Environmental Engineering for the 21st Century: The Intersection of Water Research and Policy

Chesapeake Water Environment Association
Water Resources Webinar
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We have a water crisis in the US

Number of Americans who received water from a source that violated SDWA between 1982 - 2015

9–45

Million

63

Million

Americans were exposed to potentially unsafe water more than once during the past decade.

3–10%

US Water systems in violation of SDWA each year

$384

Billion

Investment needed by US water utilities to meet water regulations

We have a global water crisis

A child dies from a water-related disease every

2

minutes

1

Million

People who die due to water, sanitation and hygiene-related illnesses each year

844

Million

People live without access to safe water

2.3

Billion

People are living without access to proper sanitation

$18.5

Billion

Revenue lost from avoidable deaths from lack of access to basic water and sanitation

•*World Health Organization and UNICEF Joint Monitoring Programm. (2017).* ***Progress on Drinking Water and Sanitation, 2017 Update and MDG Assessment.***

Water is a Grand Challenge of our times

The National Academies of
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Environmental Engineering for the 21st Century: Addressing Grand Challenges

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Motivation: 21st Century Pressures

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Study Committee

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- **Craig H. Benson** (NAE), University of Virginia, Charlottesville
- **Amanda Carrico**, University of Colorado, Boulder
- **Kartik Chandran**, Columbia University, New York City
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- **John C. Crittenden** (NAE), Georgia Institute of Technology, Atlanta
- **Daniel S. Greenbaum**, Health Effects Institute, Boston, MA
- **Steven P. Hamburg**, Environmental Defense Fund, Belmont, MA
- **Thomas C. Harmon**, University of California, Merced
- **James M. Hughes** (NAM), Emory University, Atlanta, GA
- **Kimberly L. Jones**, Howard University, Washington DC
- **Linsey C. Marr**, Virginia Polytechnic Institute and State University, Blacksburg
- **Robert Perciasepe**, Center for Climate and Energy Solutions, Arlington, VA
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- **Maxine L. Savitz** (NAE), Honeywell, Inc. (*retired*), Los Angeles, CA
- **Norman R. Scott** (NAE), Cornell University, Ithaca, NY
- **R. Rhodes Trussell** (NAE), Trussell Technologies, Inc., Pasadena, CA
- **Julie B. Zimmerman**, Yale University, New Haven, CT

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Grand Challenges

1 Sustainably supply food, water, and energy

2 Curb climate change and adapt to its impacts

3 Design a future without pollution and waste

4 Create efficient, healthy, resilient cities

5 Foster informed decisions and actions

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GRAND CHALLENGE 1:

Sustainably Supply Food, Water, and Energy

Providing life's essentials—food, water, and energy—for the world's growing population is a major challenge. Doing so in a manner that does not threaten the environment and the health or productivity of future generations is an even bigger challenge.

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- **Create new water supplies**
  - Low-cost, reliable reuse, desalination, groundwater recharge
- **Increase water-use efficiency**
  - Process and technology improvements (e.g., waterless toilets)
  - Changing behavior
- **Redesigning and revitalizing distribution systems**

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GRAND CHALLENGE 2:

Curb Climate Change and Adapt to Its Impacts

It is now more certain than ever that humans are changing Earth's climate.[97] The burning of fossil fuels for electricity generation, transportation, heating, cooling, and other energy uses has raised the concentration of global atmospheric carbon dioxide (CO_2) to more than 400 parts per million (ppm)—a level that last occurred about 3 million years ago when both global average temperature and sea level were significantly higher than today.[98] At the same time, the production of fossil fuels and agricultural and industrial processes also have emitted large amounts of methane and nitrous oxide, both powerful greenhouse gases, into the atmosphere.

