The Science of Science:
Identifying Priority Research Needs for Environmental Science, Engineering & Health

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Environmental Health Science Program
Department of Environmental Science, Baylor University
Editor in Chief, *Environmental Science & Technology Letters*

Global Horizon Scanning™

Sustainable Development Goals

www.globalgoals.org

Food

Energy

Water

THE GLOBAL GOALS
For Sustainable Development

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Pollution

is the world's largest environmental cause of disease and premature death

Pollution disproportionately kills the poor and the vulnerable.

Nearly **92 percent of pollution-related deaths occur in low-income and middle-income countries.** Children face the highest risks because small exposures to chemicals in utero and in early childhood can result in lifelong disease, disability, premature death, as well as reduced learning and earning potential.

In 2015, diseases caused by pollution were responsible for

9 million premature deaths.

That is 16 percent of all global deaths.

3 x

15 x

Exposures to contaminated air, water and soil kill more people than a high-sodium diet, obesity, alcohol, road accidents, or child and maternal malnutrition. They are also responsible for three times as many deaths as AIDS, tuberculosis, and malaria combined, and for nearly 15 times as many deaths as war and all forms of violence.

"Chemical pollution is a great and growing global problem."

The *Lancet* Commission on pollution and health

Philip J Landrigan, Richard Fuller, Nereus J R Acosta, Olusoji Adeyi, Robert Arnold, Niladri (Nil) Basu, Abdoulaye Bibi Baldé, Roberto Bertollini, Stephan Bose-O'Reilly, Jo Ivey Boufford, Patrick N Breysse, Thomas Chiles, Chulabhorn Mahidol, Awa M Coll-Seck, Maureen L Cropper, Julius Fobil, Valentin Fuster, Michael Greenstone, Andy Haines, David Hanrahan, David Hunter, Mukesh Khare, Alan Krupnick, Bruce Lanphear, Bindu Lohani, Keith Martin, Karen V Mathiasen, Maureen A McTeer, Christopher J L Murray, Johanita D Ndahimananjara, Frederica Perera, Janez Potočnik, Alexander S Preker, Jairam Ramesh, Johan Rockström, Carlos Salinas, Leona D Samson, Karti Sandilya, Peter D Sly, Kirk R Smith, Achim Steiner, Richard B Stewart, William A Suk, Onno C P van Schayck, Gautam N Yadama, Kandeh Yumkella, Ma Zhong

Lancet 2018; 391: 462–512

Executive summary

Pollution endangers planetary health, destroys eco-

ipbes
Science and Policy for People and Nature

Enter se

About ▾ | Work programme ▾ | News ▾ | Calendar

Home / Work programme / Global assessment / Global Assessment Report on Biodiversity and Ecosystem Services

Global Assessment Report on Biodiversity and Ecosystem Services

"While more food, energy and materials than ever before are now being supplied to people in most places, this is increasingly at the expense of nature's ability to provide such contributions in the future, and frequently undermines nature's many other contributions, which range from water quality regulation to sense of place. The biosphere, upon which humanity as a whole depends, is being altered to an unparalleled degree across all spatial scales. Biodiversity – the diversity within species, between species and of ecosystems – is declining faster than at any time in human history."

Why Global Horizon Scanning?

- The Global Horizon Scanning Project aims to identify important and timely environmental quality research needs
- Research questions identified, if answered, would markedly advance toward more sustainable environmental quality over the next decade
  - Unique partnership with SETAC (and ACS ENVR, AGRO in NA)

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Global. Transparent. Inclusive. Multidisciplinary. Multisector.

The Global Workshops

Africa	Langebaan, South Africa
Asia	Singapore, Singapore
Europe	Barcelona, Spain
Latin America	Buenos Aires, Argentina
North America	Salt Lake City, USA
Oceania	Nelson, New Zealand

Each workshop trichaired by experts from academia, government and business at global SETAC meetings

