Bob Ward
Alex Mofidi

Perspectives on the use of

SURFACE WATER

as a Drinking Water Source

PNWS-AWWA May 4, 2011

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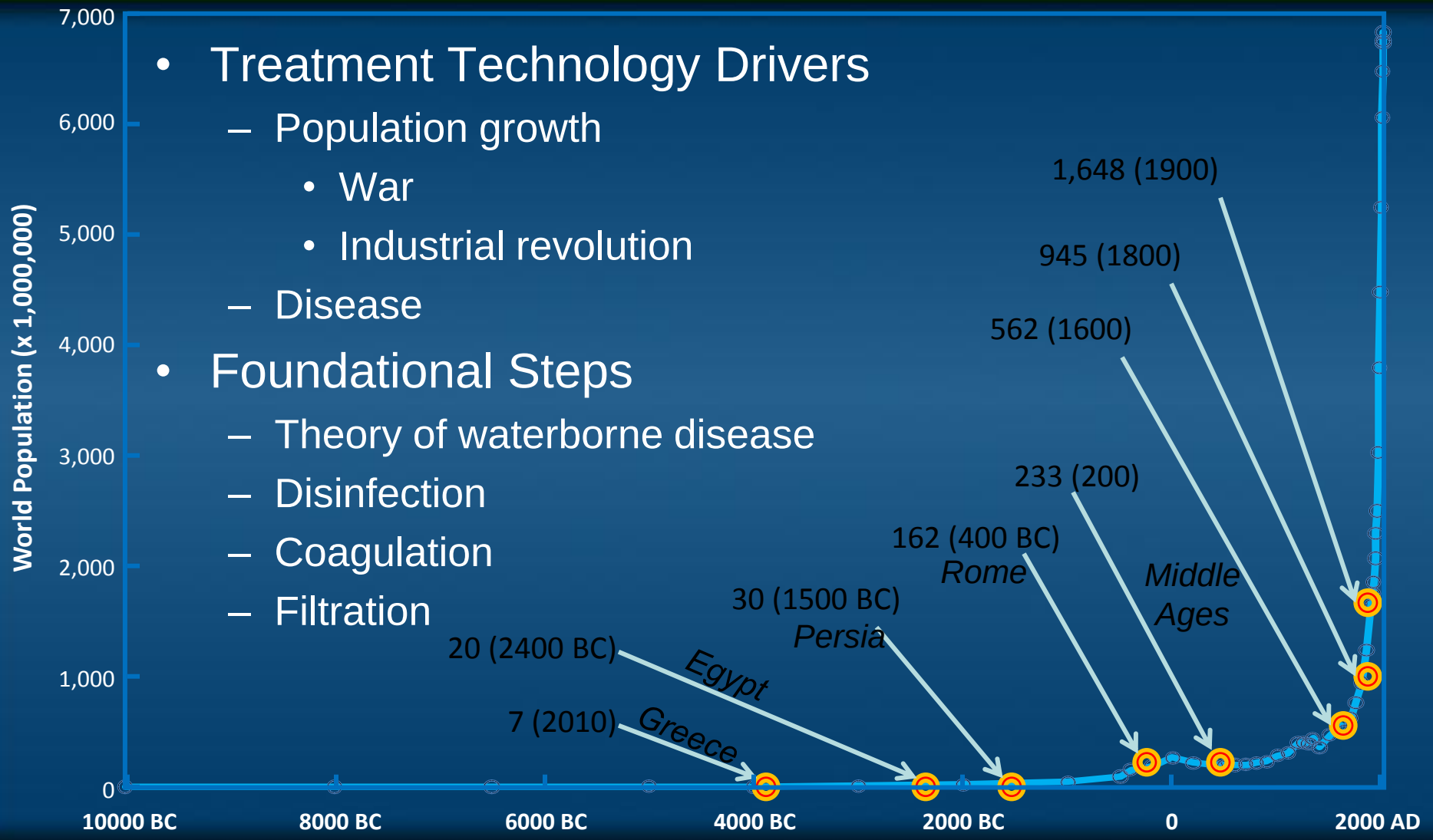
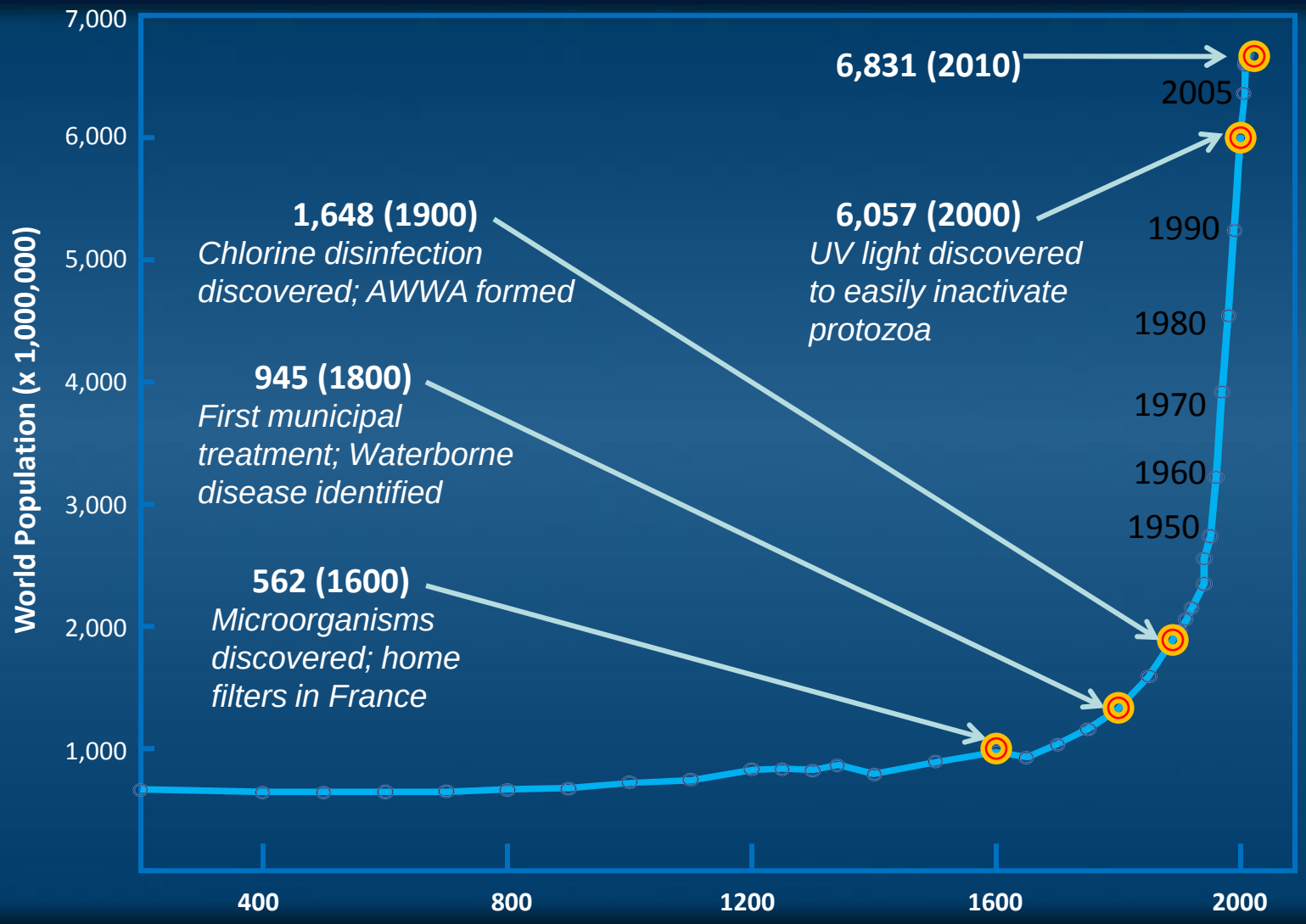
History of the World

- Treatment Technology Drivers
  - Population growth
    - War
    - Industrial revolution
  - Disease
- Foundational Steps
  - Theory of waterborne disease
  - Disinfection
  - Coagulation
  - Filtration