Sharp reduction in GHG emissions needed to avoid worst impacts

Limiting warming to 1.5 C requires:

- Dramatic reductions in CO_2
- Active removal of $C0_2$
- Powering transportation, buildings, and industry with electricity generated with low-c

Use energy more efficiently

Switch to low-carbon energy sources

- Advances to make renewables more cost effective
- Advanced nuclear to improve safety and performance

Climate intervention strategies

Design sustainable infrastructure optimized for 20th century climate

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GRAND CHALLENGE 3:

Design a Future Without Pollution or Waste

In nature, waste is a resource. One organism's waste is repurposed to sustain another. Since the Industrial Revolution, human society has adopted a more linear model. Resources and energy are used to manufacture products, which are then used and ultimately discarded as waste when those products are no longer wanted (Figure 3-1). This linear model of "take-make-waste" has been successful in providing affordable products to billions of people and advancing their standard of living. However, this production model generates over a billion tons of discarded products and by-products globally each year (see Box 3-1), and uses large amounts of energy and resources that are never recaptured. An analysis of five

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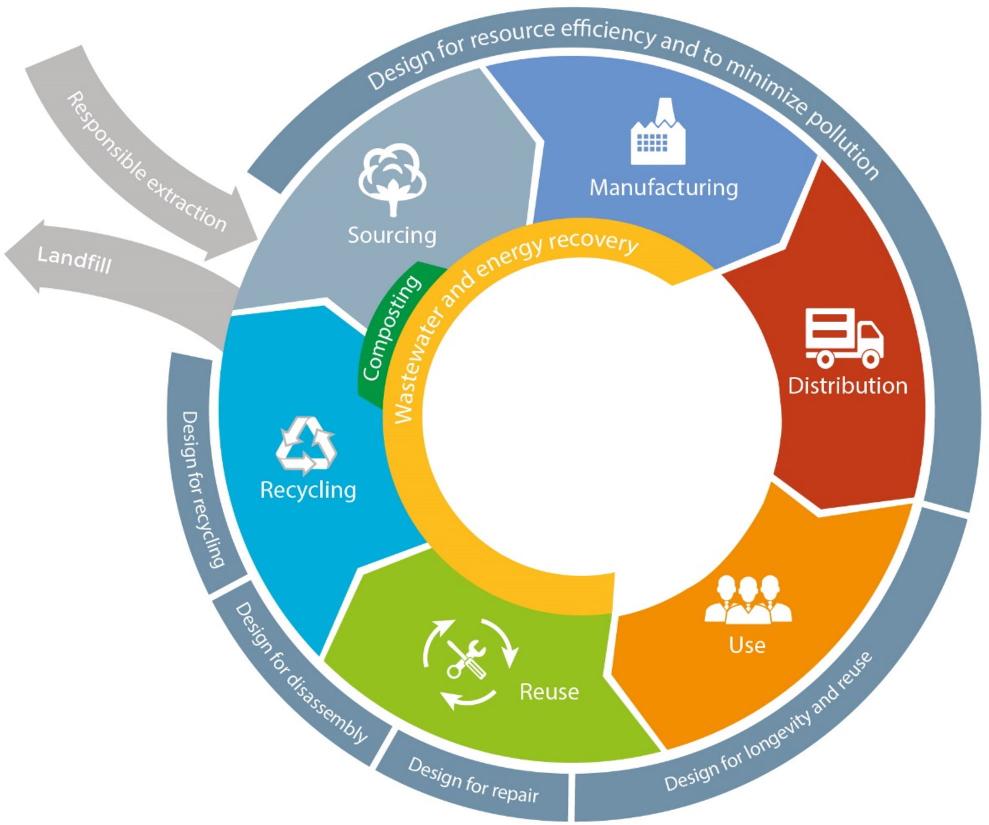
Develop a circular economy that eliminates pollution and waste, using:

Life-cycle and systems thinking

Green chemistry and engineering

Anticipate consequences



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GRAND CHALLENGE 4:

Create Efficient, Healthy, Resilient Cities

The future is increasingly urban. Cities will absorb almost all of the world's projected population growth in the next three decades, home to more than 2 billion *more* people by 2050 than today. The proportion of the world's population that lives in urban areas will grow from 55 percent in 2017 to 66 percent in 2050.[214] By 2030, 10 more cities are expected to cross the 10-million-inhabitant threshold for the first time, increasing the number of "megacities" from 31 in 2016 to 41 in 2030. The majority of these will be in lower-income countries and contain large slums—dense informal developments without government services.[215]

