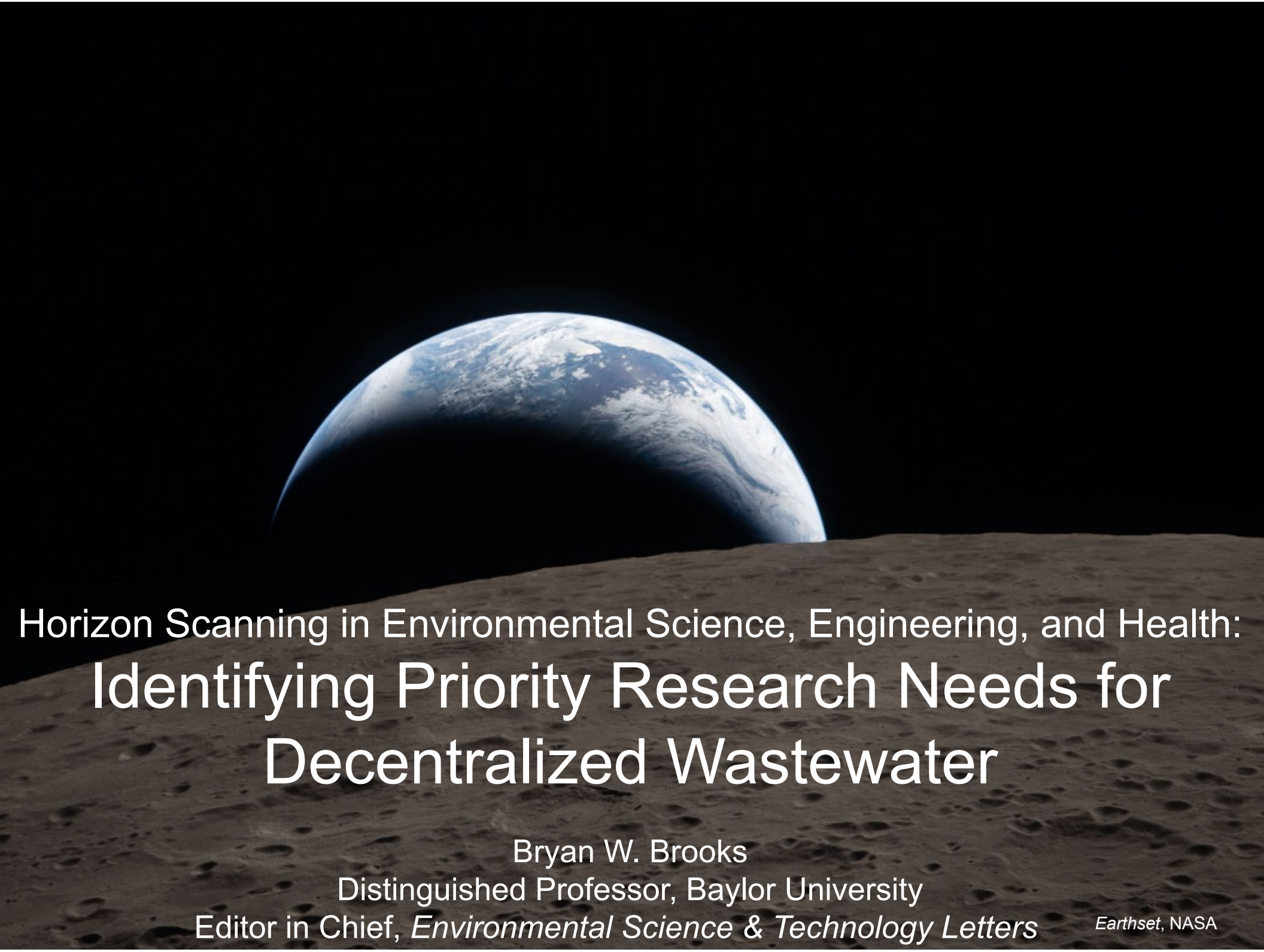


Horizon Scanning in Environmental Science, Engineering, and Health:

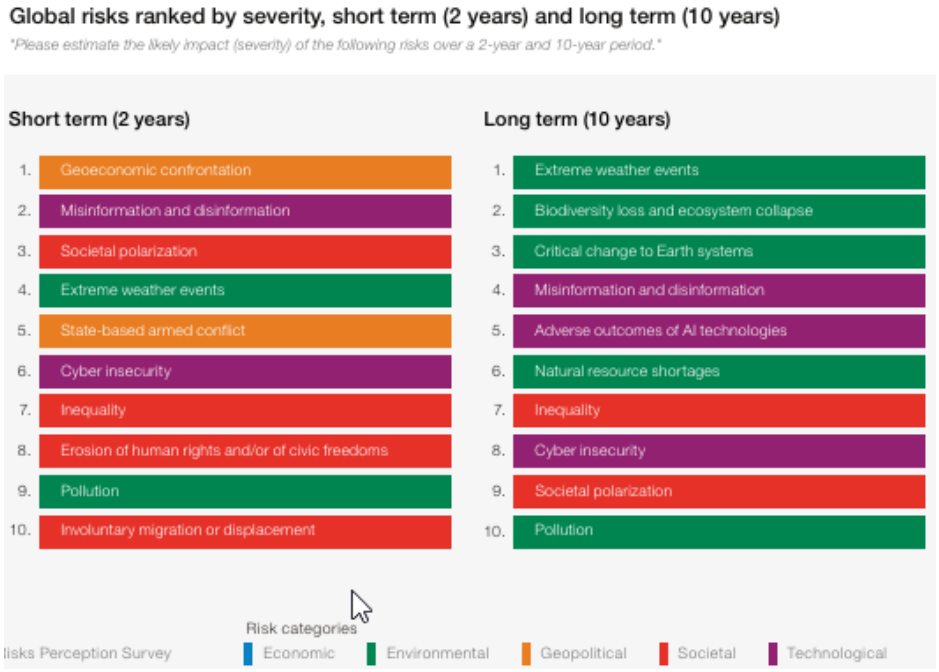
Identifying Priority Research Needs for Decentralized Wastewater

Bryan W. Brooks
Distinguished Professor, Baylor University
Editor in Chief, *Environmental Science & Technology Letters*

Earthset, NASA

Why Horizon Scanning?





EU Policy Lab

Stories

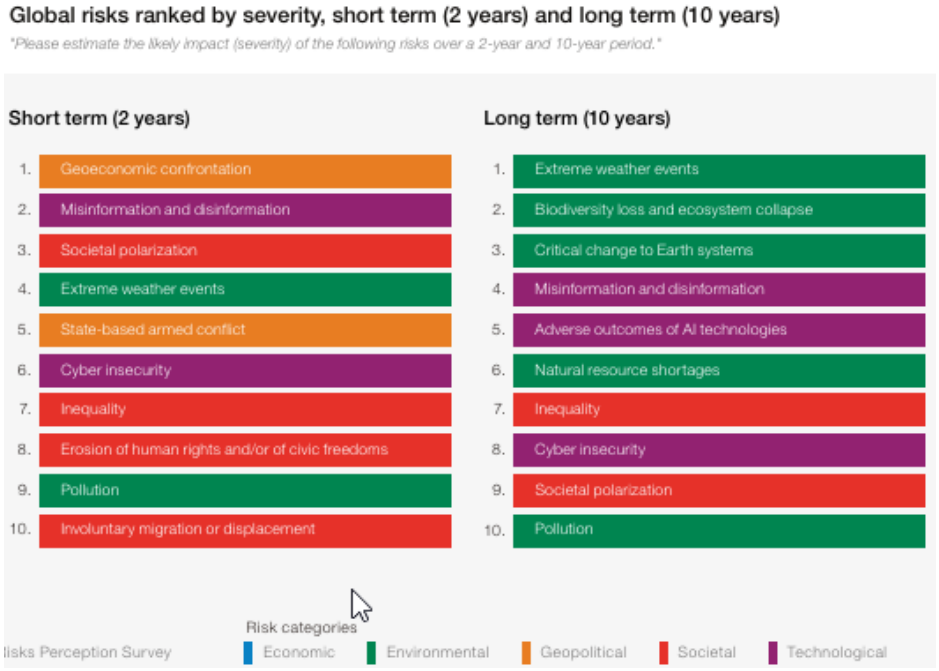
Peering into the Future: How Horizon Scanning can help shape EU Policy

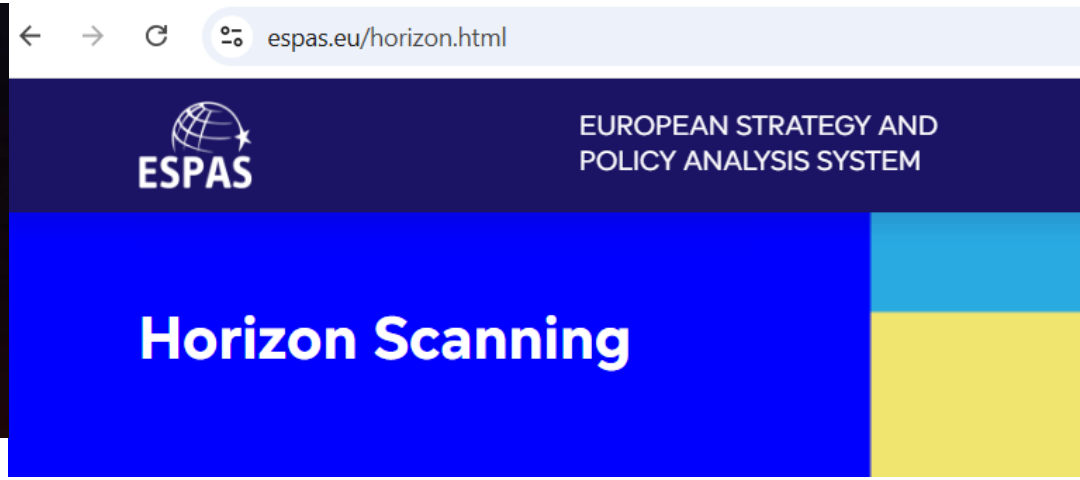
NEWS ARTICLE

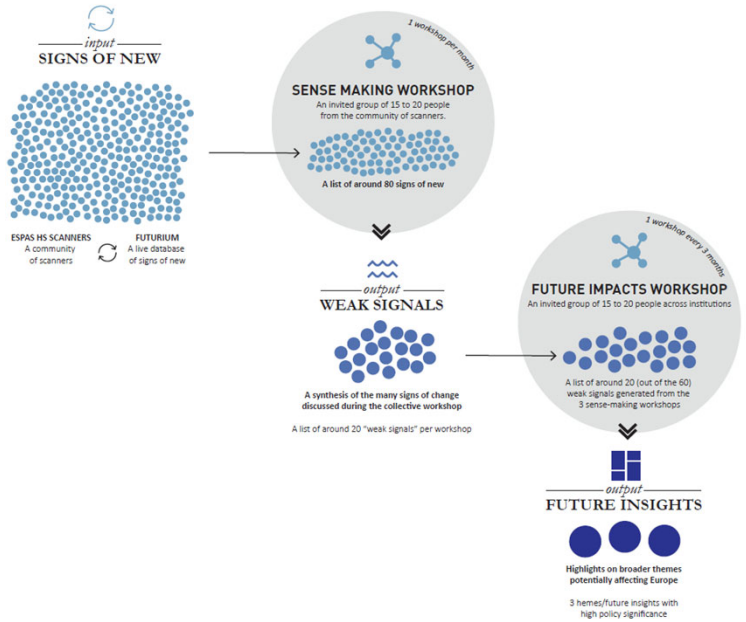
19 January 2024 — Joint Research Centre — 4 min read

Why Horizon Scanning?