149 research questions identified





Global Megatrends and Environmental Quality

Urbanization and Concentration of Chemical Use

Understand and Manage Cumulative Stressors

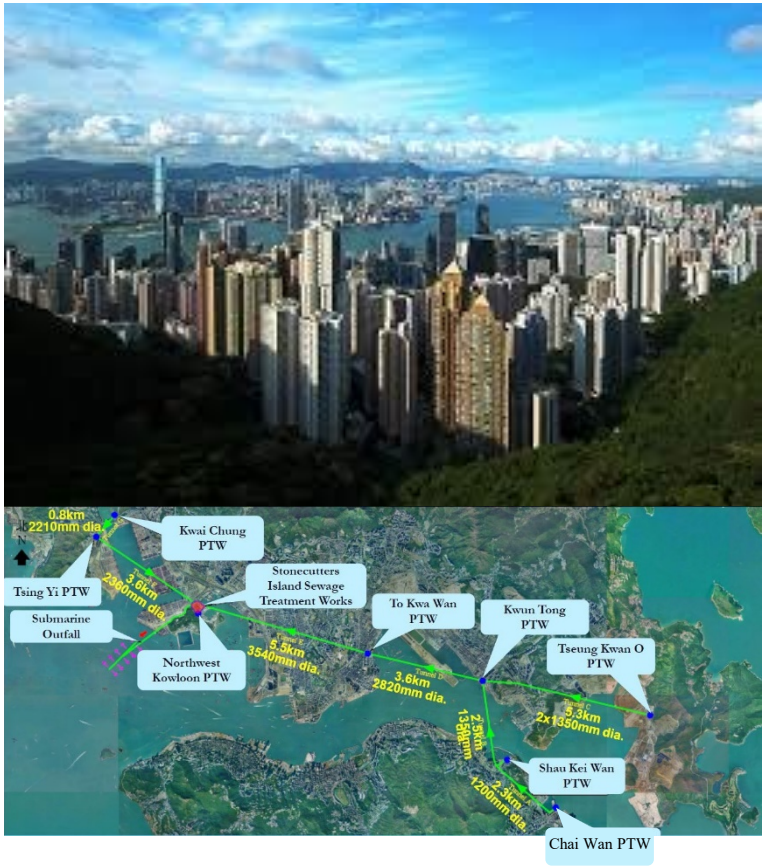
How is urbanization impacting ecological and human exposure to and release of contaminants?

More People Now Live in Cities than Ever Before...

By 2050:

- World population reaches 9.6 billion (UN)
  - In 2014, 55% lived in Asia-Pacific
- 70% of all people will live in urban areas (UN)
  - 50% of Asia-Pacific by 2018
  - 22 megacities in Asia by 2030
- Concentration of resource consumption (food, energy, water) and chemical use in urban areas

Urbanization, Water and Food Security - Hong Kong “Sewersheds” and Landfills?



Urbanization, Water and Food Security - Hong Kong “Sewersheds” and Landfills?

Urbanization, Water and Food Security - Hong Kong “Sewersheds” and Landfills?

Antimicrobial Resistance Selection Exceedances in Hong Kong “Sewersheds” and Landfills?

Environment International 115 (2018) 89–96

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Select antibiotics in leachate from closed and active landfills exceed thresholds for antibiotic resistance development

S.S. Chung[a,*], J.S. Zheng[a], S.R. Burket[b], B.W. Brooks[b,c]