Re-envision urban architecture	Assess alternatives for energy and water efficiency, other benefits
Advance smart cities	Embed sensors to monitor traffic, water, energy use, use of trash bins, etc.
	Use data to inform decision making
Create Healthy Cities	Design equitable access to recreation, green space
	Improve indoor and outdoor air quality
	Reduce water pollution
	Prevent, detect, and mitigate the spread of infectious disease
	Ensure reliable provision of clean water and manage waste
Create Resilient Cities	Assess vulnerabilities (sea level rise, heat island effects)
	Develop systems that have multiple benefits (flood control/parks)
	Building resilient infrastructure

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GRAND CHALLENGE 5:

Foster Informed Decisions and Actions

Addressing the world's largest environmental problems will require major shifts in our approaches and actions.[259] New strategies and technologies will only be effective in solving these grand challenges with widespread adoption, which may require regulatory changes at the governmental level and behavioral changes at the community and individual levels. For this to happen, decision makers in the public and private sectors and a significant portion of the general public must believe that the environmental problems are serious enough to warrant change—and that proposed solutions are worth adopting. In other words, addressing grand environmental challenges requires, in addition to effective solutions, a pervasive recognition that implementing those solutions is in our best interest.

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Understand community context for challenges and solutions	**Understand broader economic, social, institutional factors** **Create open dialogue**
Increase diversity in the engineering community	**Increase the pipeline** **Engage traditionally underserved communities**
Identify appropriate policy solutions	**Educate the public** **Create incentives** **Set rules and policies**

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THE ULTIMATE CHALLENGE FOR ENVIRONMENTAL ENGINEERING:

Preparing The Field to Address A New Future

Historically, the discipline of environmental engineering has centered around public health and sanitation and its practitioners' primary objectives have been to provide clean water and properly manage waste. These services are vital for the health and prosperity of society, lengthening life spans, and improving quality of life. The world now faces a number of challenges that are fundamentally broader in scope and larger in scale than the problems that environmental engineers have solved in the past. Communities have grown larger than ever. Technological innovation and major social changes occur over the course of years, rather than decades. Humans now influence the environment on a global as well as a local scale.

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Evolving Practice

Cultivate a more diverse workforce, from K-12 through graduate training.

Enhance stakeholder engagement

Use tools to help stakeholders understand the consequences of decision alternatives

Evolving Environmental Science and Engineering Education

Enhance curriculum	build emphasis on complex systems and social science
	keep pace with global challenges
Build essential skills among graduates	collaboration
	critical thinking
	real-world problem solving
	effective communication

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Possible Strategies for Improving Education

Increase reliance on graduate training to allow more breadth in undergraduate training.

Create practice and service-based models

Grand Challenges Scholars Programs

Evolving Research

Universities should promote and reward interdisciplinary work	Enhance interdisciplinary mentoring
Research and funding institutions should facilitate effective collaboration	Early career awards on interdisciplinary themes
	Expand interdisciplinary research support
	Develop Engineering Research Centers around grand challenges