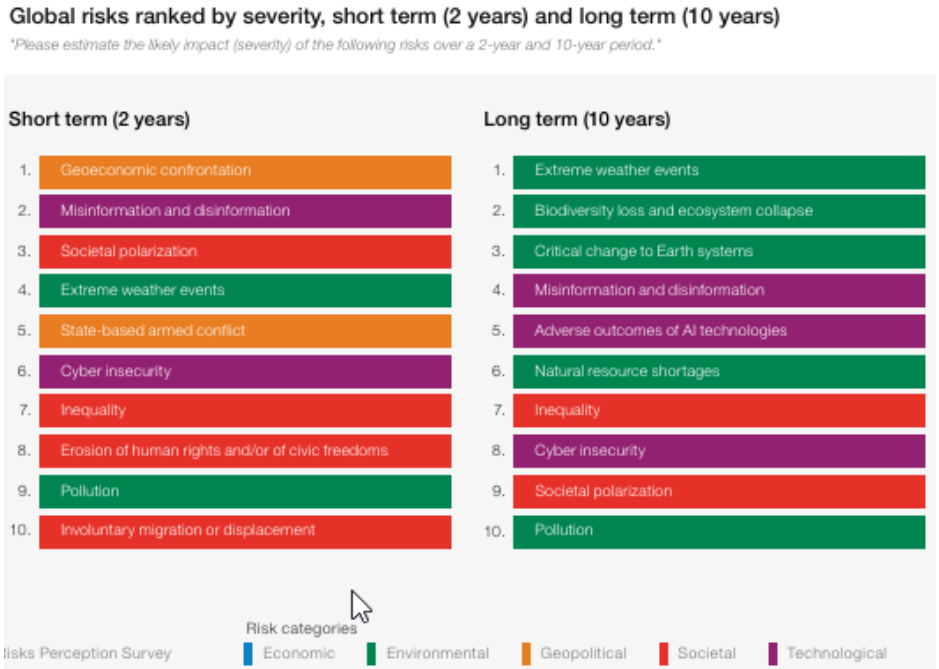


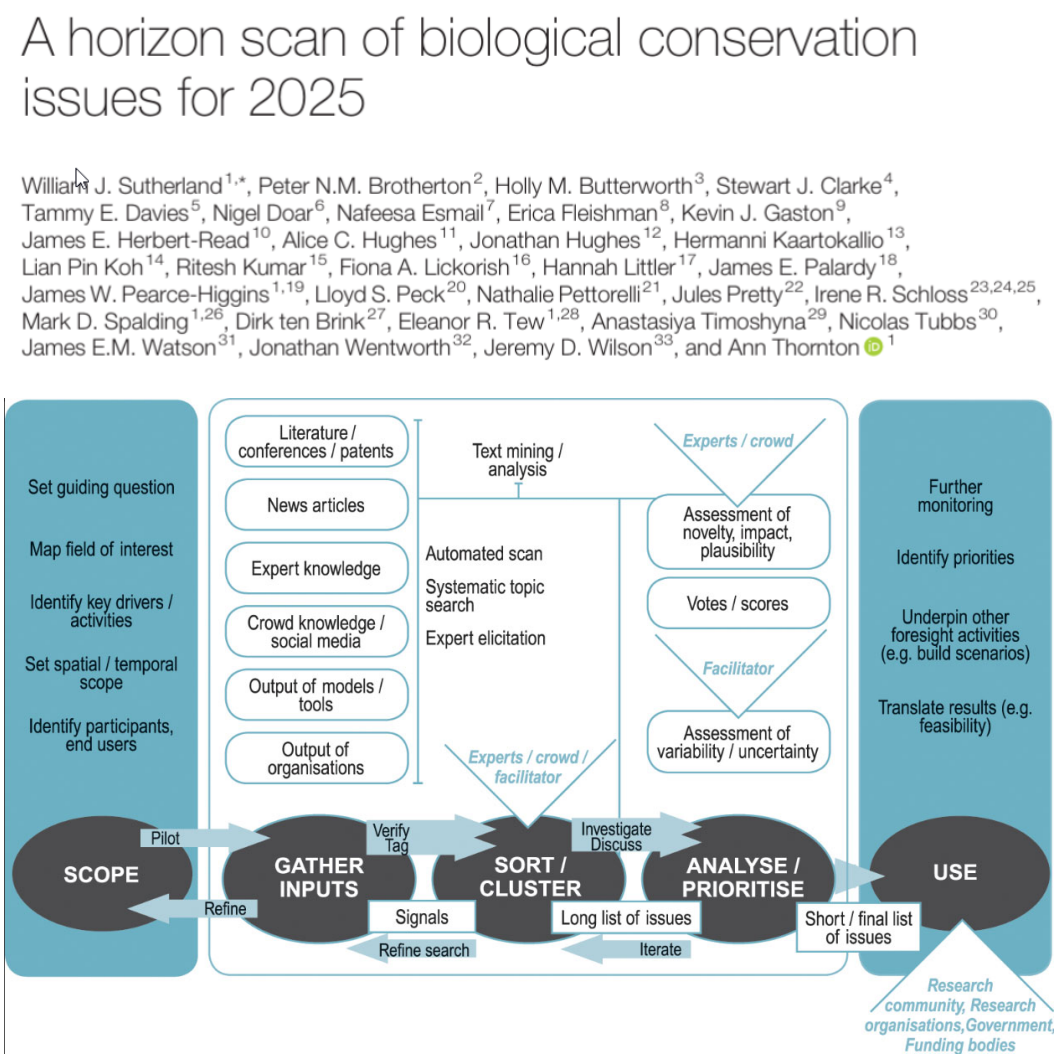




Why Horizon Scanning?







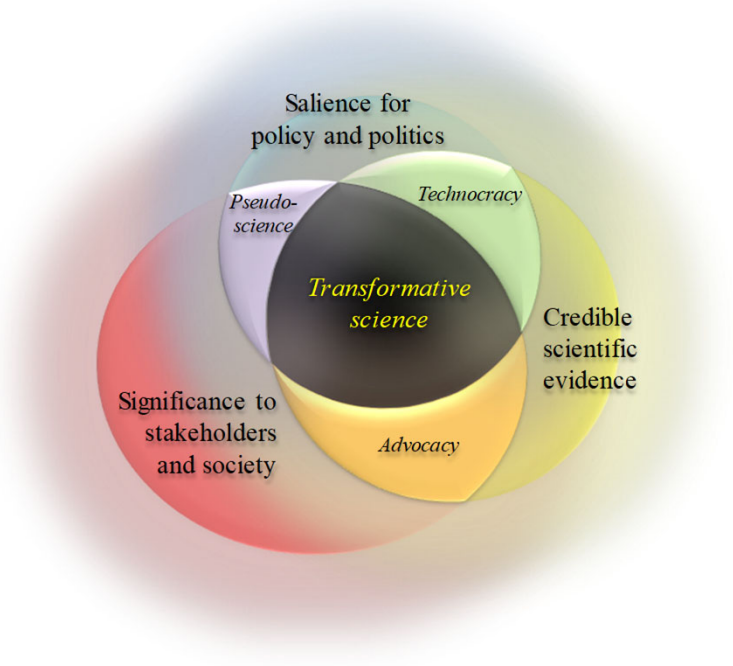
Sutherland et al 2025. *Trends Ecol Evol*

Why Horizon Scanning?

Key Questions Approach

- Engages experts across disciplines and sectors
- Systematic way to identify major research and policy directions
- These are inherently bottom-up exercises

potentially more legitimacy



Brooks et al. 2013. *IEAM*; Rudd et al. 2014. *IEAM*

Why Horizon Scanning?

Pharmaceuticals and Personal Care Products in the Environment

SETAC PRESS

Environmental Toxicology and Chemistry, Vol. 28, No. 12, pp. 2469–2472, 2009
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Printed in the USA
0730-7268/09 $12.00 + .00

Pharmaceuticals and Personal Care Products in the Environment
Editorial

PHARMACEUTICALS AND PERSONAL CARE PRODUCTS: RESEARCH NEEDS FOR THE NEXT DECADE

ehp Environmental Health Perspectives

Pharmaceuticals and Personal Care Products in the Environment: What Are the Big Questions?

Alistair B.A. Boxall,[1] Murray A. Rudd,[1] Bryan W. Brooks,[2] Daniel J. Caldwell,[3] Kyungho Choi,[4] Silke Hickmann,[5] Elizabeth Innes,[6] Kim Ostapyk,[6] Jane P. Staveley,[7] Tim Verslycke,[8] Gerald T. Ankley,[9] Karen F. Beazley,[10] Scott E. Belanger,[11] Jason P. Berninger,[2] Pedro Carriquiriborde,[12] Anja Coors,[13] Paul C. DeLeo,[14] Scott D. Dyer,[11] Jon F. Ericson,[15] François Gagné,[16] John P. Giesy,[17] Todd Gouin,[18] Lars Hallstrom,[19] Maja V. Karlsson,[1] D. G. Joakim Larsson,[20] James M. Lazorchak,[21] Frank Mastrocco,[15] Alison McLaughlin,[6] Mark E. McMaster,[22] Roger D. Meyerhoff,[23] Roberta Moore,[6] Joanne L. Parrott,[22] Jason R. Snape,[24] Richard Murray-Smith,[24] Mark R. Servos,[25] Paul K. Sibley,[26] Jürg Oliver Straub,[27] Nora D. Szabo,[28] Edward Topp,[29] Gerald R. Tetreault,[25] Vance L. Trudeau,[28] and Glen Van Der Kraak[26]

Environmental Toxicology and Chemistry—Volume 43, Number 3—pp. 481–487, 2024
Received: 15 January 2024 | Accepted: 16 January 2024

Introduction

Pharmaceuticals and Personal Care Products in the Environment: What Progress Has Been Made in Addressing the Big Research Questions?