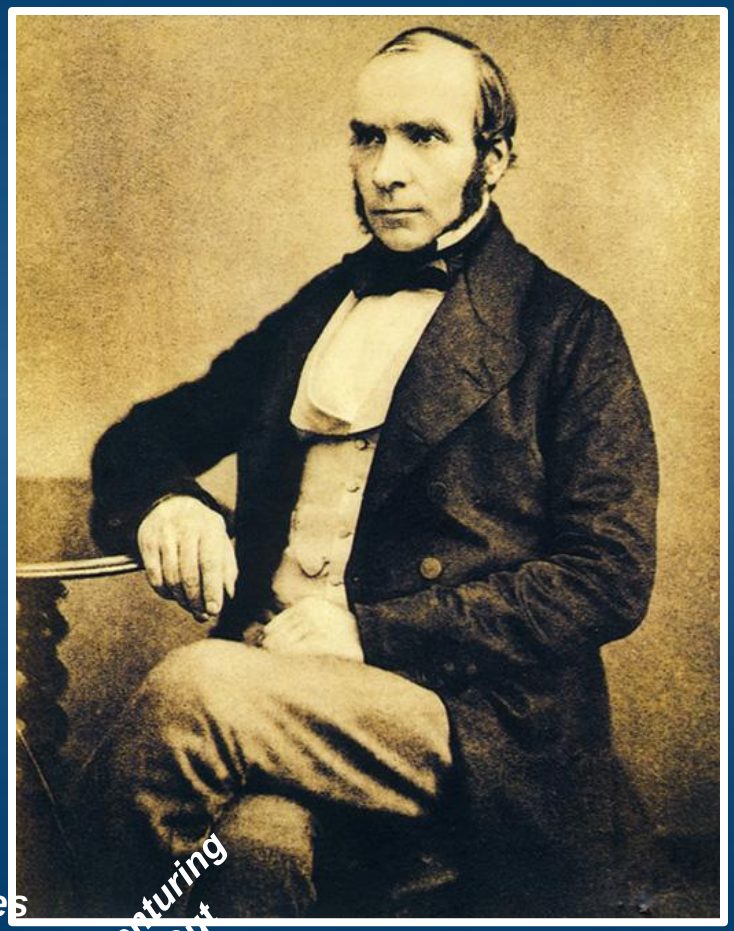
Exponential World Growth Rate

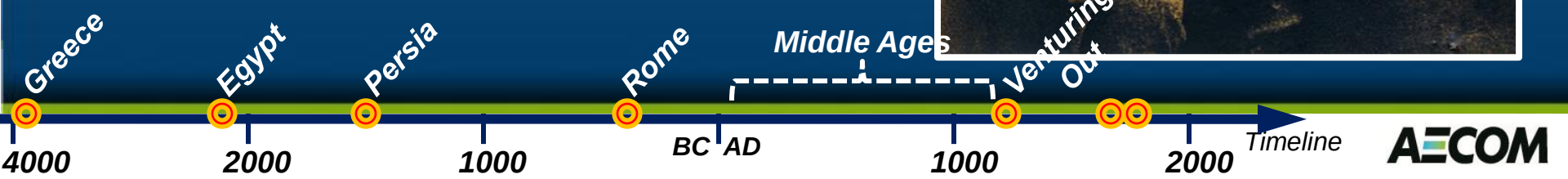


Scientific Development

- 19th Century Science
  - Epidemiology discovered
  - Linking disease with water
  - Discovery of microorganisms
  - Germ theory
  - Discovery of disinfection and the use of chlorine in hospitals

John Snow circa1850





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Joint Water Commission WTP

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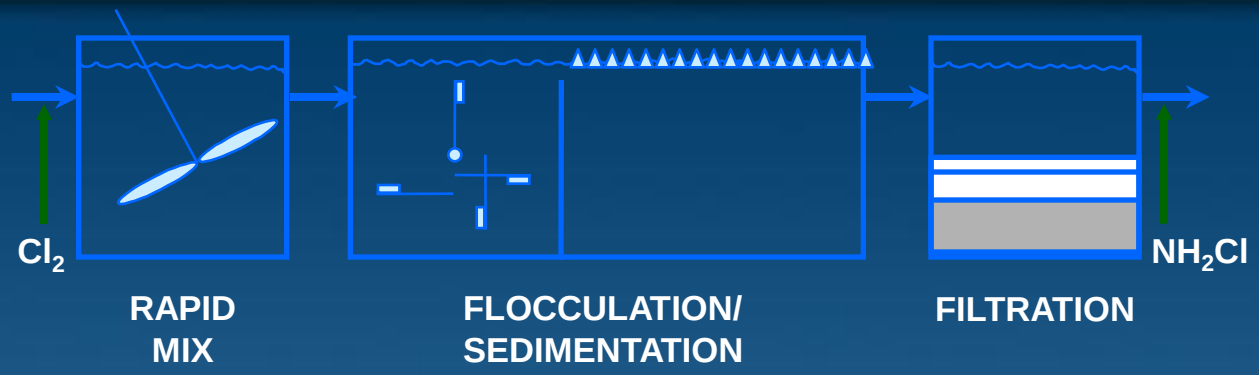
Treatment Issues Today

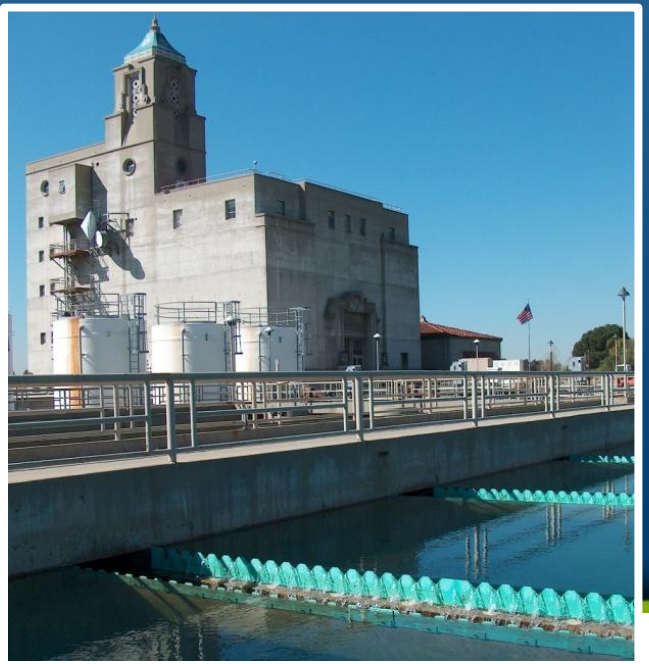
- LT 2 Compliance is a big reason. *Giardia*, *Crypto*, and future “bugs”

Future Disinfectant-Resistant Organisms

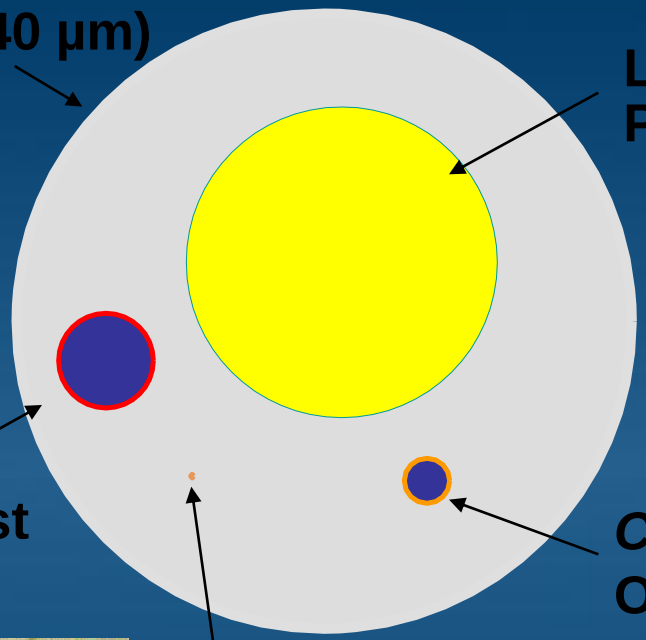
Surface Water Treatment Basics

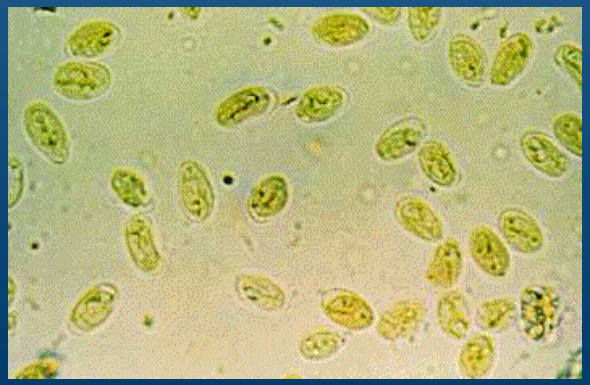


Settling (conventional)



Relative Sizes of Small Particles





Pressure versus Immersed Membranes

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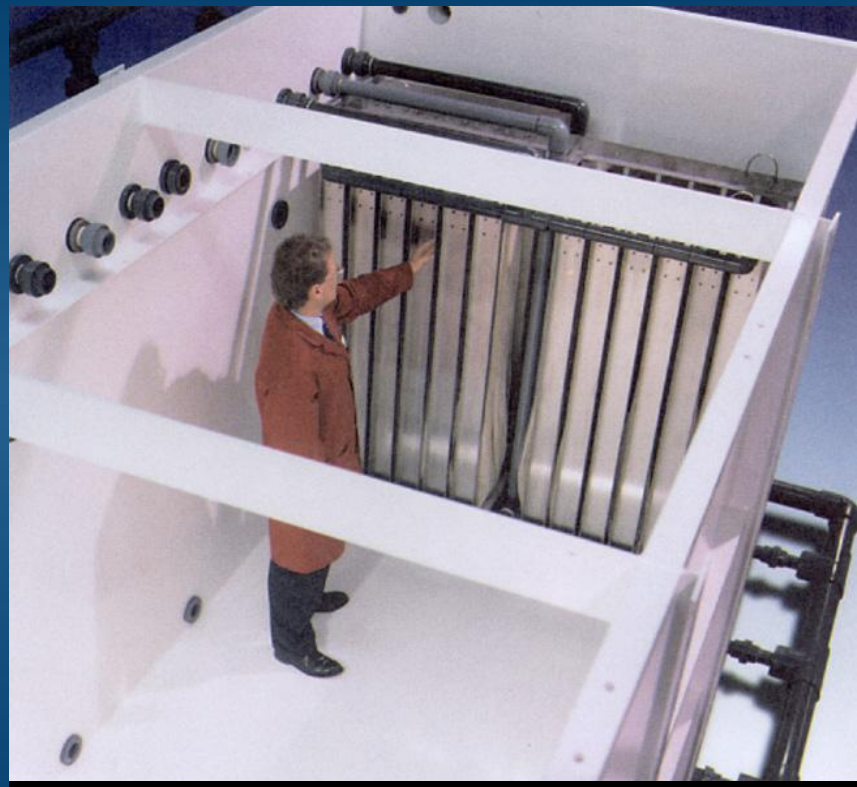