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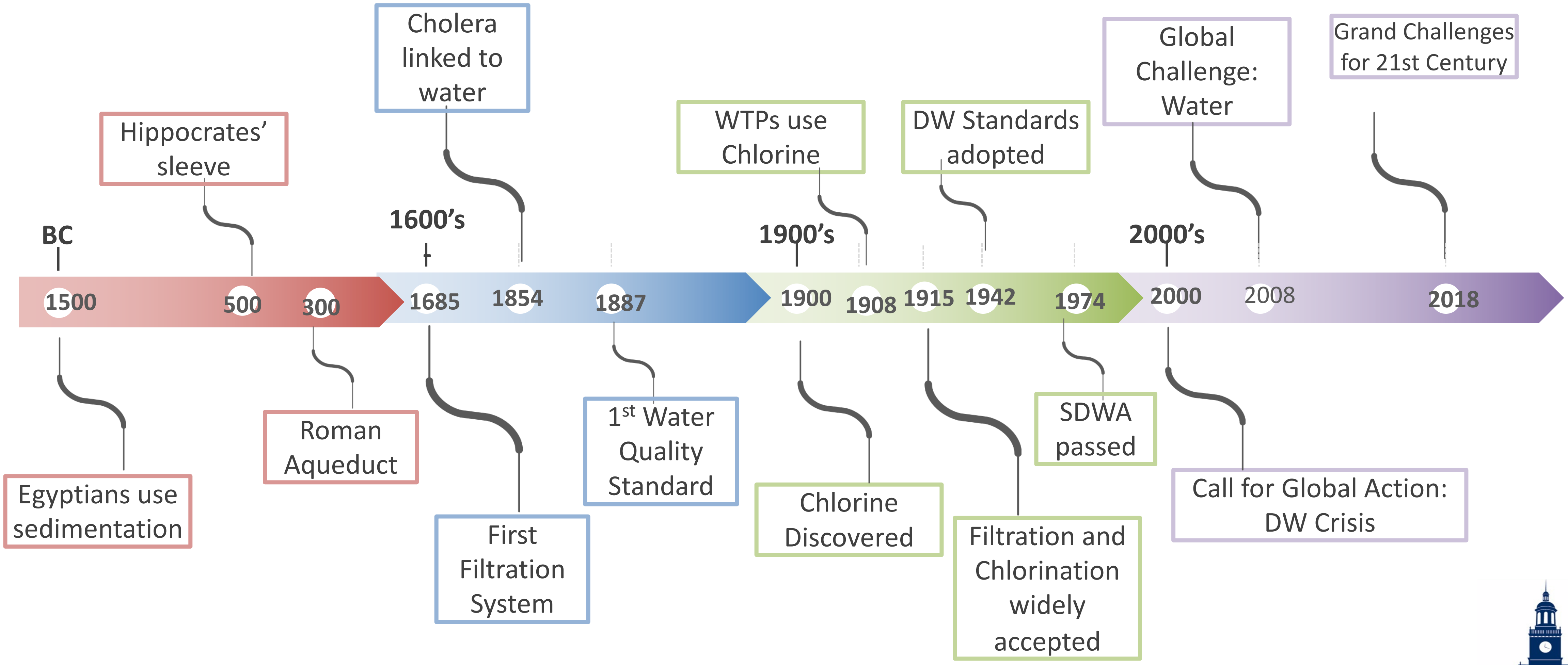
How can water research (innovation) evolve?



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Sustainable Water: Next Generation Solutions

We need greater than incremental improvements

- Water and sanitation innovations happen very slowly
- Water industry is traditionally risk averse
- Policy drives innovation

We need to focus on sustainable solutions (forward thinking)

- Partnerships between universities, industries, government agencies

What are some key targets for improvement?

- Multi-barrier approaches – improve efficiency, primarily for emerging contaminants (classes of contaminants)
- Enabling technologies for reuse and recovery ("fit for use")
- Increase in multi-contaminant removal
- Decentralized treatment
- Reduce energy cost of treatment