Alistair B. A. Boxall[a,*] and Bryan W. Brooks[b]

[a]Department of Environment and Geography, University of York, York, United Kingdom
[b]Department of Environmental Science, Center for Reservoir and Aquatic Systems Research, Institute of Biomedical Studies, Baylor University, Waco, Texas, USA

Brooks et al. 2009. *Environ Toxicol Chem*; Boxall et al. 2012. *Environ Health Perspect*; Boxall and Brooks. 2024. *Environ Toxicol Chem*

Why Horizon Scanning?

Towards Sustainable Environmental Quality

Environmental Toxicology and Chemistry—Volume 37, Number 9—pp. 2281–2295, 2018
Received: 9 April 2018 | Revised: 28 April 2018 | Accepted: 11 June 2018 2281

Critical Review

Toward Sustainable Environmental Quality: Priority Research Questions for Europe

Paul J. Van den Brink,[a,b] Alistair B.A. Boxall,[c,*] Lorraine Maltby,[d] Bryn W. Brooks,[e] Murray A. Rudd,[f] Thomas Backhaus,[g] David Spurgeon,[h] Violaine Verougstraete,[i] Charmaine Ajao,[j] Gerald T. Ankley,[k] Sabine E. Apitz,[l] Kathryn Arnold,[c] Tomas Brodin,[m] Miguel Cañedo-Argüelles,[n,o] Jennifer Chapman,[c] Jone Corrales,[e] Marie-Agnès Coutellec,[p] Teresa F. Fernandes,[q] Jerker Fick,[r] Alex T. Ford,[s] Gemma Giménez Papiol,[t] Ksenia J. Groh,[u] Thomas H. Hutchinson,[v] Hank Kruger,[w] Jussi V.K. Kukkonen,[x] Stefania Loutseti,[y] Stuart Marshall,[z] Derek Muir,[aa] Manuel E. Ortiz-Santaliestra,[ab] Kai B. Paul,[ac] Andreu Rico,[ad] Ismael Rodea-Palomares,[ae] Jörg Römbke,[af] Tomas Rydberg,[ag] Helmut Segner,[ah] Mathijs Smit,[ai] Cornelis A.M. van Gestel,[aj] Marco Vighi,[ad] Inge Werner,[ak] Elke I. Zimmer,[al] and Joke van Wensem[am]

Environmental Toxicology and Chemistry—Volume 38, Number 8—pp. 1606–1624, 2019
Received: 13 February 2019 | Revised: 19 March 2019 | Accepted: 16 May 2019 1606

Critical Review

Toward Sustainable Environmental Quality: Priority Research Questions for North America

Anne Fairbrother,[a] Derek Muir,[b] Keith R. Solomon,[c] Gerald T. Ankley,[d] Murray A. Rudd,[e] Alistair B.A. Boxall,[f] Jennifer N. Apell,[g] Kevin L. Armbrust,[h] Bonnie J. Blalock,[i] Sarah R. Bowman,[j] Linda M. Campbell,[k] George P. Cobb,[l] Kristin A. Connors,[m] David A. Dreier,[n] Marlene S. Evans,[b] Carol J. Henry,[o] Robert A. Hoke,[p] Magali Houde,[b] Stephen J. Klaine,[q,1] Rebecca D. Klaper,[r] Sigrun A. Kullik,[s] Roman P. Lanno,[t] Charles Meyer,[u] Mary Ann Ottinger,[v] Elias Oziolor,[l] Elijah J. Petersen,[w] Helen C. Poynton,[i] Pamela J. Rice,[x] Gabriela Rodriguez-Fuentes,[y] Alan Samel,[z] Joseph R. Shaw,[aa] Jeffery A. Steevens,[bb] Tim A. Verslycke,[cc] Doris E. Vidal-Dorsch,[dd] Scott M. Weir,[ee] Peter Wilson,[ff] and Bryan W. Brooks[m,gg,*]

Integrated Environmental Assessment and Management — Volume 14, Number 3—pp. 344–357
344 Received: 25 April 2017 | Returned for Revision: 14 August 2017 | Accepted: 14 November 2017

Environmental Policy & Regulation

Toward Sustainable Environmental Quality: Identifying Priority Research Questions for Latin America

Tatiana Heid Furley,† Julie Brodeur,‡ Helena C Silva de Assis,§ Pedro Carriquiriborde,‖ Katia R Chagas,† Jone Corrales,# Marina Denadai,†† Julio Fuchs,‡‡ Renata Mascarenhas,§§ Karina SB Miglioranza,‖ Diana Margarita Miguez Caramés,‖‖## José Maria Navas,††† Dayanthi Nugegoda,‡‡‡ Estela Planes,§§§ Ignacio Alejandro Rodriguez-Jorquera,‖‖‖ Martha Orozco-Medina,### Alistair BA Boxall,†††† Murray A Rudd,‡‡‡‡ and Bryan W Brooks#*

Integrated Environmental Assessment and Management — Volume 00, Number 00—pp. 1–19
Received: 7 March 2019 | Returned for Revision: 26 April 2019 | Accepted: 24 June 2019 1

Workshop Synthesis

Towards Sustainable Environmental Quality: Priority Research Questions for the Australasian Region of Oceania

Sally Gaw,†† Andrew Harford,† Vincent Pettigrove,§ Graham Sevicke-Jones,‖ Therese Manning,# James Ataria,†† Tom Cresswell,‡‡ Katherine A Daffron,§§ Frederic DL Leusch,‖‖ Bradley Moggridge,## Marcus Cameron,††† John Chapman,‡‡‡ Gary Coates,§§§ Anne Colville,‖‖‖ Claire Death,### Kimberly Hageman,†††† Kathryn Hassell,§ Molly Hoak,‡‡‡‡ Jennifer Gadd,§§§§ Dianne F Jolley,‖‖‖‖‖ Ali Karami,#### Konstantinos Kotzakoulakis,‡‡‡‡‡ Richard Lim,‖‖‖‖‖ Nicole McRae,† Leon Metzeling,††††† Thomas Mooney,‡ Jackie Myers,§ Andrew Pearson,§§§§§ Minna Saaristo,‖‖‖‖‖‖ Dave Sharley,###### Julia Stuthe,‡‡‡‡‡‡ Oliver Sutherland,‡‡‡‡‡‡ Oliver Thomas,§§§§§§ Louis Tremblay,†† ‖‖‖‖‖‖‖‖‖‖ Waitangi Wood,####### Alistair BA Boxall,††††††† Murray A Rudd,‡‡‡‡‡‡‡ and Bryan W Brooks§§§§§§§*

Environmental Toxicology and Chemistry—Volume 39, Number 8—pp. 1485–1505, 2020
Received: 11 March 2020 | Revised: 3 April 2020 | Accepted: 22 May 2020 1485

Critical Review

Toward Sustainable Environmental Quality: Priority Research Questions for Asia

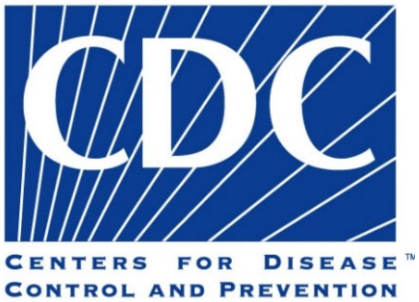
Kenneth M.Y. Leung,[a,b,*] Katie W.Y. Yeung,[a] Jing You,[c] Kyungho Choi,[d] Xiaowei Zhang,[e] Ross Smith,[f] Guang-Jie Zhou,[a] Mana M.N. Yung,[g] Carlos Arias-Barreiro,[h] Youn-Joo An,[i] S. Rebekah Burket,[j] Robert Dwyer,[k] Nathalie Goodkin,[l] Yii Siang Hii,[m] Tham Hoang,[n] Chris Humphrey,[o] Chuleemas Boonthai Iwai,[p] Seung-Woo Jeong,[q] Guillaume Juhel,[r] Ali Karami,[s] Katerina Kyriazi-Huber,[t] Kuan-Chun Lee,[u] Bin-Le Lin,[v] Ben Lu,[w] Patrick Martin,[l] Mae Grace Nillos,[x] Katharina Oginawati,[y] I.V.N. Rathnayake,[z] Yenny Risjani,[aa] Mohammad Shoeb,[bb] Chin Hon Tan,[r] Maria Claret Tsuchiya,[cc] Gerald T. Ankley,[dd] Alistair B.A. Boxall,[ee] Murray A. Rudd,[ff] and Bryan W. Brooks[c,l]

Global Horizon Scanning™

Brooks et al. 2013. *IEAM;* Furley et al. 2018. *IEAM;* Van den Brink et al. 2018. *Environ Toxicol Chem*; Fairbrother et al. 2019. *Environ Toxicol Chem* ; Gaw et al. 2019. *IEAM*; Leung et al. 2019. *Environ Toxicol Chem*; Brooks et al. 2026, In press. *Environ Toxicol Chem*

Why Horizon Scanning?

Environmental Public Health Practice









Environmental Health Practice Challenges and Research Needs for U.S. Health Departments

Bryan W. Brooks,[1] Justin A. Gerding,[2] Elizabeth Landeen,[3] Eric Bradley,[4] Timothy Callahan,[5] Stephanie Cushing,[6] Fikru Hailu,[7] Nancy Hall,[8] Timothy Hatch,[9] Sherise Jurries,[10] Martin A. Kalis,[2] Kaitlyn R. Kelly,[1] Joseph P. Laco,[2] Niki Lemin,[11] Carol McInnes,[12] Greg Olsen,[13] Robert Stratman,[14] Carolyn White,[15] Steven Wille,[16] and John Sarisky[2]

29 Priority Problem Statements for Common EH Programs

https://www.cdc.gov/environmental-health-practice/php/data-research/uncover-eh/index.html

Brooks et al. 2019. *Environ Health Perspect;* Gerding et al. 2019. *JEH*; Gerding et al. 2020. *AJPH*

What are the Key Research Needs for Onsite Wastewater?

NOW-R²

Needs for Onsite Wastewater Recycling Research

Unique Partnership with NOWRA (and many others!)