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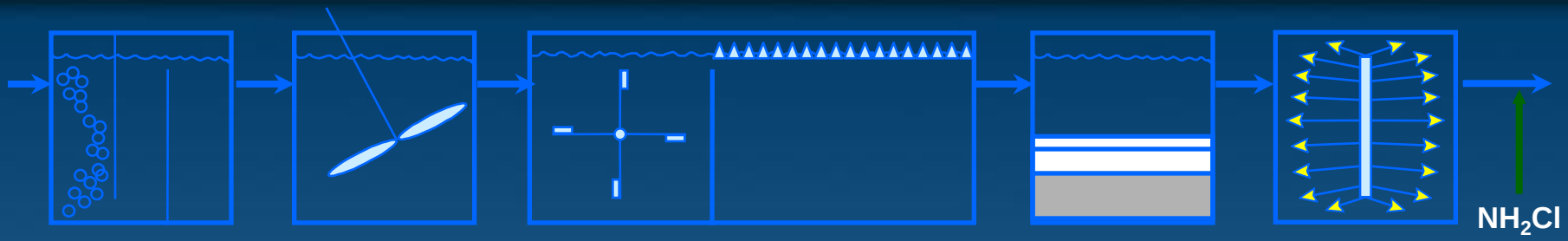
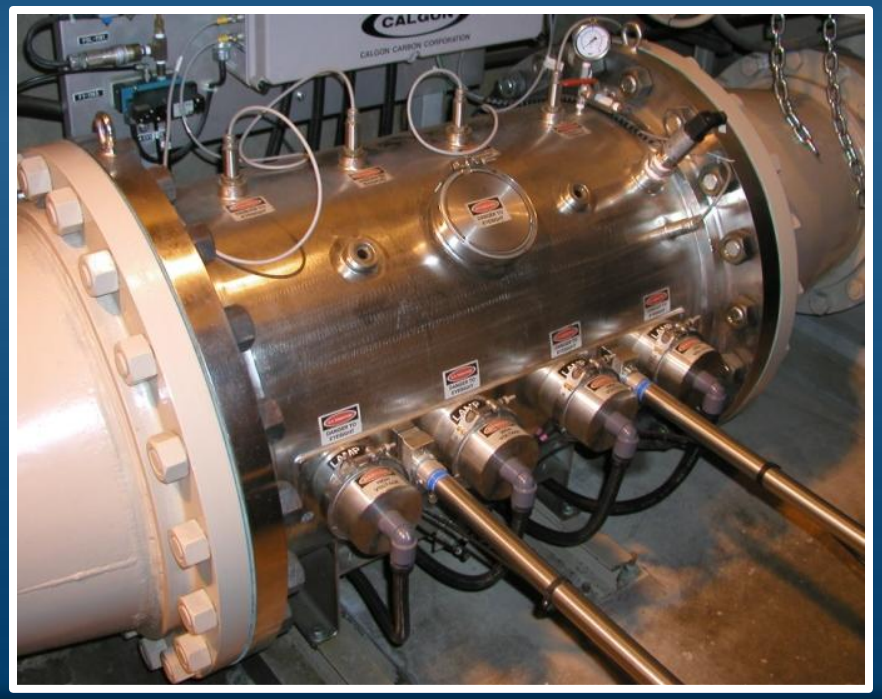
Surface Water Disinfection Advances



Pre Disinfection | RAPID MIX | FLOCCULATION/ SEDIMENTATION | FILTRATION | UV DISINFECTION

UV: Instantaneous (speed of light)



Ozone For Taste and Odor Control

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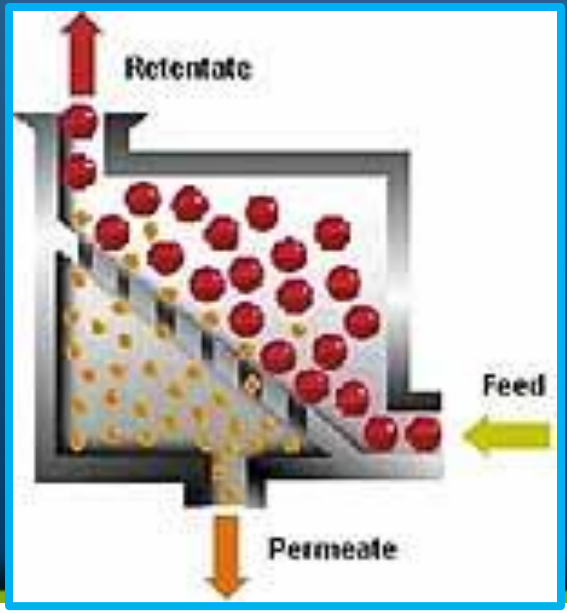
Surface Water Particle Removal Advances

- **Microfiltration / Ultrafiltration: Second(s), limited chemical use**



Civilizations Formed Around Water

- Importance
  - Quantity
  - Aesthetics
  - ‘Healthy’ sources
- Challenges
  - Natural contaminants
    - Turbidity
    - Algae

4000 2000 1000 BC AD 1000 2000 Timeline

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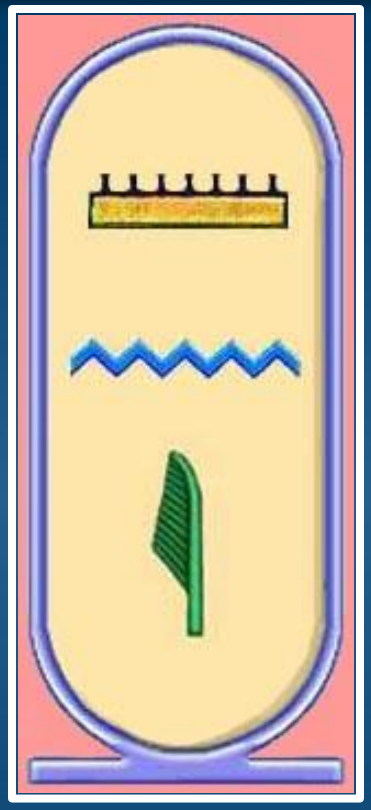
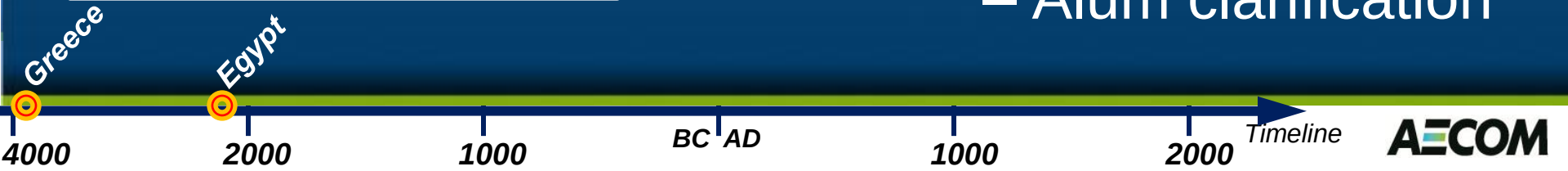
Improving Water Quality

- Ancient Greece
  - Boiling water, heated iron
  - Aeration basins
  - Charcoal, sand & gravel filters
  - Sunlight exposure