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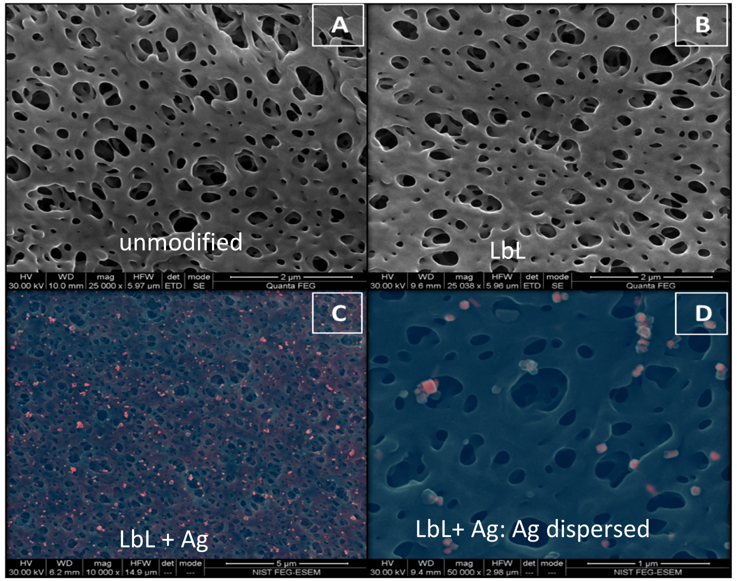
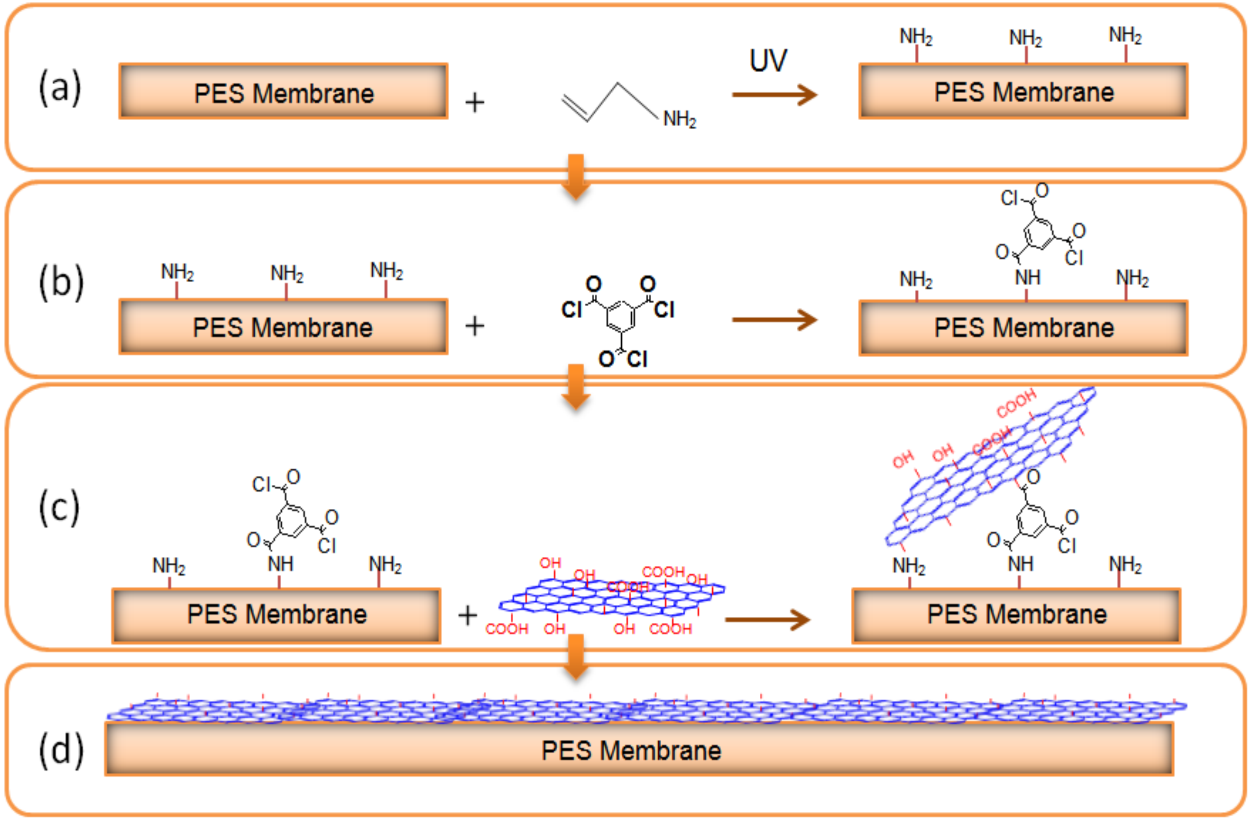
Reduce costs of membrane treatment: Innovation in Membrane Materials

