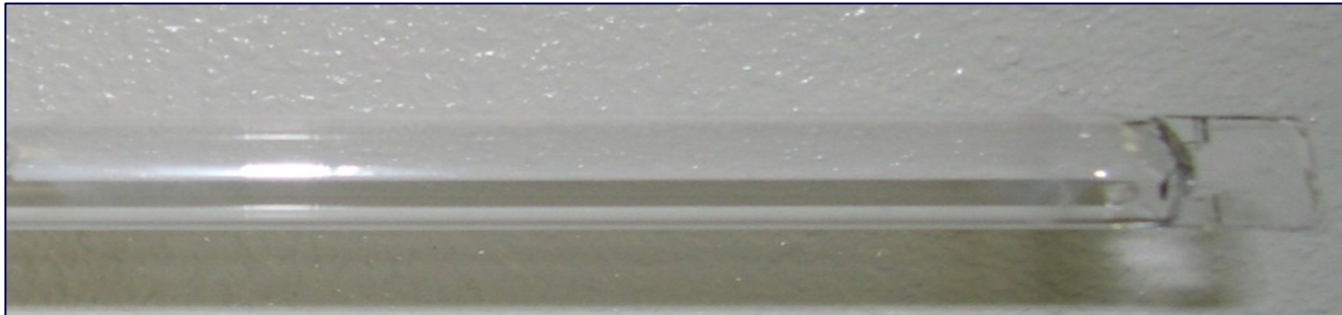


*Ozone Treatment at Cahirsiveen*

# UV : Comparison Of Electrode Lamp & Microwave Lamp

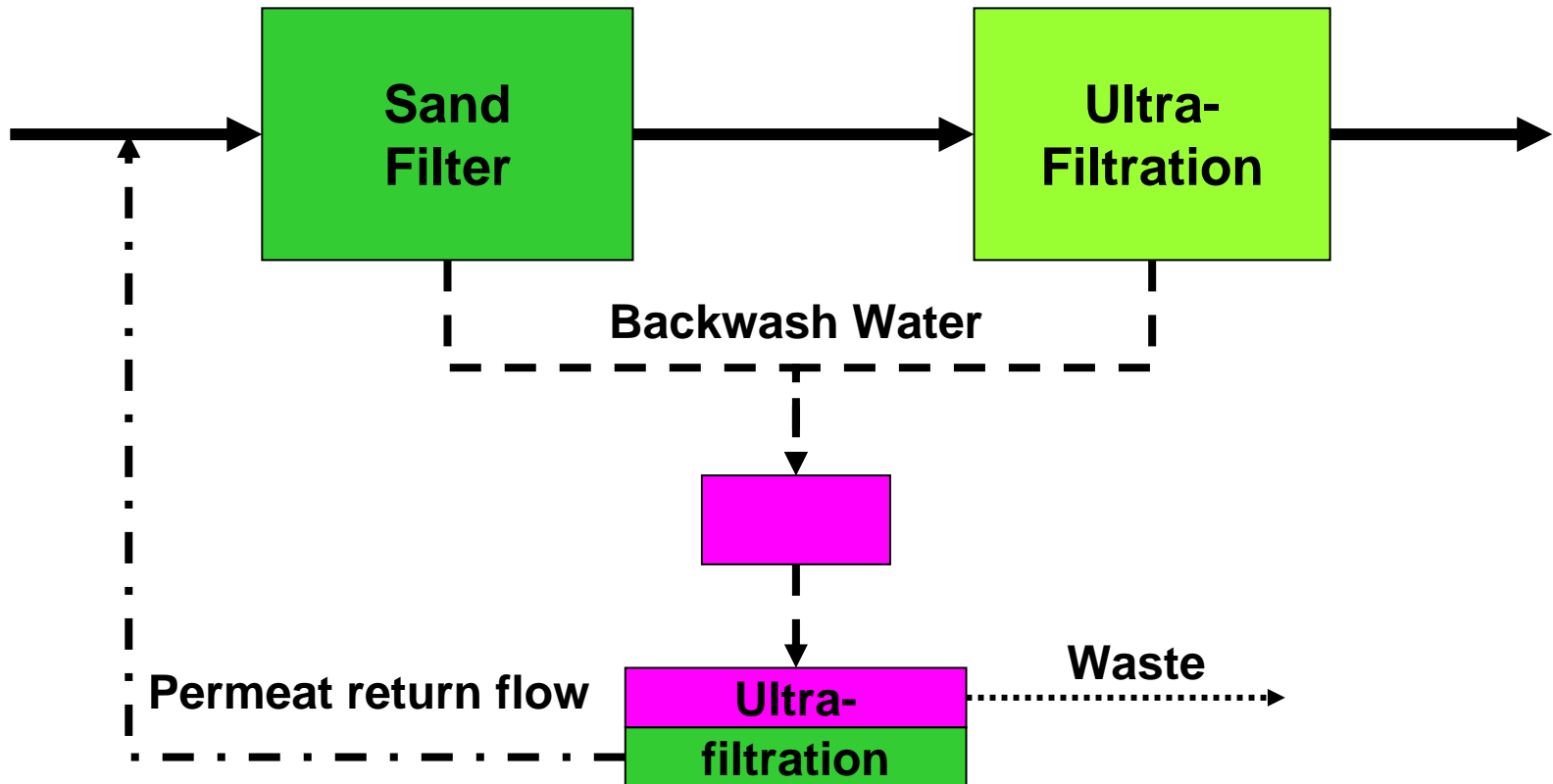


Electrode  
Lamp



Microwave  
Lamp

# Membrane stages for specific applications: membrane filters for treatment of backwash water



**total efficiency of the treatment plant:  
99 %**