- Ancient Egypt
  - Alum clarification



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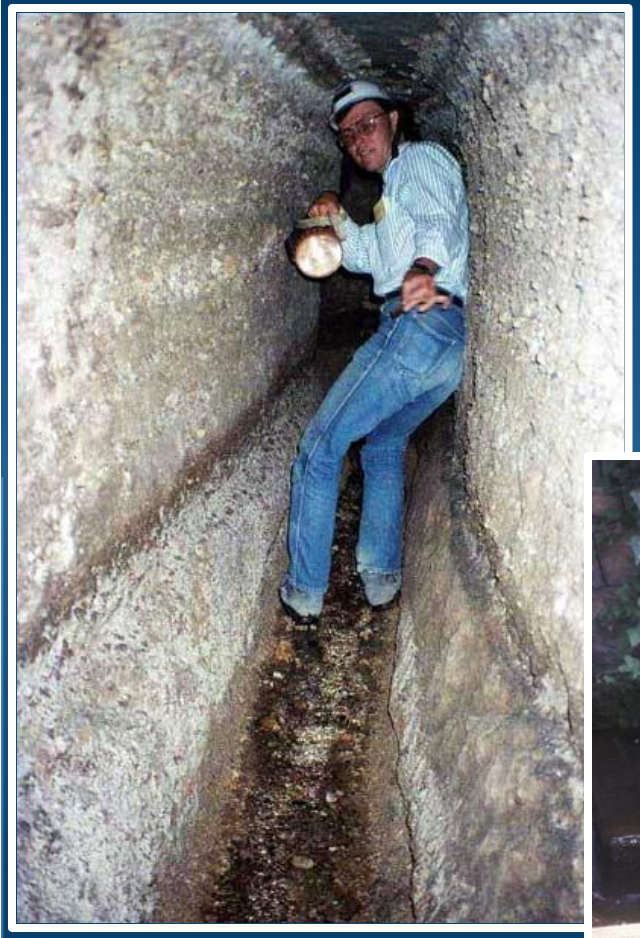
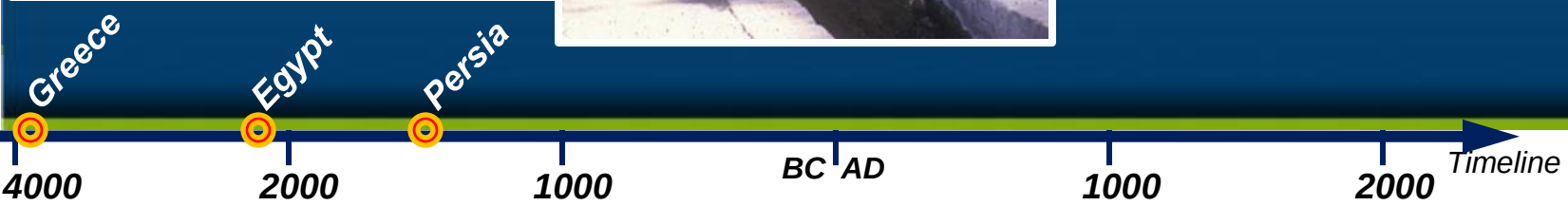
Bringing Water to the People

Ancient Persian Qanats (Underground aqueducts)



- Persia
  - Underground (Qanat) aqueducts



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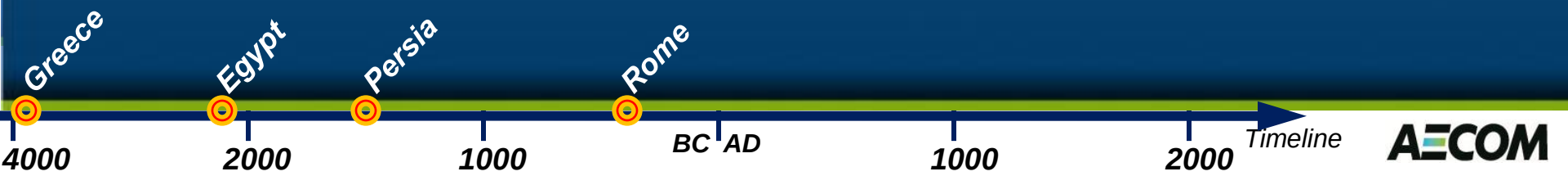
Bringing Water to the People

- Rome
  - 130 MGD aqueduct system

Ancient Roman above-ground aqueducts



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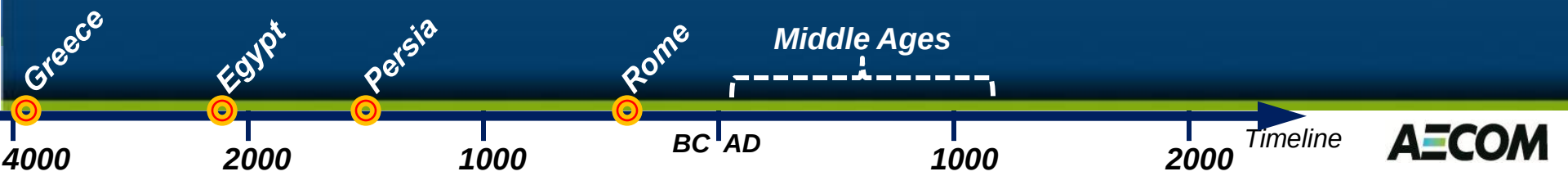
On the Heels of Invention….

Basilica Sant' Apollinare Nuovo
Ravenna, Italy
circa 500 AD

- Middle Ages
  - War and pestilence
  - Technology faltered
  - Hippocrates advocates boiling water with cloth straining



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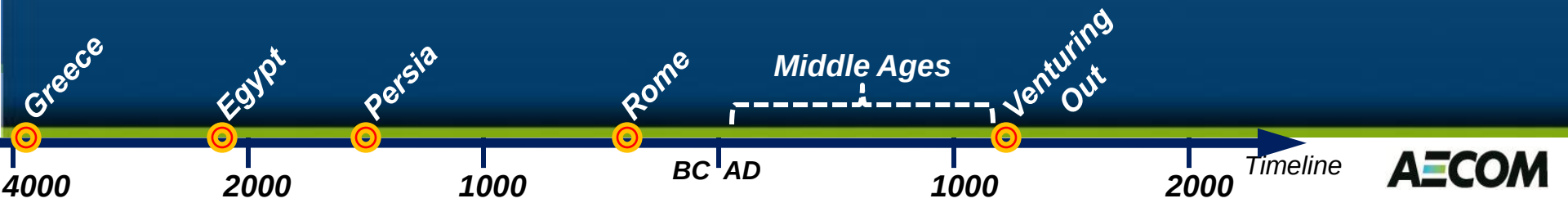
On the Heels of Invention….

Porous stone, used for water filtration circa 1000 AD

- "Venturing Out"
  - Escaping disease, war
  - 'Portable' Technology
  - Cloth and stone filtering



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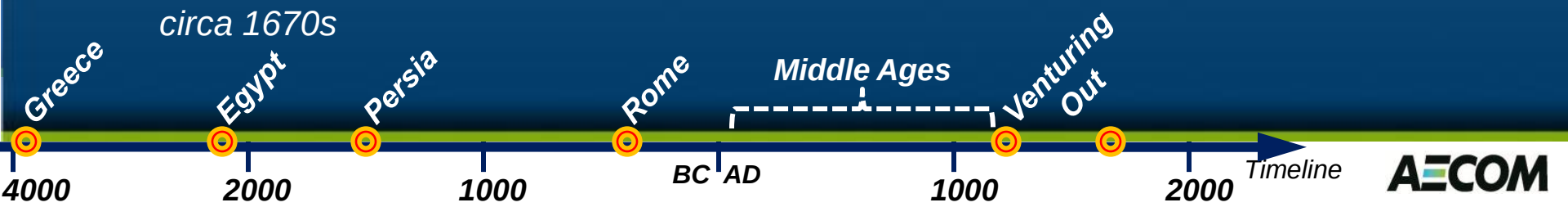
Modern Surface Water Advances

Leeuwenhoek microscope circa 1670s

- 17th-18th Century Europe
  - Microorganisms discovered
  - In-home water filters patented in France
  - Cities becoming larger
- 19th Century Scotland
  - First municipal treatment, distributed by horse & cart
  - Scottish regional piped distribution system



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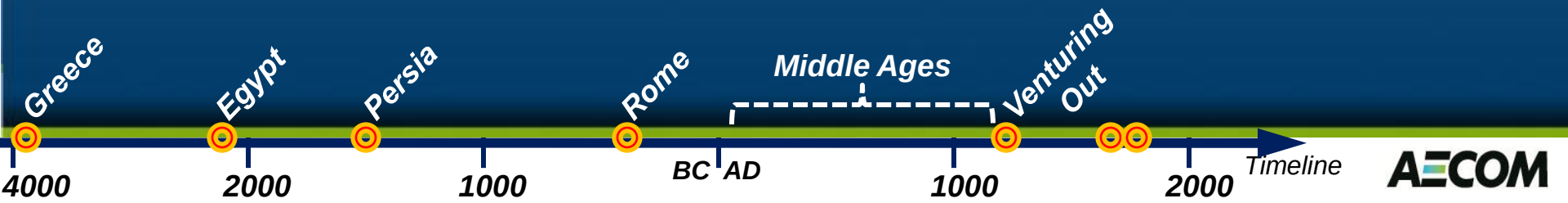
Modern Surface Water Advances

The FIRST piped water distribution system: Loch Katrine in Glasgow, Scotland, 1800s

- 17th-18th Century Europe
  - Microorganisms discovered
  - In-home water filters patented in France
  - Cities becoming larger
- 19th Century Scotland
  - First municipal treatment, distributed by horse & cart
  - FIRST regional piped distribution system



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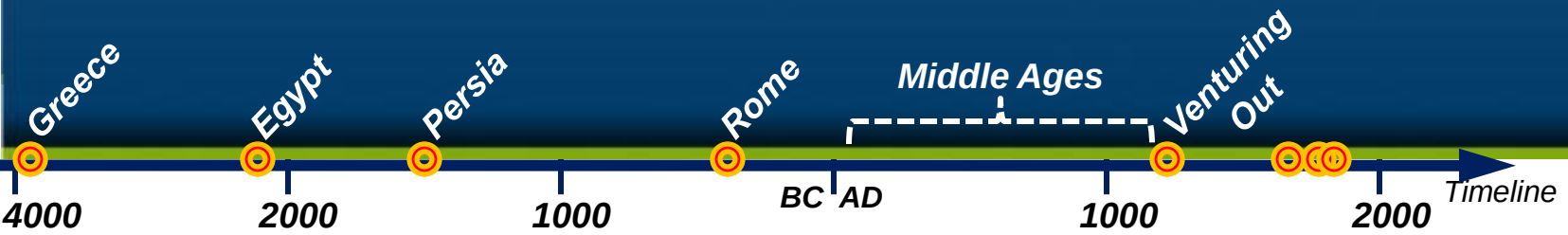
Technology Development