Surface modification

Silver NP



Graphene Oxide



Fatou et al., 2012, Igbinigun et al., 2016

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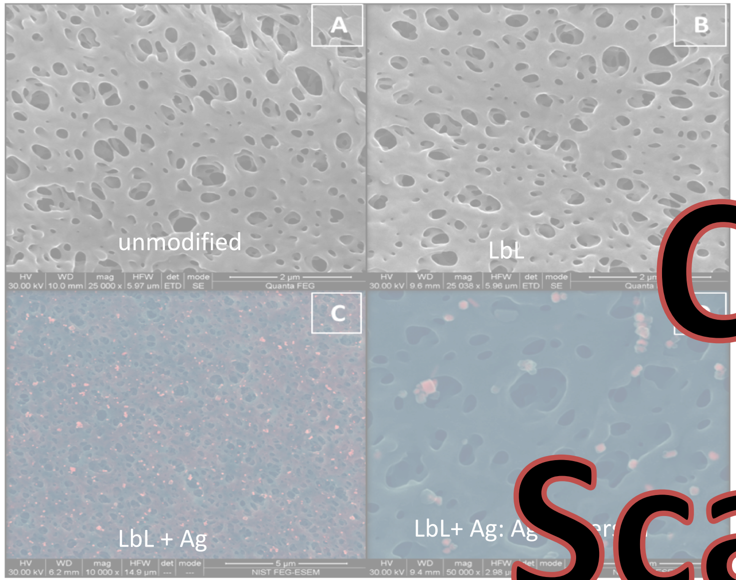
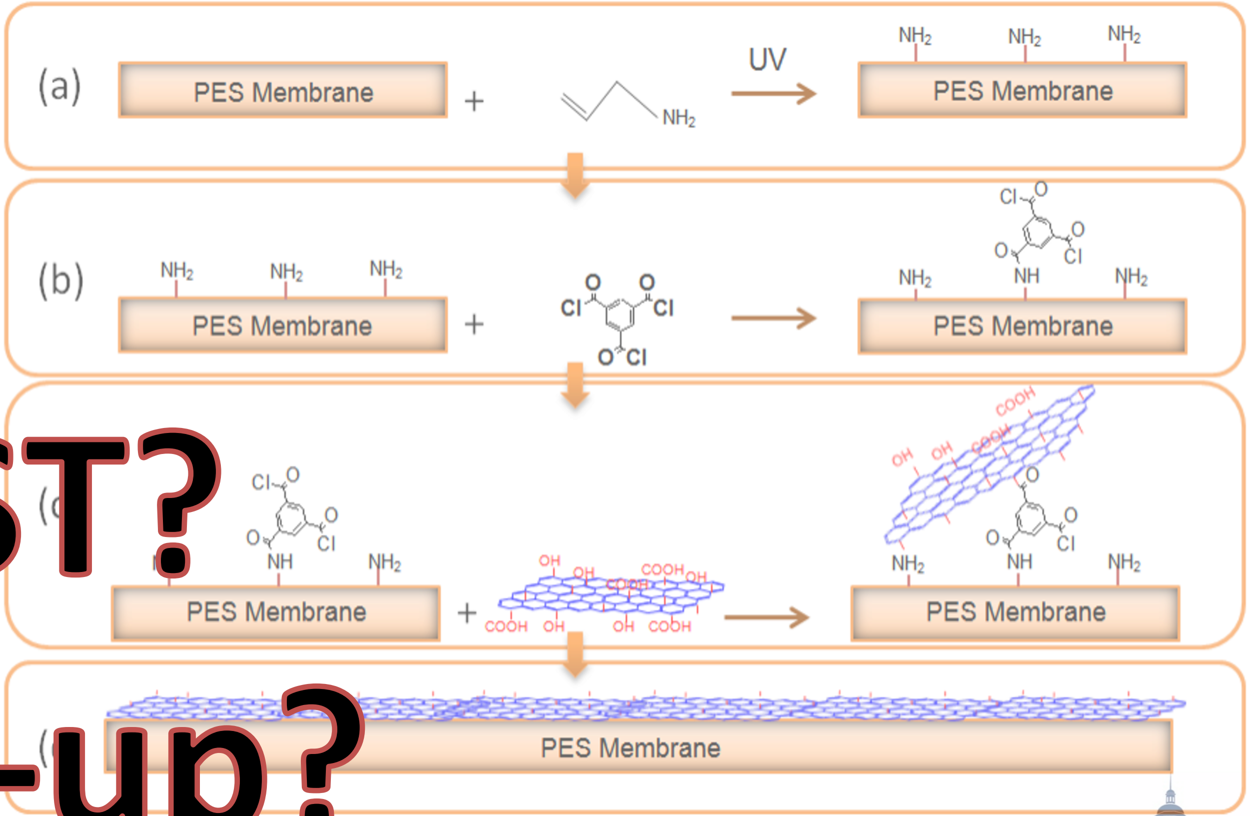
Reduce costs of membrane treatment: Innovation in Membrane Materials