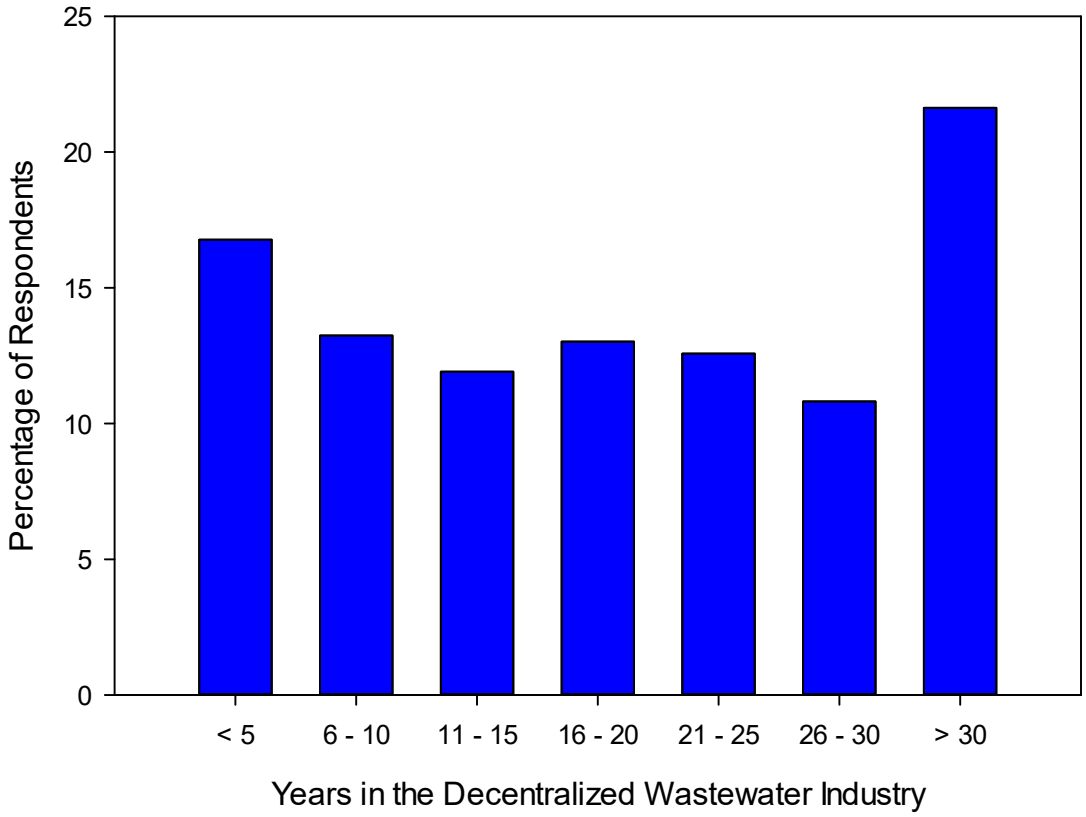
Steering Committee with Diverse Representation

Followed established survey and workshop synthesis methods

Survey input from 450+ professionals in 45 states from business, government, academic, NGOs

Synthesis workshop in San Marcos, Texas after NOWRA Mega-Conference

Years of Experience in Decentralized Wastewater



ADVANCEMENT OF THE **SCIENCE**

Identifying Workforce Education, Training, and Outreach Needs in Decentralized Wastewater and Distributed Water Reuse

Jamie Holodak
Honors College, Baylor University

Jacob K. Stanley, MS, PhD
Center for Reservoir and Aquatic Systems Research, Baylor University

Alissa H. Cox, MS, PhD
New England Onsite Wastewater Training Program, University of Rhode Island

Thomas W. Groves
National Onsite Wastewater Recycling Association

Anish Jantrania, MBA, PhD, PE
Department of Biological and Agricultural Engineering, Texas A&M University

Jeffrey Moeller, MS, PE
The Water Research Foundation

Kris Neset, MSM, PE
National Center for Environmental Health, Centers for Disease Control and Prevention

Christopher Walker, MSEH
National Environmental Health Association

Harry Zhang, PhD, PE
The Water Research Foundation

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Sara F. Heger, MS, PhD
Water Resources Center, University of Minnesota

Bryan W. Brooks, MS, PhD
Center for Reservoir and Aquatic Systems Research, Baylor University
Environmental Health Science Program, Department of Environmental Science,

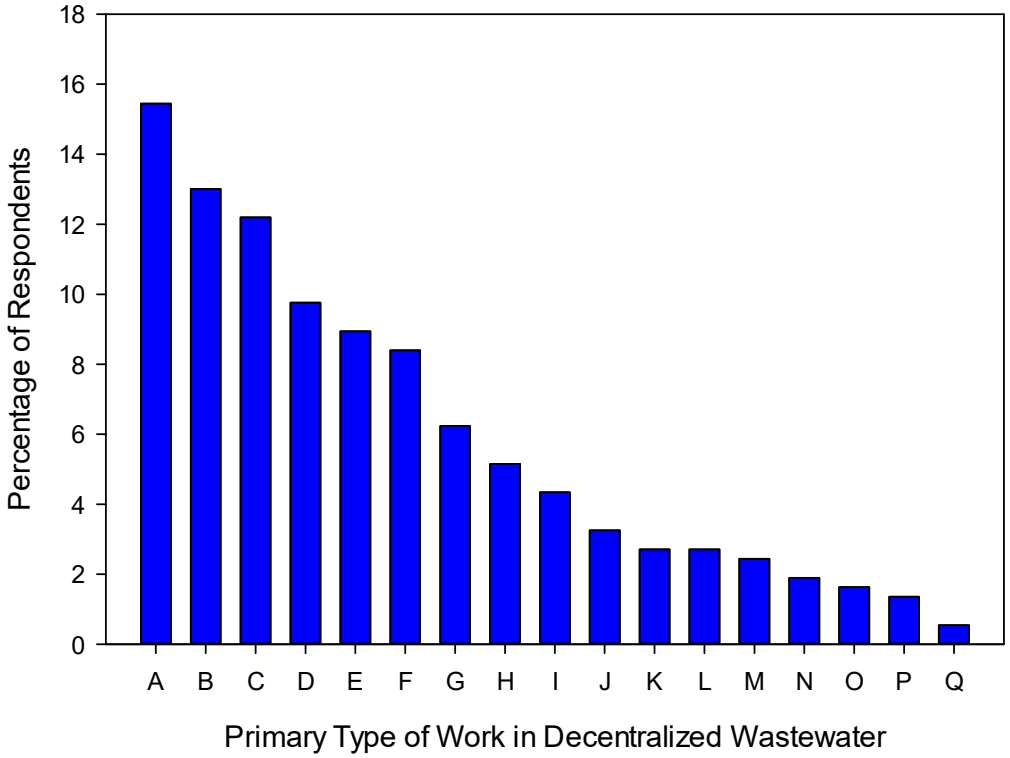
Abstract Although decentralized wastewater and distributed water reuse professionals represent a key part of environmental public health and environmental engineering, an understanding of workforce challenges has remained elusive. Here we begin to address the critical need of understanding education, training, and outreach needs for decentralized wastewater and distributed water reuse. We specifically engaged professionals working in health departments and other government agencies, industry, academia, and nongovernmental organizations. We examined workforce characteristics related to education, training, and outreach. We found that 37% of decentralized wastewater and distributed water reuse professionals plan to retire within 5 years, approximately 25% of these professionals do not hold any type of certification, and education and training are insufficient to meet current workforce demands.

We further report 10 problem statements associated with timely education, training, and outreach needs, which represent important opportunities for improving the practice of decentralized wastewater and distributed water reuse. Strategic education, training, and outreach activities are necessary to ensure workforce preparedness, to promote education with owners of onsite technologies, and to expand advanced training and translational research programs in decentralized wastewater and distributed water reuse. Our findings can specifically support decision making aimed at sustaining and advancing the decentralized wastewater and distributed water reuse workforce.

10 Problem Statements for Training, Education and Outreach

Holodak et al 2023. *Journal of Environmental Health*

What is the primary type of work you do in decentralized wastewater?



A: Engineer; B: Environmental Health; C: Installer; D: Designer; E: Regulator at tribal, territorial or state level; F: Academic researcher; G: Service provider; H: Public inspector; I: Academic educator; J: Soil scientist; K: Government researcher; L: Soil evaluator; M: Pumper: N: Operator; O: Private inspector; P: Regulator at federal level; Q: Funder

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Holodak et al 2023. *Journal of Environmental Health*

Identifying Key Research Questions

- Address important gaps in knowledge
- Be answerable through a realistic research design
- Have a factual answer that does not depend on value judgments
- Cover a spatial and temporal scale that could realistically be addressed by a research team (e.g., $5-10M over 5 years)
    - Not a PhD thesis. Not a “moonshot”.
- Not be answerable by “it all depends” or “yes” or “no”
- If related to impact and interventions, should contain a subject, an intervention, and a measurable outcome

We asked professionals two questions…

What technical scientific research question (e.g., innovation, design, resiliency, resource recovery), if answered, would substantially advance the science of decentralized wastewater over the next decade?

What environmental management (e.g., science-policy, implementation, enforcement) research question, if answered, would substantially advance the practice of decentralized wastewater over the next decade?

28 Priority Research Questions Identified Across Six Themes

Themes and Priority Research Questions
Treatment, Performance, and Resource Recovery
How can we develop onsite systems that can be implemented and interfaced within broader circular economy and food–energy–water nexus efforts, while maintaining effectiveness and reliability across different economic conditions and geographic regions?
How can we develop effective, efficient, and economically viable treatment approaches with resource recovery (e.g., nutrients, septage, water) for diverse beneficial reuse applications?
How can we adapt, develop, and validate robust treatment approaches, which are effective for diverse constituents (e.g., per- and polyfluoroalkyl substances (PFAS), pharmaceuticals and personal care products (PPCPs), quaternary ammonia compounds (QACs), fats, oil, and grease (FOG)) for various water reuse applications (e.g., fit for purpose)?
How does soil characteristics and heterogeneity influence design, efficacy, and reliability, particularly with influences of lot size (e.g., planning, zoning), climate, geomorphology, and waste stream diversity (e.g., PFAS, QACs, PPCPs)?
How can we identify and develop interventions for failing systems (e.g., due to diverse reasons) that are smaller, more affordable, scalable, and user-friendly, particularly given current funding inequities?
Resiliency, Efficacy, and Sustainability
How could sensors improve integration, sustainability, affordability, and management?
How can implementation of onsite systems to enhance resiliency be demonstrated, considering climate change, natural disasters, and economic gradients?
How can a multiscale model be developed to assist in integration of waste and wastewater infrastructure?
How could a decentralized needs assessment afford better understanding of the needs across the U.S. and how decentralized wastewater is influenced by regulations?
Environmental Quality and Public Health
What are the public health, environmental, social, and economic impacts of failing systems?
How does climate change or extreme weather impact operation and performance of decentralized wastewater management systems infrastructure?
What water quality parameters are appropriate for achieving risk reduction among various reuse applications?
What is the contribution of emerging contaminants from onsite wastewater sources to groundwater contamination?
What is the quantifiable role and relative contribution of decentralized wastewater compared to other contaminant sources on water quality?
What is the current capacity for septage treatment and disposal or appropriate use that is adequate for the community needs and safety?
Assessment, Monitoring, and Operation and Maintenance
What are the definitions of malfunction, failure, and end of life, and how are these applied to operation and maintenance schema for protecting public health and the environment?
How do we encourage ongoing maintenance for all onsite systems looking more toward the public/private utility model?
What data, including geographic information systems (GIS), materials, flow, design and other elements, are collected and easily accessible, and how are they currently used?
What current and future systems, including data, outreach, education, and regulation, are economically viable for performance, operation, and maintenance monitoring?
How does public understanding of decentralized systems influence utilization, funding support, and failure rates?
Implementation
How can more consistent regulations be developed and implemented across the U.S.?
How does maintenance, regulations, and enforcement influence the treatment effectiveness of systems?
How can we develop regional asset management strategies for decentralized wastewater and distributed water reuse to individual and cluster sustainable solutions and achieve responsible management that is economically viable?
What are economical effective solutions for septage treatment?
Regulations, Enforcement, and Environmental Justice
What are the best practices (e.g., link to creative mechanisms for property inspection at point of sale), principles, and guidelines that can be developed for implementation, considering the existing workforce shortages and regulatory challenges of implementing a common code or National Pollutant Discharge Elimination System (NPDES) program for decentralized wastewater?
When, what kind, and where are environmental justice issues pervasive for decentralized wastewater, and how can this challenge be informed by new and existing data collection approaches (e.g., census, real estate transactions, geospatial information)?
How can individuals with ongoing challenges with decentralized systems (e.g., renters, homeowners, small businesses) receive adequate support to ensure equitable access to services intended to protect public health and the environment?
What are the most effective (e.g., successful), efficient, and equitable approaches to link all people at the local level to identify, apply, and secure available and new funding opportunities, while revisioning distribution of revenue streams (e.g., installation fees) for strategic efforts (e.g., research)?