- 19th Century Technology
  - Poughkeepsie slow sand filter plant was a 'first' in America

Poughkeepsie WTP circa 1875



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US Regulations

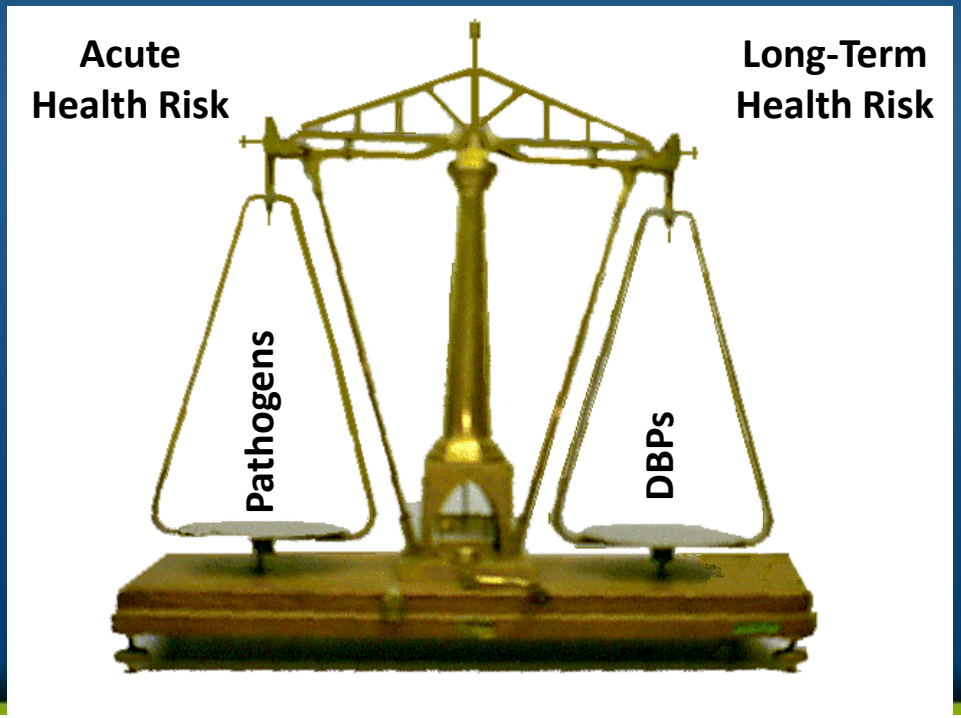
- Exponential U.S. Growth
  - 1893 Interstate Quarantine Act (USPHS created)
  - 1912: Common drinking water cup banned
  - 1914: Trains must show <2 coliforms /100 mL
  - 1925: First treatment regulation (softening)
    - Metals requirements (lead, copper, zinc)
    - Bacteria <1 coliform /100 mL

US Regulations, continued

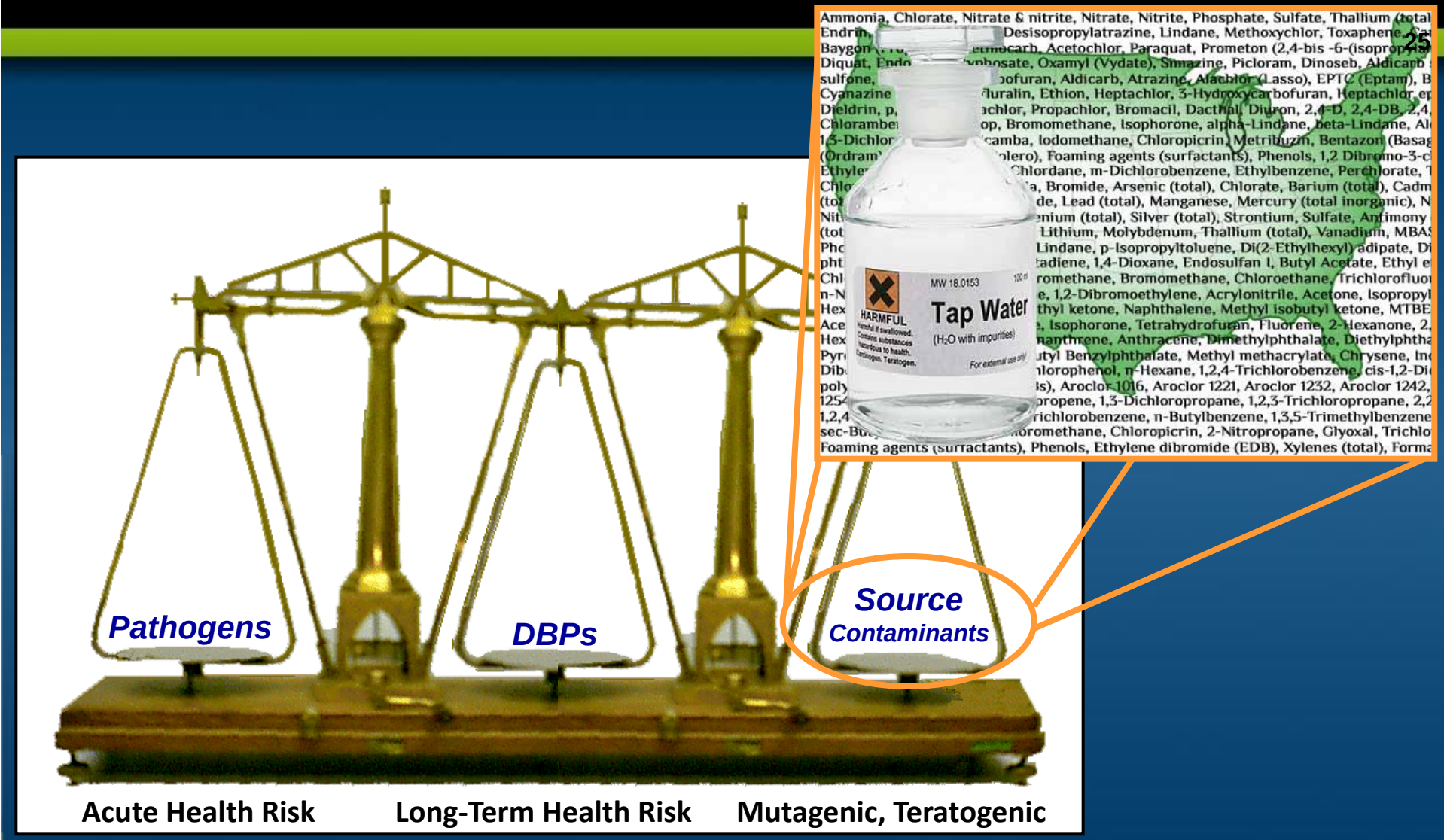
- 1946, 1962
  - Distribution system bacteria monitoring
  - Various chemical monitoring
- 1970: President Nixon Creates USEPA
- 1974 Safe Drinking Water Act (SDWA)
  - First legally binding standards
  - Systems >25 persons
  - ’75, ’76, ’79 (THMs), & ’80 amendments

US Regulations, continued

- 1986, 1989 SDWA Amendments
  - MCLs, MCLGs
  - Long-term health protection



S (Regulatory Soup, Science, Engineering)



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US Regulatory Change: Chronic Health?

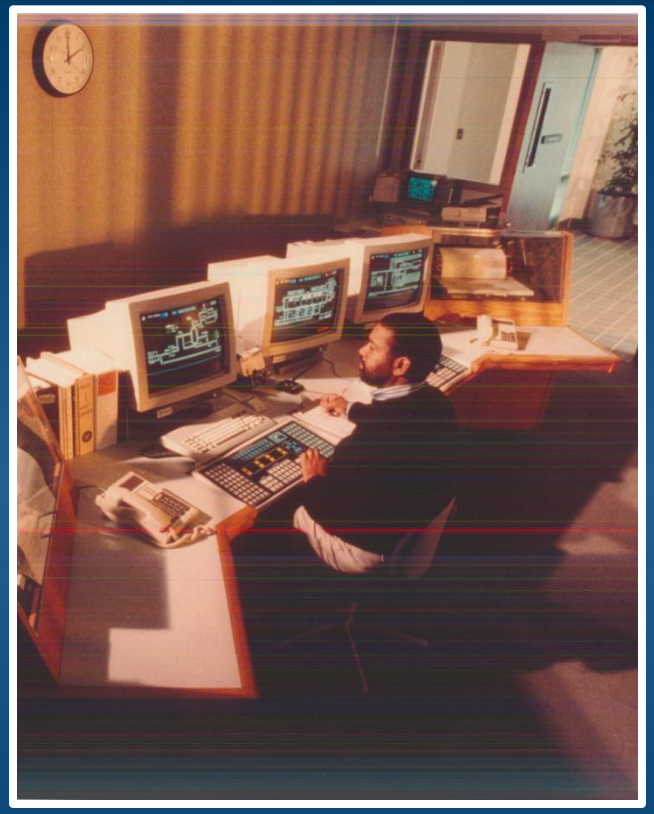
- Scientific Methods Finding Contaminants
  - Parts per million (mg/L, 1 drop/barrel)
  - Parts per billion (µg/L, 1 drop/tanker truck)
  - Parts per trillion (ng/L, 1 drop/football stadium)
- Engineering Advances
  - Biological processes
  - Ion exchange
  - Ballasted flocculation
  - More…
- Population Trends…….