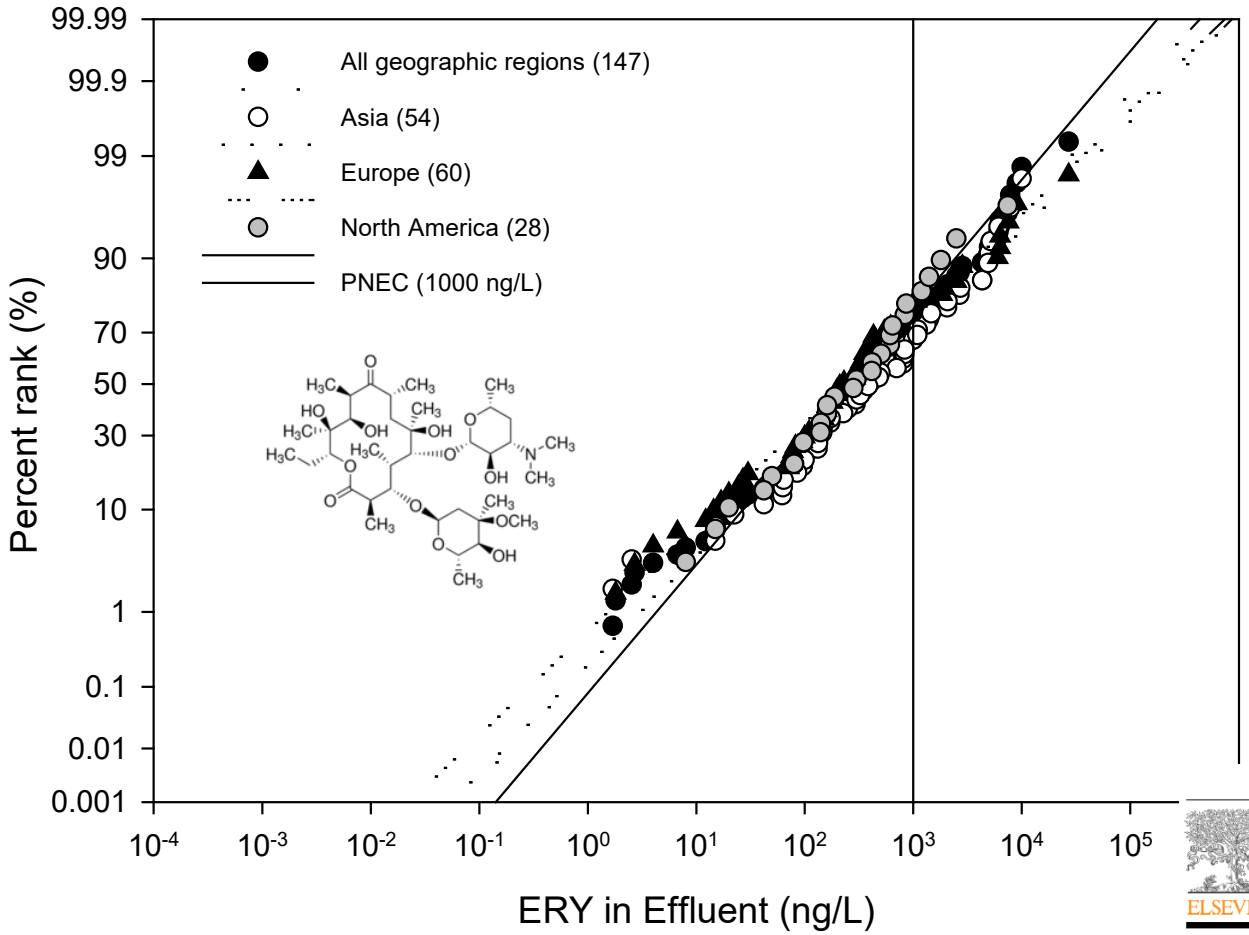
Inherent Connections among Human Health, Ecosystems and Environmental Quality

Coupled Human and Ecological Frameworks

Integrative Needs for Public Health and the Environment

What environmental factors, natural or anthropogenic, lead to antibiotic resistance?

What/where should we prioritize for further study?



Effluents in Asia exceeded an ABR PNEC 33% of the time compared to 18% for North America and 20% in Europe