Brooks et al 2026. *Environmental Science & Technology* https://pubs.acs.org/doi/full/10.1021/acs.est.5c02138

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Brooks et al 2026. *Environmental Science & Technology* https://pubs.acs.org/doi/full/10.1021/acs.est.5c02138

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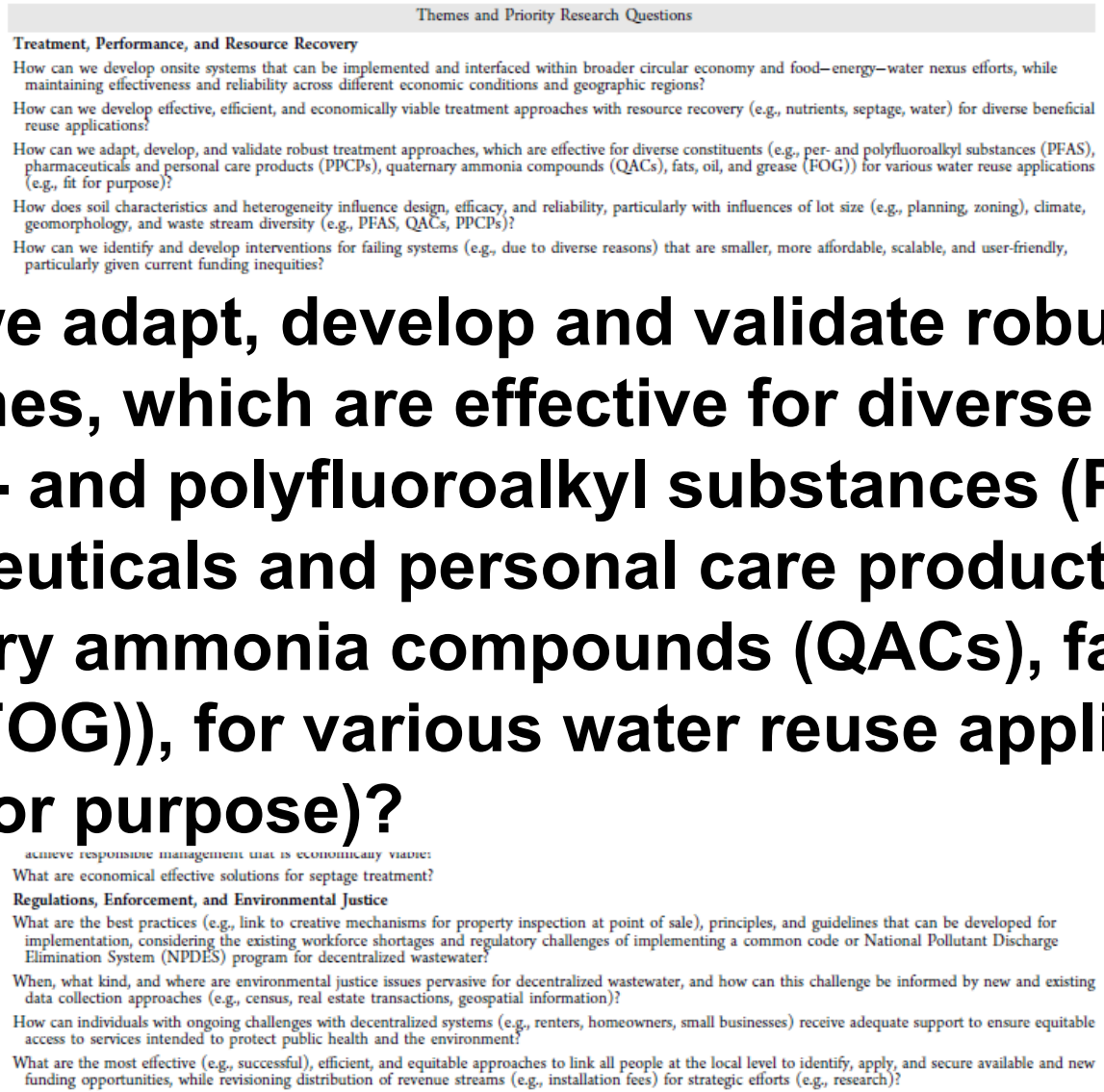
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How can we develop effective, efficient, and economically viable treatment approaches with resource recovery (e.g., nutrients, septage, water) for diverse beneficial reuse applications?
How can we adapt, develop, and validate robust treatment approaches, which are effective for diverse constituents (e.g., per- and polyfluoroalkyl substances (PFAS), pharmaceuticals and personal care products (PPCPs), quaternary ammonia compounds (QACs), fats, oil, and grease (FOG)) for various water reuse applications (e.g., fit for purpose)?
How does soil characteristics and heterogeneity influence design, efficacy, and reliability, particularly with influences of lot size (e.g., planning, zoning), climate, geomorphology, and waste stream diversity (e.g., PFAS, QACs, PPCPs)?
How can we identify and develop interventions for failing systems (e.g., due to diverse reasons) that are smaller, more affordable, scalable, and user-friendly, particularly given current funding inequities?
Resiliency, Efficacy, and Sustainability
How could sensors improve integration, sustainability, affordability, and management?
How can implementation of onsite systems to enhance resiliency be demonstrated, considering climate change, natural disasters, and economic gradients?
How can a multiscale model be developed to assist in integration of waste and wastewater infrastructure?

How can implementation of onsite systems to enhance resiliency be demonstrated, considering climate change, natural disasters and economic gradients?

How do we encourage ongoing maintenance for all onsite systems looking more toward the public/private utility model?
What data, including geographic information systems (GIS), materials, flow, design and other elements, are collected and easily accessible, and how are they currently used?
What current and future systems, including data, outreach, education, and regulation, are economically viable for performance, operation, and maintenance monitoring?
How does public understanding of decentralized systems influence utilization, funding support, and failure rates?
Implementation
How can more consistent regulations be developed and implemented across the U.S.?
How does maintenance, regulations, and enforcement influence the treatment effectiveness of systems?
How can we develop regional asset management strategies for decentralized wastewater and distributed water reuse to individual and cluster sustainable solutions and achieve responsible management that is economically viable?
What are economical effective solutions for septage treatment?
Regulations, Enforcement, and Environmental Justice
What are the best practices (e.g., link to creative mechanisms for property inspection at point of sale), principles, and guidelines that can be developed for implementation, considering the existing workforce shortages and regulatory challenges of implementing a common code or National Pollutant Discharge Elimination System (NPDES) program for decentralized wastewater?
When, what kind, and where are environmental justice issues pervasive for decentralized wastewater, and how can this challenge be informed by new and existing data collection approaches (e.g., census, real estate transactions, geospatial information)?
How can individuals with ongoing challenges with decentralized systems (e.g., renters, homeowners, small businesses) receive adequate support to ensure equitable access to services intended to protect public health and the environment?
What are the most effective (e.g., successful), efficient, and equitable approaches to link all people at the local level to identify, apply, and secure available and new funding opportunities, while revisioning distribution of revenue streams (e.g., installation fees) for strategic efforts (e.g., research)?

Brooks et al 2026. *Environmental Science & Technology* https://pubs.acs.org/doi/full/10.1021/acs.est.5c02138

28 Priority Research Questions Identified Across Six Themes



Themes and Priority Research Questions

Treatment, Performance, and Resource Recovery

How can we develop onsite systems that can be implemented and interfaced within broader circular economy and food–energy–water nexus efforts, while maintaining effectiveness and reliability across different economic conditions and geographic regions?