Today's Discussion

- Emerging Issues
  - Drought & reuse
  - Contamination of sources

“Foundational” Conventional Treatment

- One-Size (Almost) Fits All
- Conventional Treatment
  - Pathogen disinfection
  - Particle destabilization
  - Particle and organics removal
- Variables
  - Chemicals
  - Engineering design
- ‘New’ Changes: Tailoring to Source Specifics



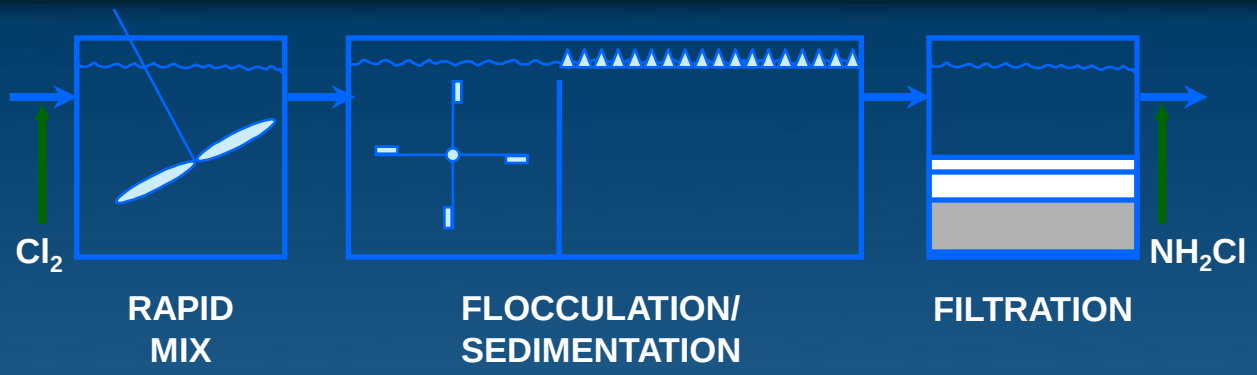
Treatment "Tailoring"

- Drivers
  - Contaminants
  - Aesthetics
  - Reuse
- Enablers
  - Digital technology
  - Energy / power
  - Funding
- 1st & 3rd World Inequality

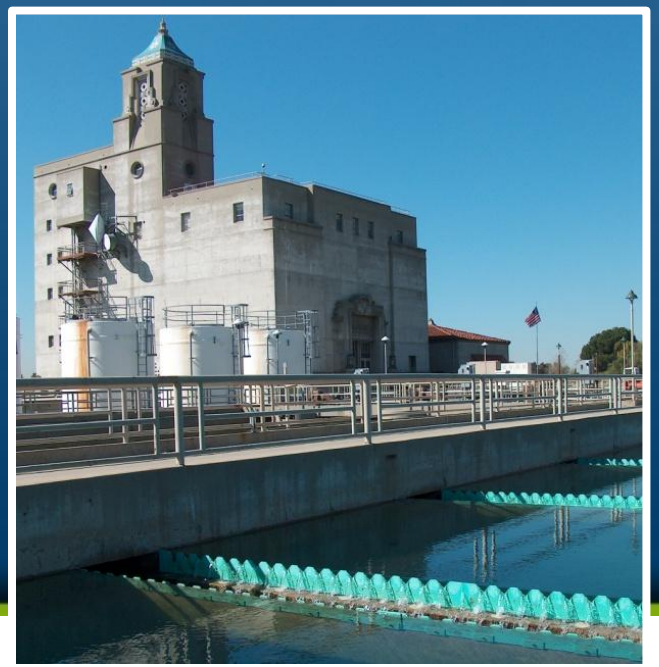
Drivers for Change: Contaminants

- Contrived (man-made)
  - Industrial and other produced chemicals
  - Ground, surface, and sea water (and polar regions)
  - Reservoir s (power generation, flood protection)
    - Nutrient loading / biostability
    - Algal by-products
- “Natural”
  - Interaction with animals, minerals, and insects
  - Climate change related
    - Extended Drought
    - Extended Flooding

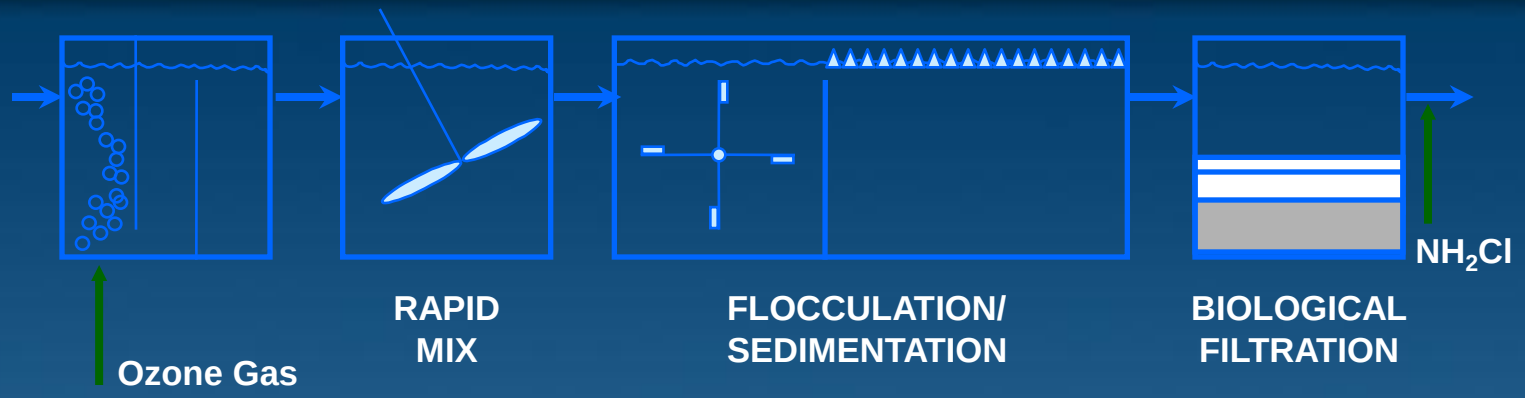
Surface Water Disinfection Advances



Chlorine-based: Hours / days of exposure

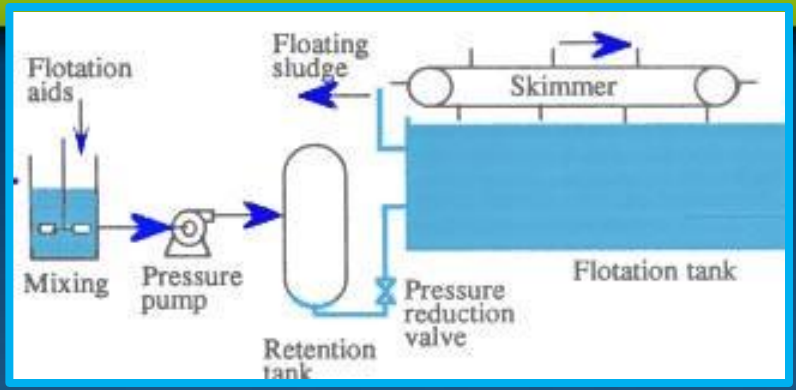


Surface Water Disinfection Advances



Ozone gas: **Minutes of exposure**

Surface Water Particle Removal Advances

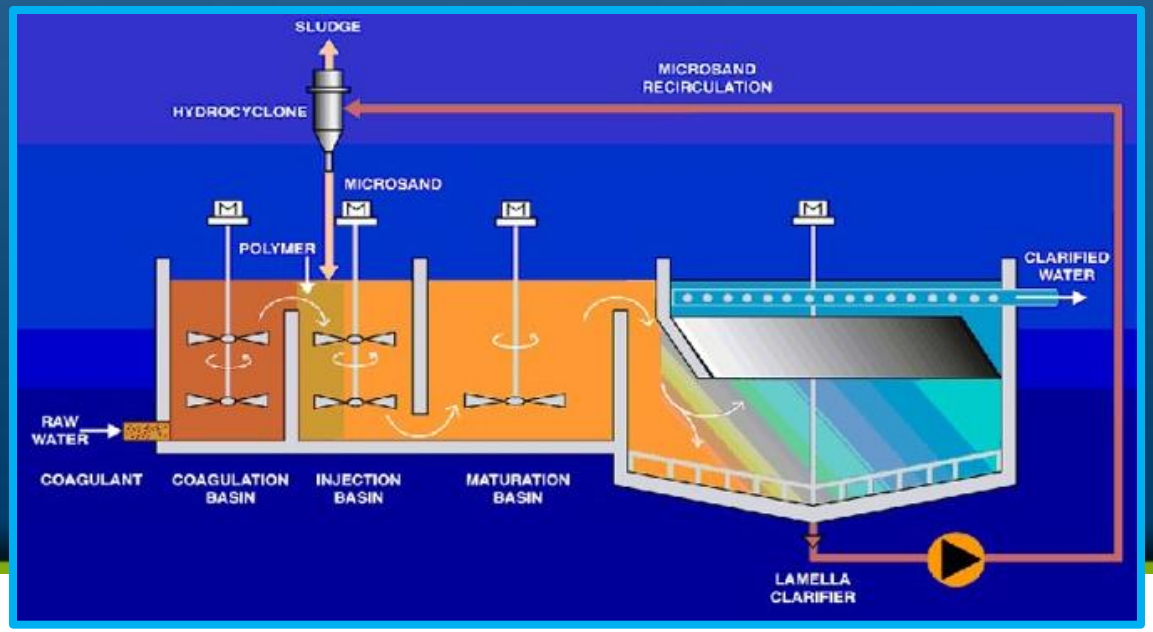


Dissolved Air Flotation:

Minutes, less chemical

Surface Water Particle Removal Advances

Ballasted Flocculation: **Minutes, less chemicals**



Surface Water Particle Removal Advances

Microfiltration
40 gpm

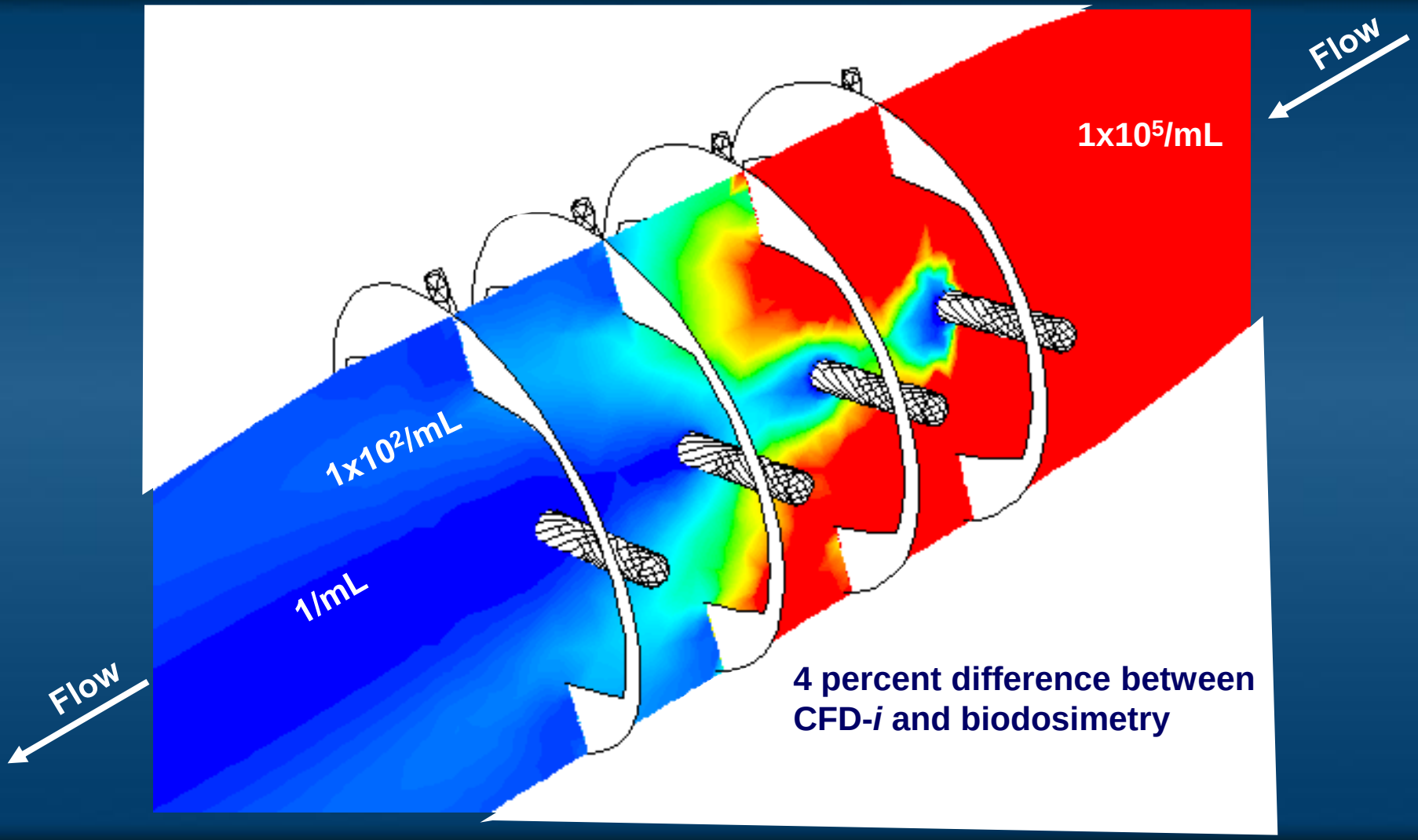
Microfiltration
30 MGD

Removing Contaminants……

Reverse Osmosis
18” Diameter Membranes

- Large-Scale Micropollutant Removal
  - Pharmaceuticals
  - Pollutants / Toxins

Operating at the Speed of Light……



Mofidi et al., 2004

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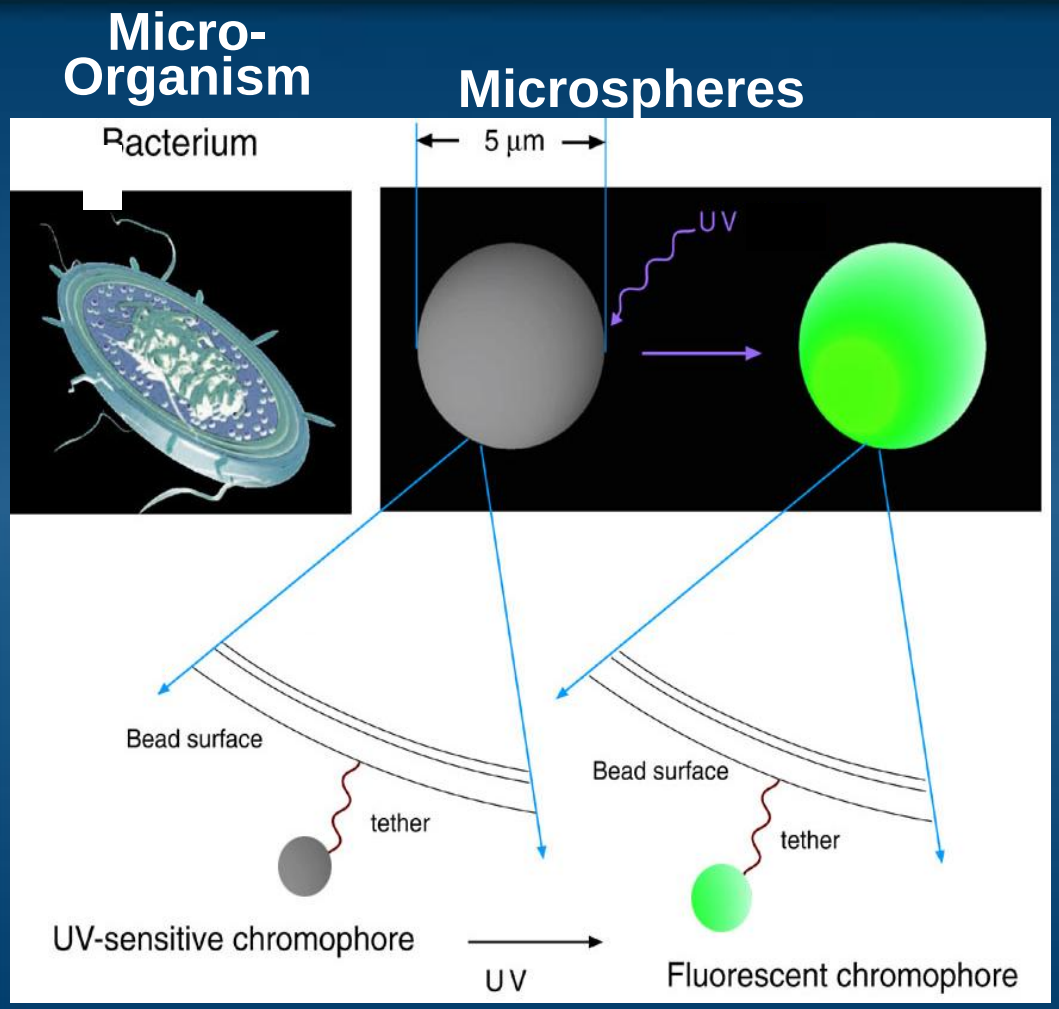
“Micro” and “Nano” Materials……



- Particle mimics microorganisms (size ~ 5 µm)
- Trajectory through UV reactor similar to microorganisms’
- Linked UV-sensitive chromophore
- Becomes fluorescent under UV irradiation
- Bead fluorescence intensity correlated to UV dose received
- FI measured by flow cytometry