Surface modification

Silver NP



Graphene Oxide



COST?

Scale-up?

Fatou et al., 2012, Igbinigun et al., 2016

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Innovation in Water and Wastewater Treatment

Innovation is driven by regulatory actions	Long process to implement new regulations
	Regulations sometimes identify best available technology, which includes current treatment options
	Industry is slow to accept new technologies
Researchers should consider potential barriers to implementation	Cost
	Ease of operation
	Need for retrofitting

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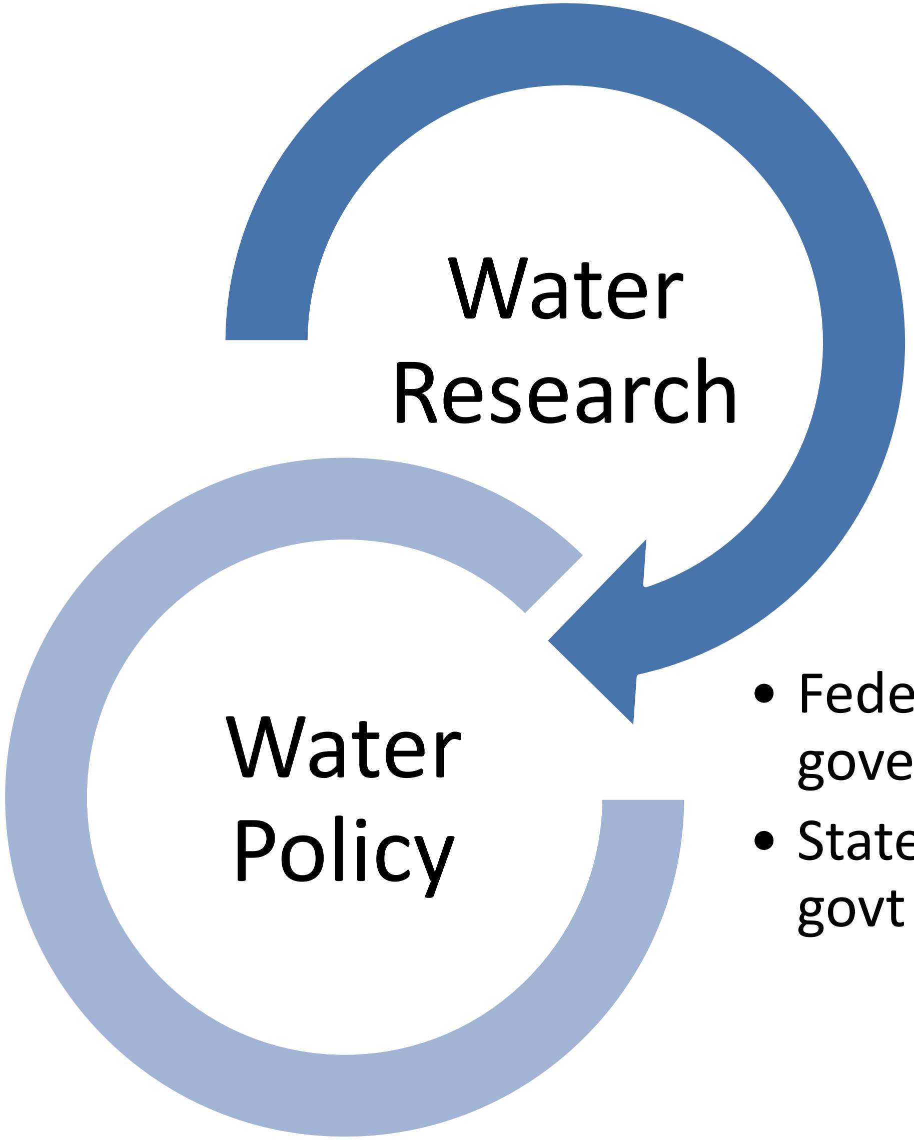