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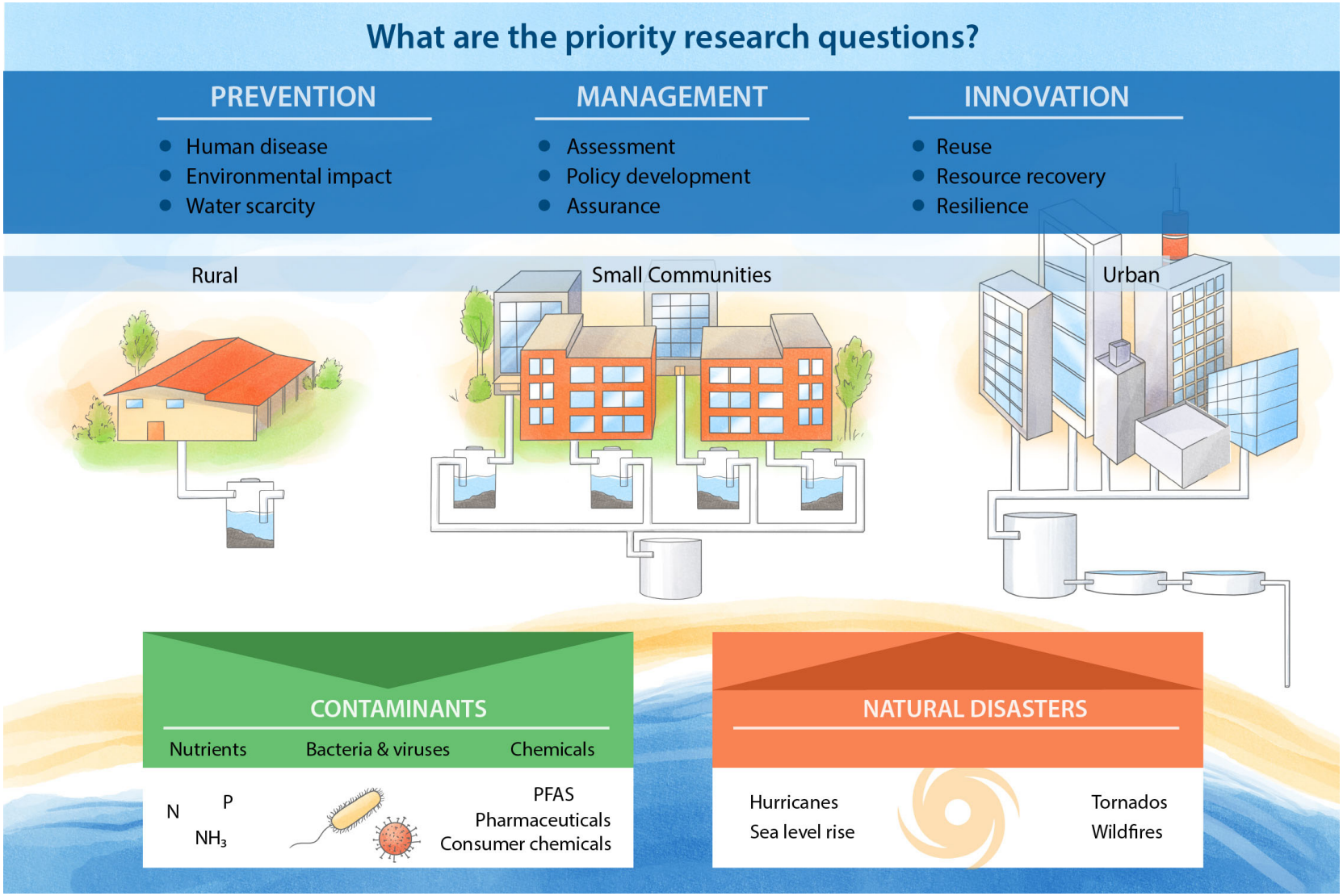
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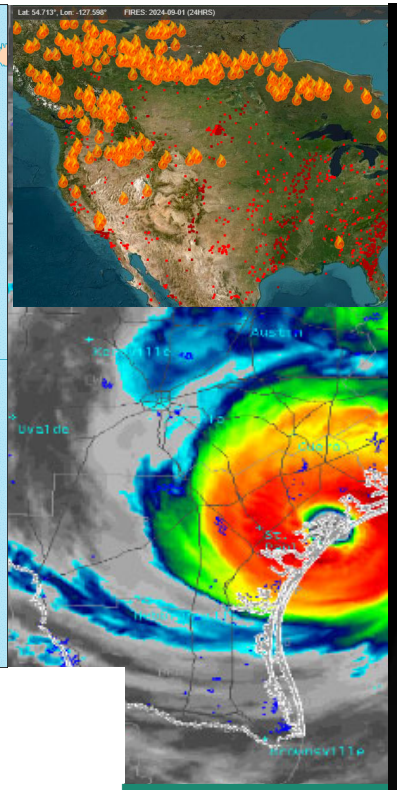
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Impacts from Disasters are Increasing around the World

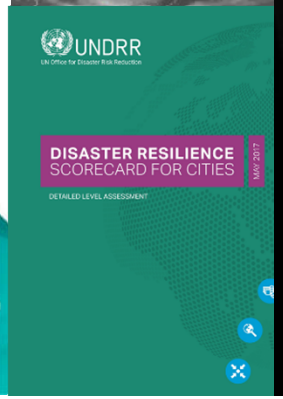
What is the Sendai Framework for Disaster Risk Reduction?

The Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework) was the first major agreement of the post-2015 development agenda and provides Member States with concrete actions to protect development gains from the risk of disaster.



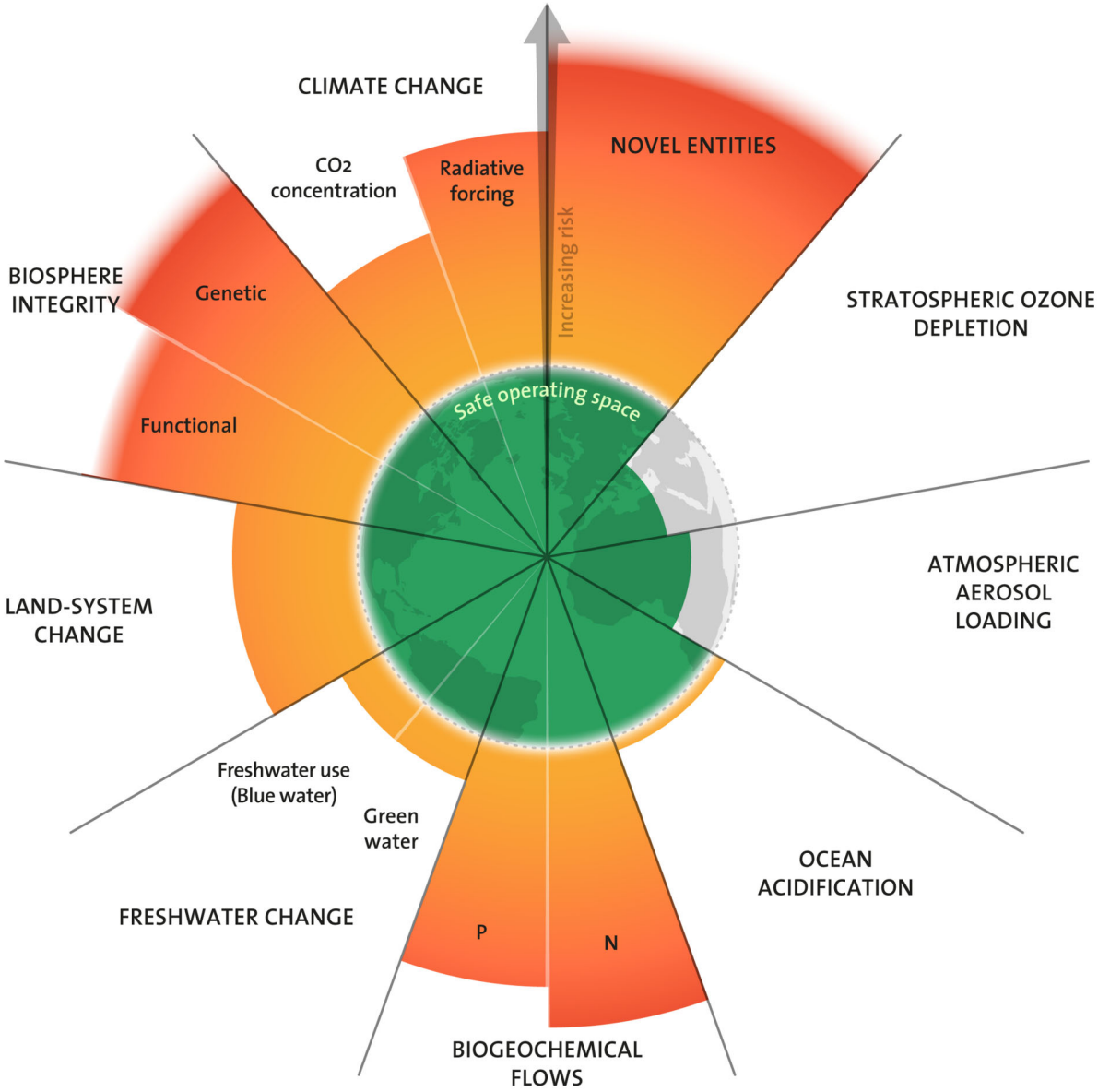






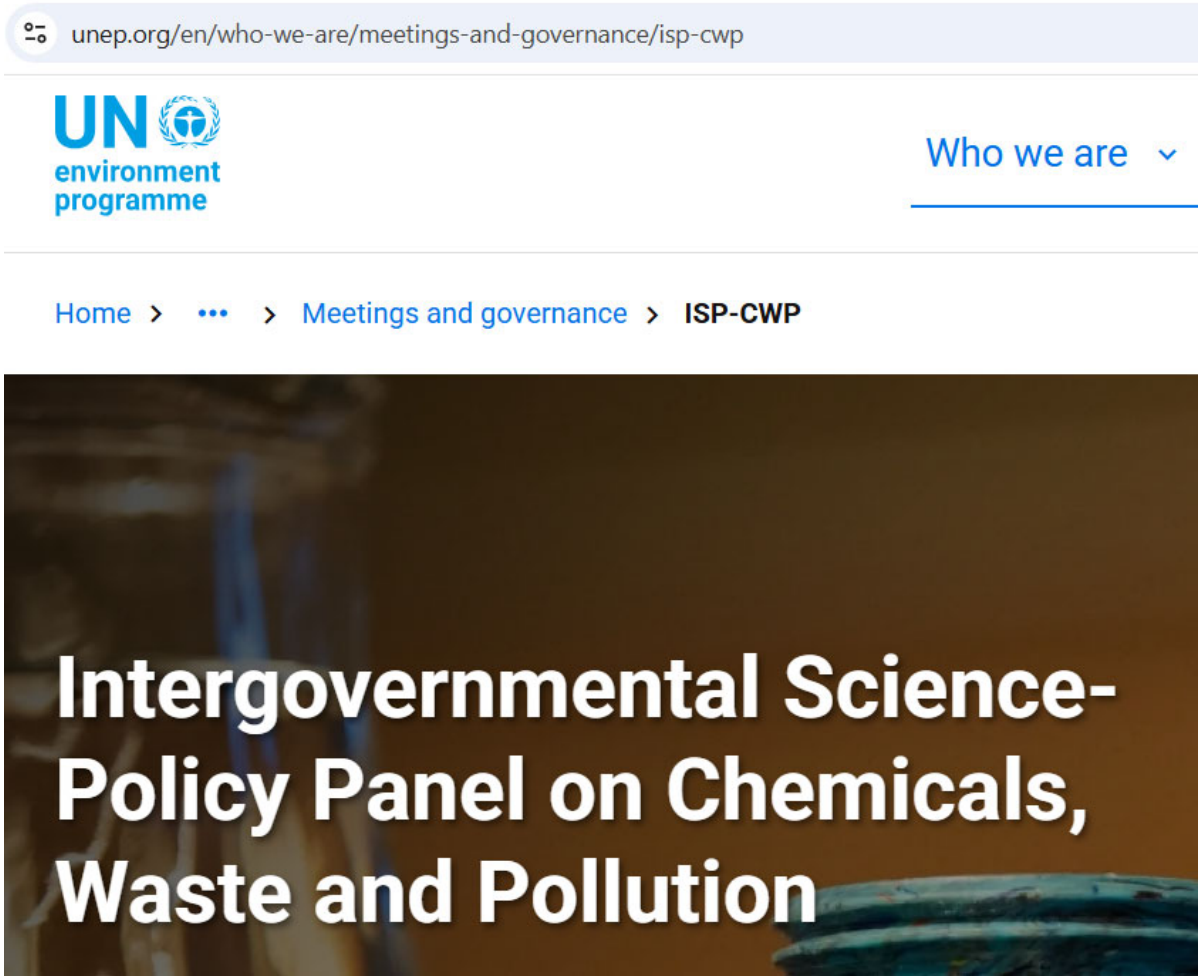


Earth System Boundaries for Novel Entities?



www.stockholmresilience.org/research/planetary-boundaries.html

Earth System Boundaries for Novel Entities? An Intergovernmental Science-Policy Panel on Chemicals, Waste and Pollution...