Shen & Mofidi et al., 2009

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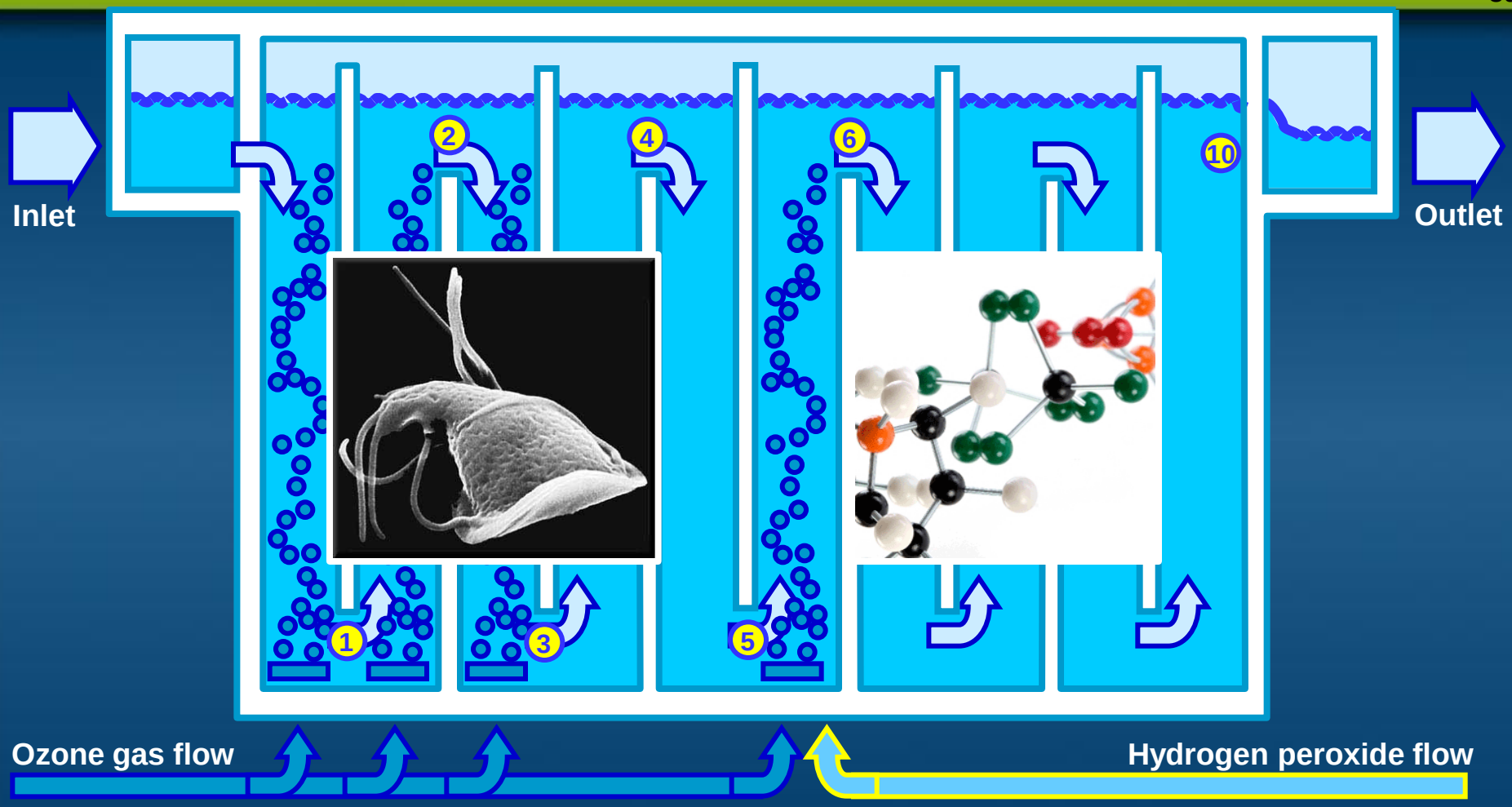
Tailoring Treatment: Multiple Objectives



● = Locations where ozone residual is monitored (disinfection credits are only calculated through cell 6)

Mofidi, 2006

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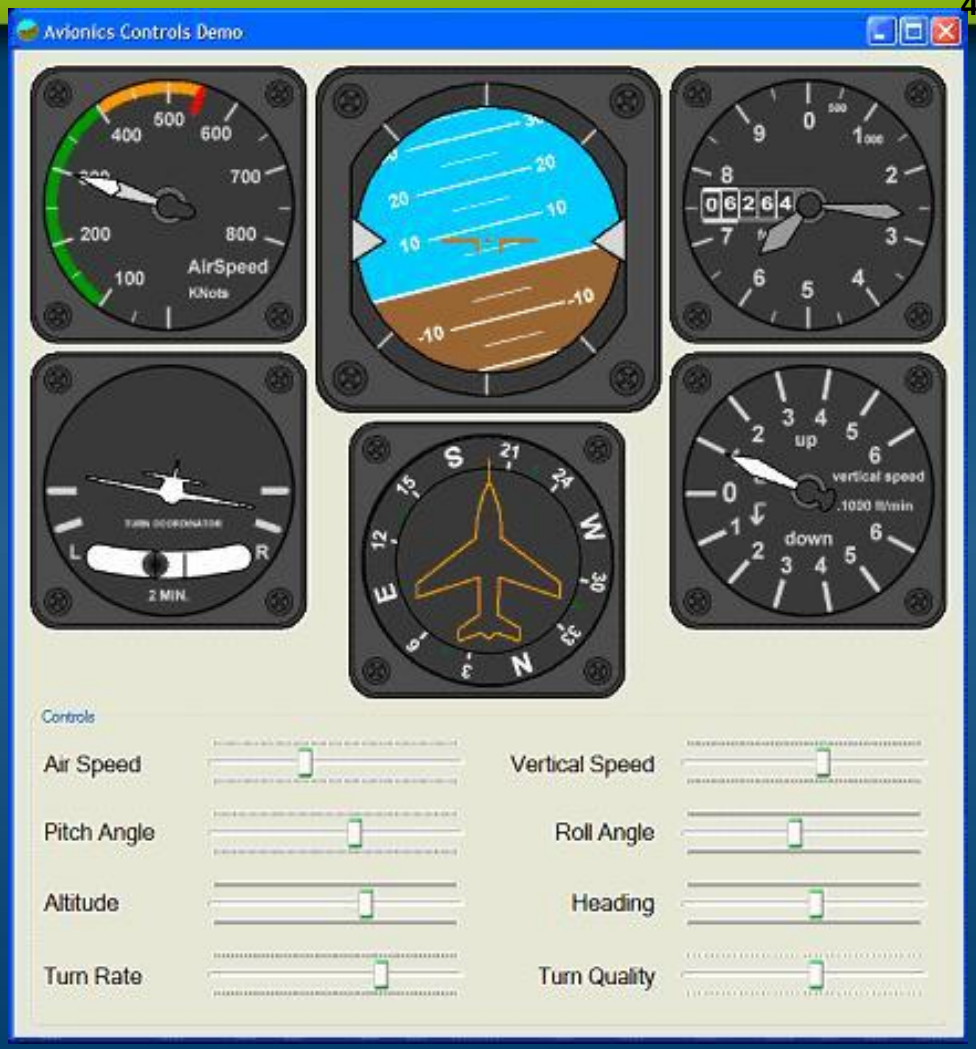
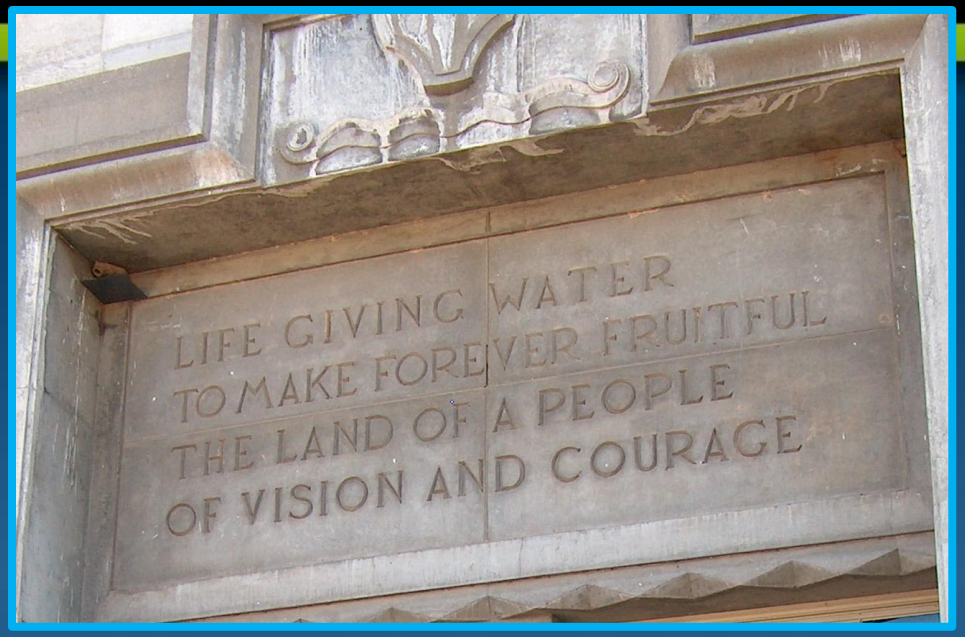
“Perfecting” Treatment: Data Management

- Optimize real-time data monitoring
- Identify additional means to improve treatment efficiency
- Increase number of treatment barriers
  - Reduced time in the water use cycle
  - Increase protection against disease



Thank You!



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