- Universities
- Industries (R&D)
- Government Labs

- Federal government
- State and local govt

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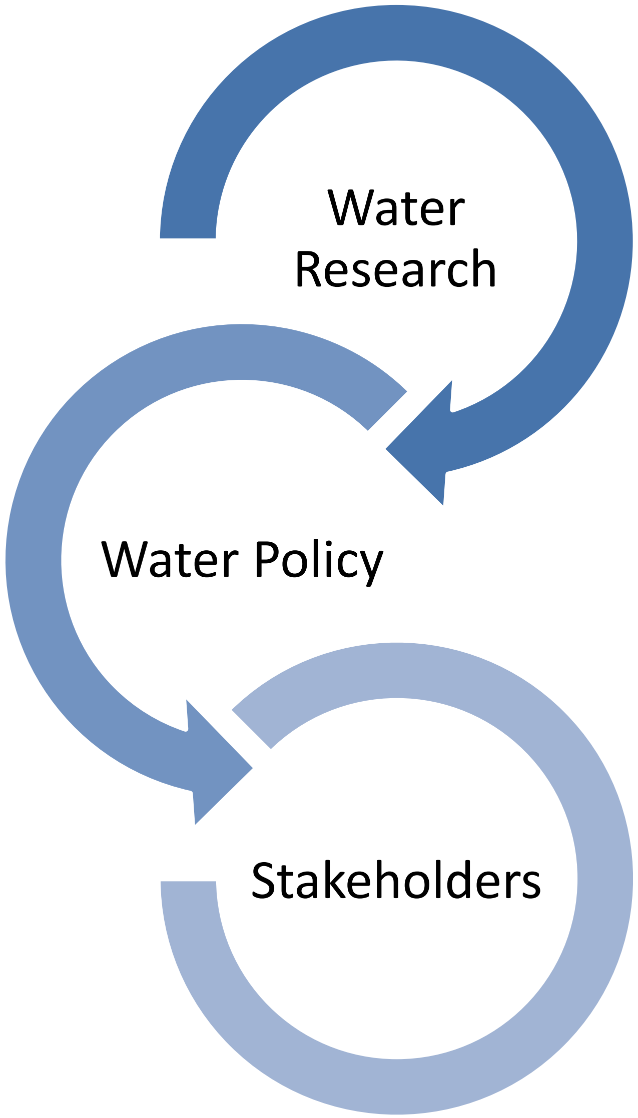

University and Laboratory Researchers

- Environmental Engineers
- Chemical Engineers
- Ecologists
- Toxicologists
- Chemists
- Biologists

Federal and State Government Elected and Appointed Officials

- Economists
- Lawyers
- Social Scientists
- Finance and Marketing

Stakeholders

- Community Groups
- Utilities
- Business Owners
- Clients

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Thank you!

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