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Policy Analysis

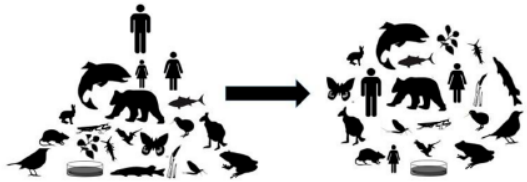
Toward a Global Understanding of Chemical Pollution: A First Comprehensive Analysis of National and Regional Chemical Inventories

Zhanyun Wang,* Glen W. Walker, Derek C. G. Muir, and Kakuko Nagatani-Yoshida

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At least 350,000 chemicals and mixtures of chemicals registered for global production and use. In 2018, 28,712 for New Zealand…more, more and more…

Chemicals, Waste and Pollution Prevention



Orienting from Indigenous Knowledge:
From Anthropocentric Toward Ecocentric Systems-based Management

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We need a global science-policy body on chemicals and waste

Major gaps in current efforts limit policy responses

ZHANYUN WANG, ROLF ALTENBURGER, THOMAS BACKHAUS, ADRIAN COVACI, MIRIAM L. DIAMOND, JOAN O. GRIMALT, RAINER LOHMANN, ANDREAS SCHÄFFER, MARTIN SCHERINGER, [...], AND NORIYUKI SUZUKI +2 authors Authors Info & Affiliations

SCIENCE · 19 Feb 2021 · Vol 371, Issue 6531 · pp. 774-776 · DOI: 10.1126/science.abe9090

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Policy Analysis

Outside the Safe Operating Space of the Planetary Boundary for Novel Entities

Linn Persson,* Bethanie M. Carney Almroth, Christopher D. Collins, Sarah Cornell, Cynthia A. de Wit,* Miriam L. Diamond, Peter Fantke, Martin Hassellöv, Matthew MacLeod, Morten W. Ryberg, Peter Søgaard Jørgensen, Patricia Villarrubia-Gómez, Zhanyun Wang, and Michael Zwicky Hauschild

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Perspective

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The Human Exposome: Integrating the Environment, Human Health, and Society for the Next 60 years

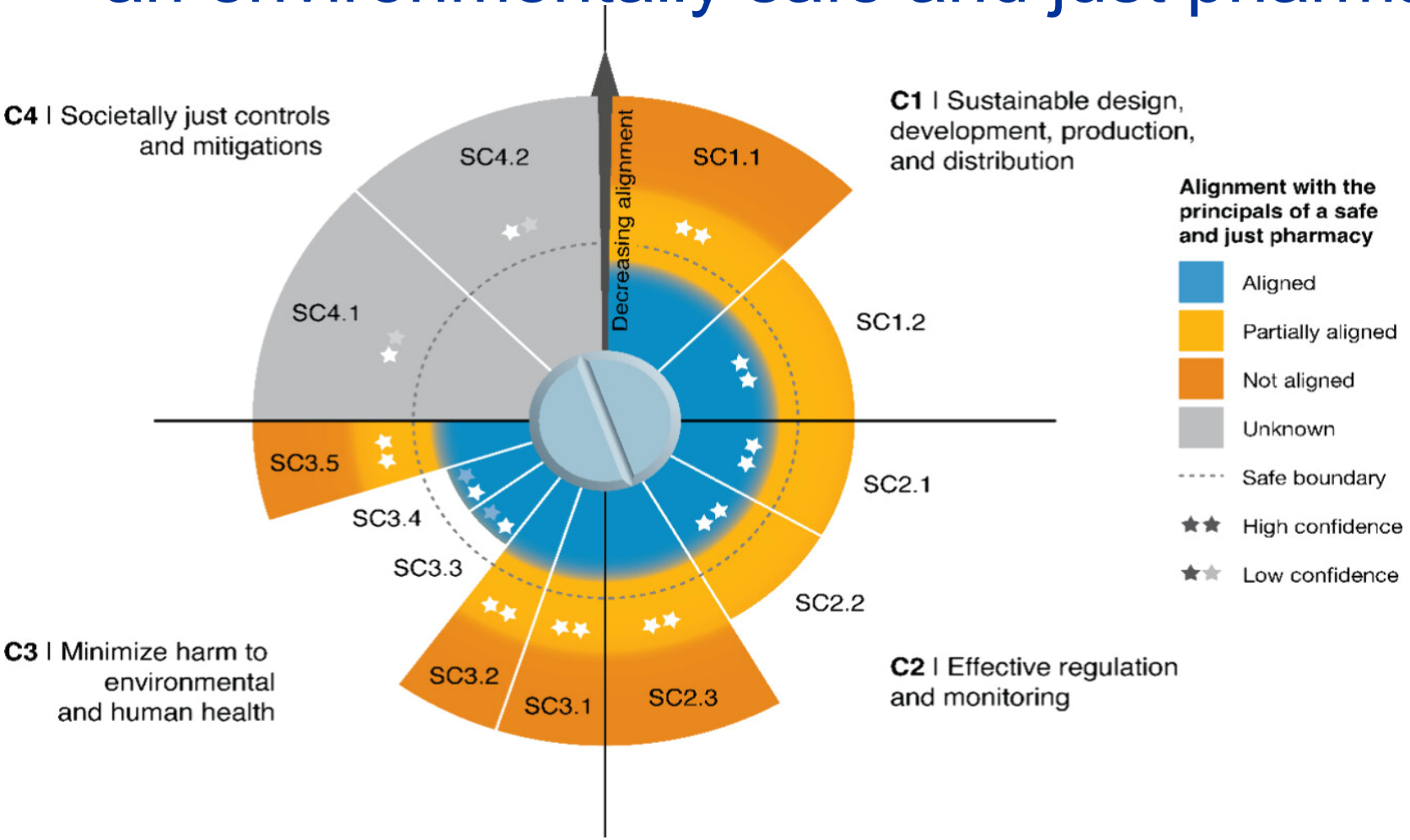
Published as part of Environmental Science & Technology special issue "60th Anniversary of Environmental Science and Technology".

Pablo Gago-Ferrero,* Alexandria B. Boehm, Heileen Hsu-Kim, Xiang-Dong Li, Jacqueline MacDonald Gibson, Martine Vrijheid, Bin Wang, and Julie Zimmerman

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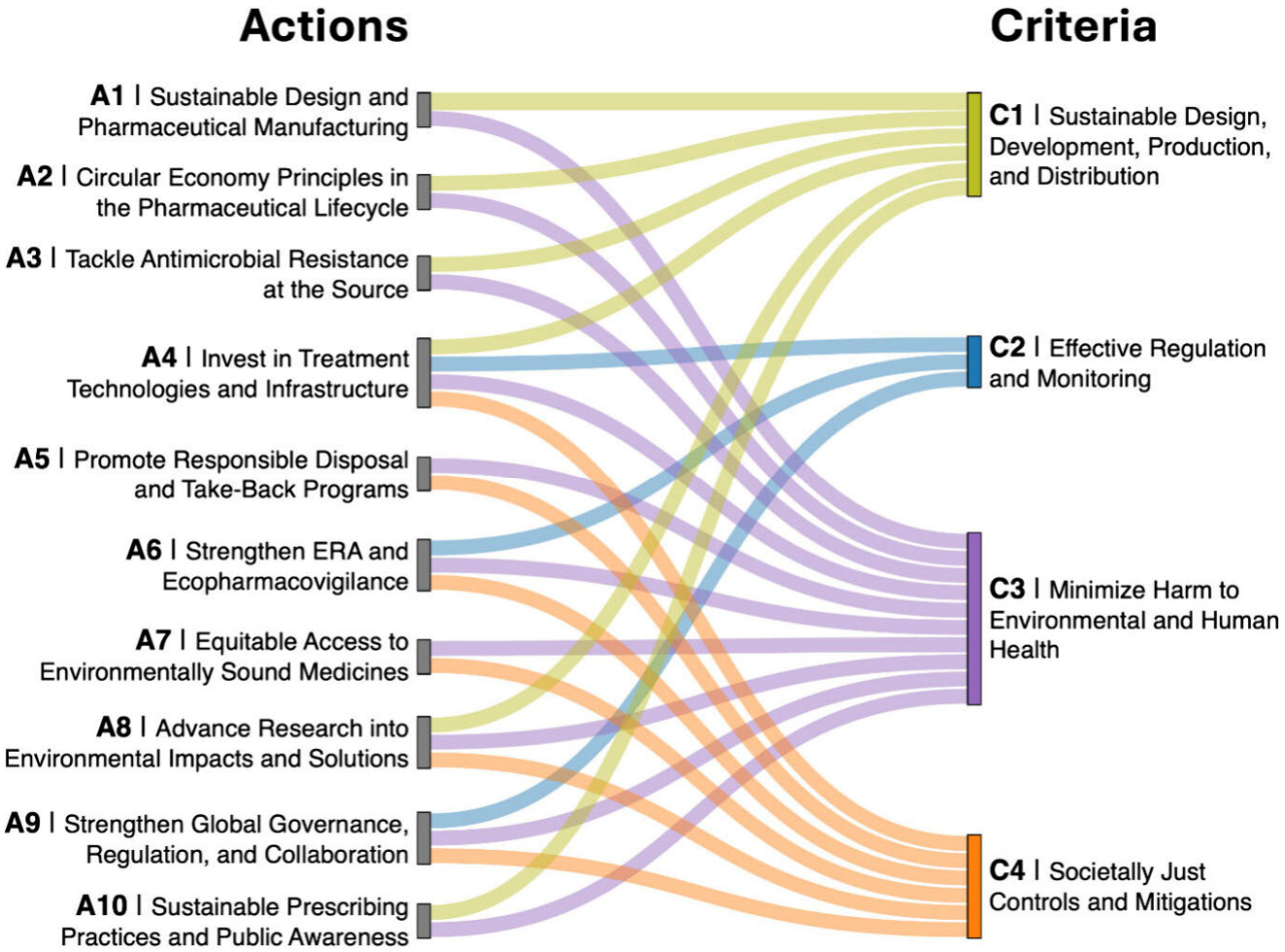
Wang et al 2020. *ES&T*; Wang et al. 2021. *Science*; Persson et al. 2022. *ES&T*; Ataria et al. 2023. *ES&T* ; Gago-Ferrero et al. 2026. *ES&T*

Earth System Boundaries for Novel Entities? Pharmaceuticals are exceeding new criteria for an environmentally safe and just pharmacy…



Boxall et al. 2026. *ES&T*

Earth System Boundaries for Novel Entities? Pharmaceuticals require actions to realize an environmentally safe and just pharmacy…





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Policy Analysis

Environmentally Safe and Just Pharmacy: A Framework and Action Plan for Operating within the Earth System Boundary for Novel Entities

Published as part of Environmental Science & Technology special issue "Safe and Just Earth System Boundaries for Novel Entities".

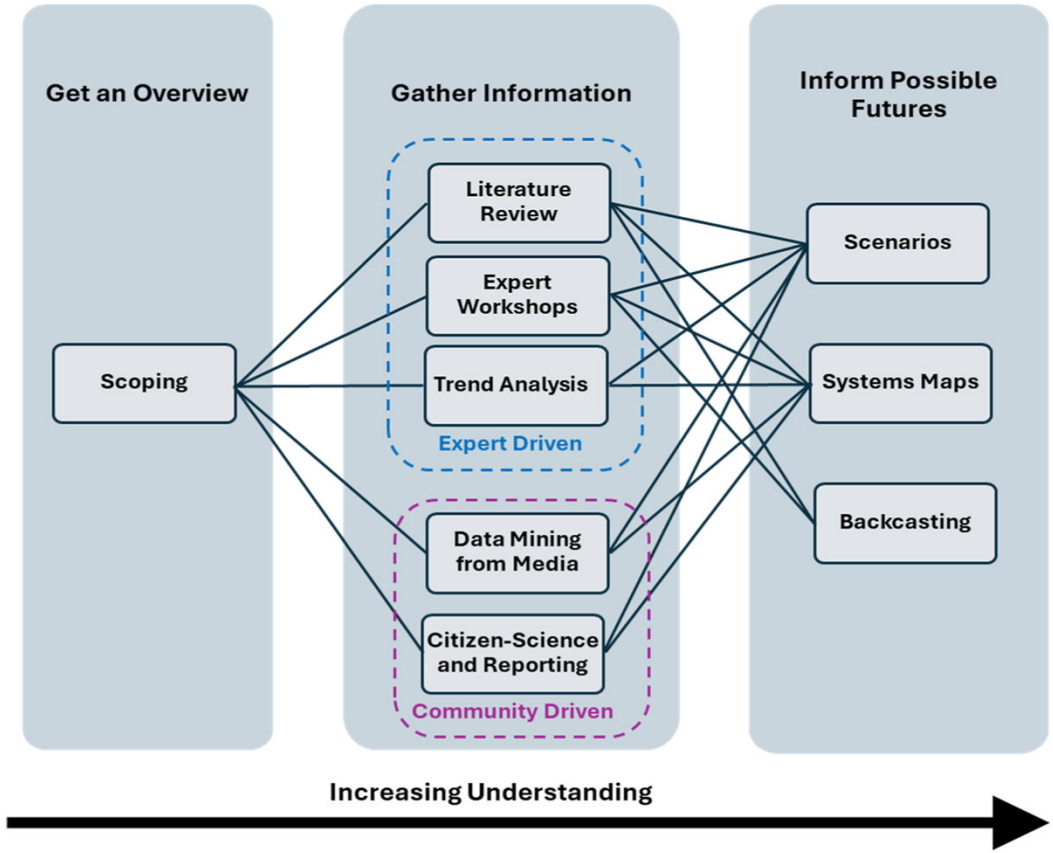
Alistair B. A. Boxall,* Priyanie Amerasinghe, Sally Beckenham, Michael G. Bertram, Sally Gaw, Austin D. Gray, Karen A. Kidd, Laura M. Langan, Kenneth M. Y. Leung, Jack L. Manera, Karina S. B. Miglioranza, Rik Oldenkamp, and Bryan W. Brooks*

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Boxall et al. 2026. *ES&T*

Where do we go from here with novel entities?

We must continue to innovate, and think and work together!



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Perspective

Aligning Horizon Scanning Approaches with Differing Needs and Topics at the Science–Policy Interface on Chemicals, Waste, and Pollution

Gabriel Sigmund,* Ricardo O. Barra, Michael G. Bertram, Miriam L. Diamond, Alex T. Ford, İpek İmamoğlu, Jinhui Li, Rainer Lohmann, Andreas Schäffer, Martin Scheringer, Kateřina Šebková, Maria Clara V. M. Starling, Noriyuki Suzuki, Penny Vlahos, Roland Weber, and Bryan W. Brooks*

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Sigmund et al 2026. *ES&T*

Global Estuaries Monitoring (GEM) Programme



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UNEP

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

国家海洋环境监测中心
NATIONAL MARINE ENVIRONMENTAL MONITORING CENTER

UNIVERSITY of York

Baylor University

world harbour project

sims sydney institute of marine science

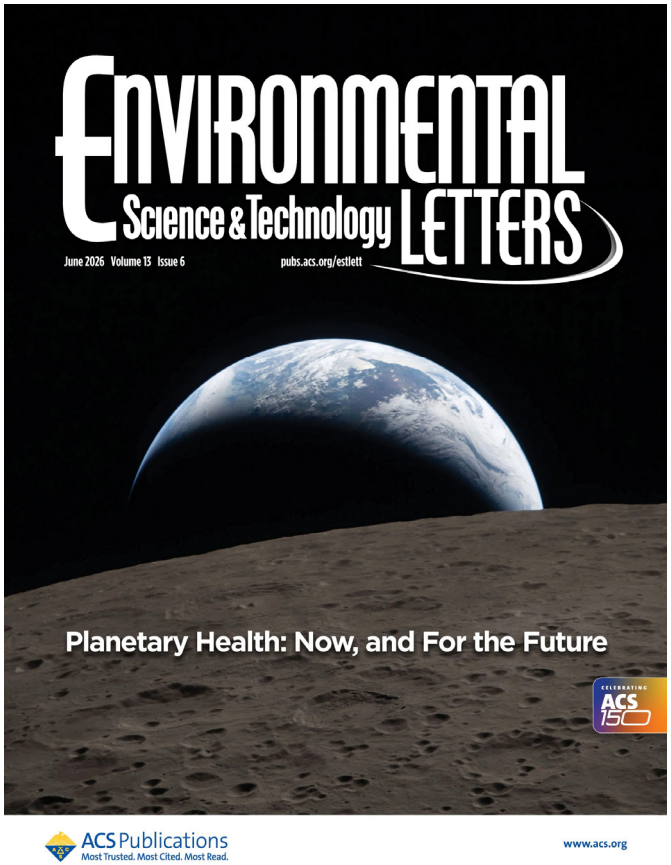
MEL
State Key Laboratory of Marine Environmental Science

Phase I



www.globalestuaries.org; Adedipe et al. 2024. *Environ Int*; Luo et al. 2025. *Mar Pollut Bull*

Planetary Health



"the health of human civilization and the state of the natural systems on which it depends"

Whitmee et al. 2015. *Lancet*



- Engage Earth System Boundaries for Novel Entities
- Realize an *Earth System Exposome*
- Innovate Chemistry for the Future

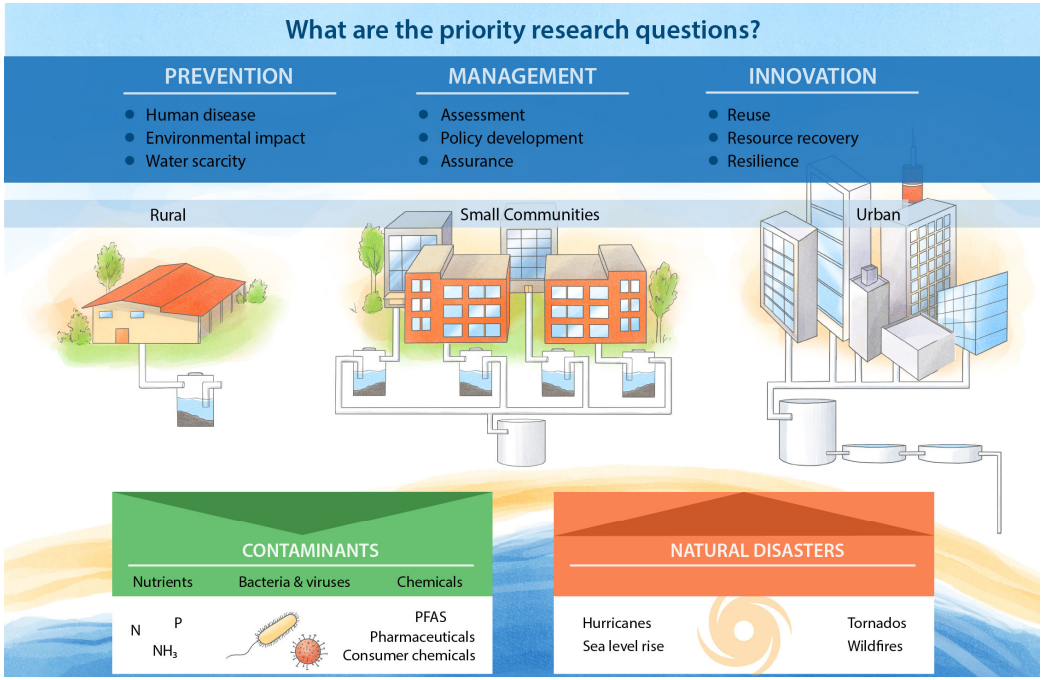
Brooks, Anastas, Diamond, Klanova. *ES&T Letters*. 2026

Identifying Opportunities for Planetary Health



Thank you!

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Policy Analysis

Identifying Priority Research Questions for Decentralized Wastewater

Bryan W. Brooks,* Timothy Callahan, Jacob K. Stanley, Jamie Holodak, Kevin M. Stroski, Alissa H. Cox, Thomas W. Groves, Anish Jantrania, Jeff C. Moeller, Kris Neset, Christopher Walker, Harry Zhang, Amal Bakchan, Kelly D. Alley, Jim Bell, Allison Blodig, Eric Casey, Donna Cosper, Victor D'Amato, Mark A. Elliott, Greg Graves, Roxanne Groover, Robert Himschoot, Mary G. Lusk, Jillian Maxcy-Brown, David Meints, Rojelio Mejia, Matt Pace, Benjamin J. Ryan, Brian Scheffe, Tom Schimelfenig, June E. Wolfe, and Sara F. Heger

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Thank you!







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Thank you!



Joe C. Yelderman, Jr.