Environmental Pollution 238 (2018) 440–451

Contents lists available at ScienceDirect

Environmental Pollution

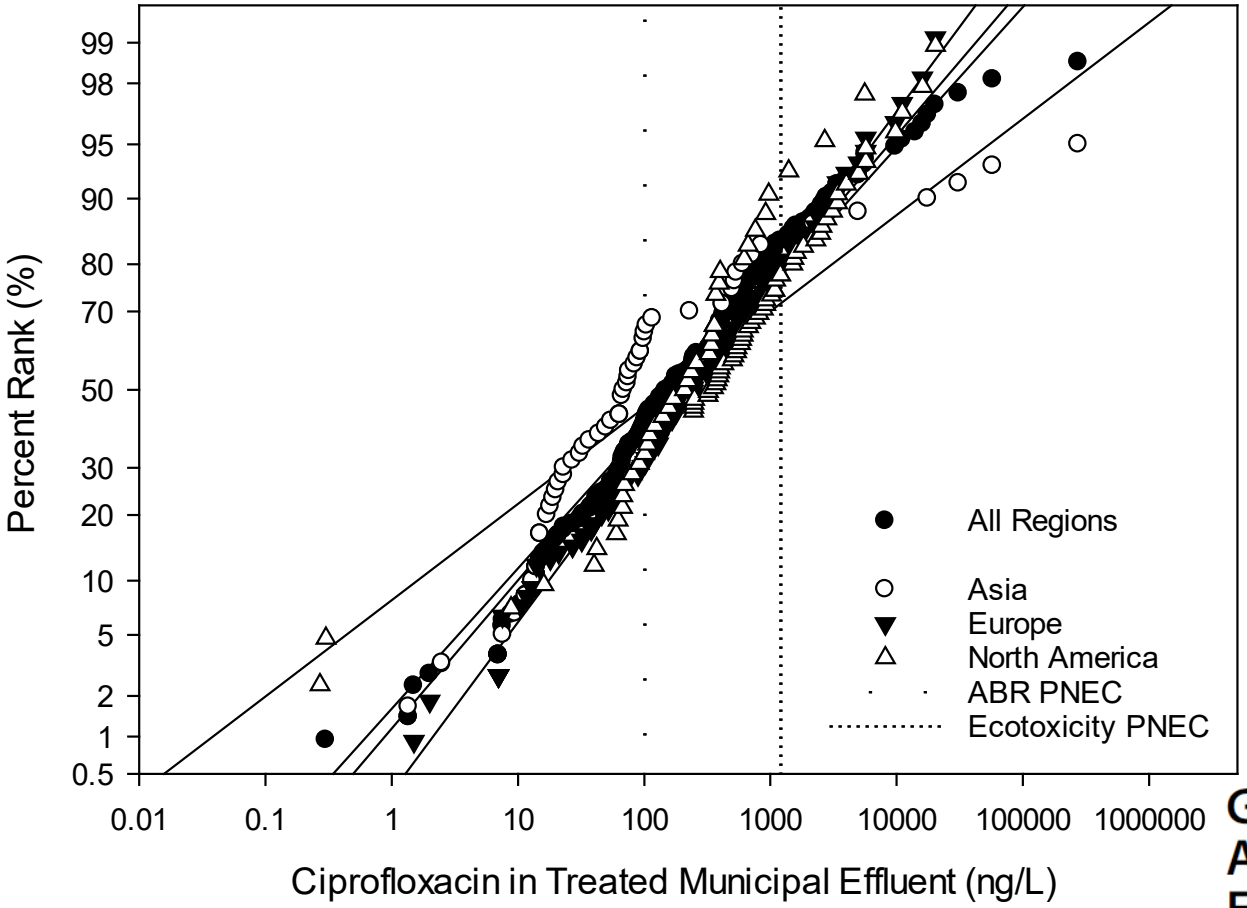
journal homepage: www.elsevier.com/locate/envpol

Global review and analysis of erythromycin in the environment: Occurrence, bioaccumulation and antibiotic resistance hazards☆

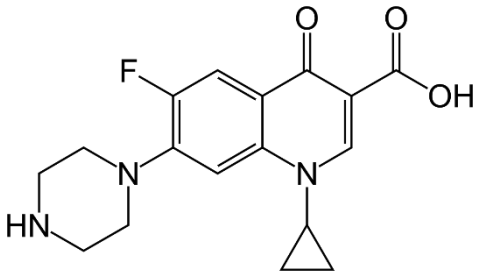
Bruno Henrique Schafhauser [a], Lauren A. Kristofco [b], Cíntia Mara Ribas de Oliveira [a, *], Bryan W. Brooks [b, c, **]

Schafhauser et al. 2018; Bengtsson-Palme and Larsson 2016.

What/where should we prioritize for further study?



Across all geographic regions, 58% of municipal effluents exceeded the ABR PNEC (100 ng/L) for ciprofloxacin



Global Aquatic Hazard Assessment of Ciprofloxacin: Exceedances of Antibiotic Resistance Development and Ecotoxicological Thresholds

Kaitlyn R. Kelly*, Bryan W. Brooks*,†,1

Kelly and Brooks. 2018; Kraupner et al 2018.

Urbanization, Water and Food Security - Hong Kong "Sewersheds" and Landfills?

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

Article

Cite This: J. Agric. Food Chem. XXXX, XXX, XXX–XXX

pubs.acs.org/JAFC

At the Intersection of Urbanization, Water, and Food Security: Determination of Select Contaminants of Emerging Concern in Mussels and Oysters from Hong Kong

S. Rebekah Burket,[†] Yelena Sapozhnikova,[‡] J. S. Zheng,[§] Shan Shan Chung,[§] and Bryan W. Brooks*[,†]

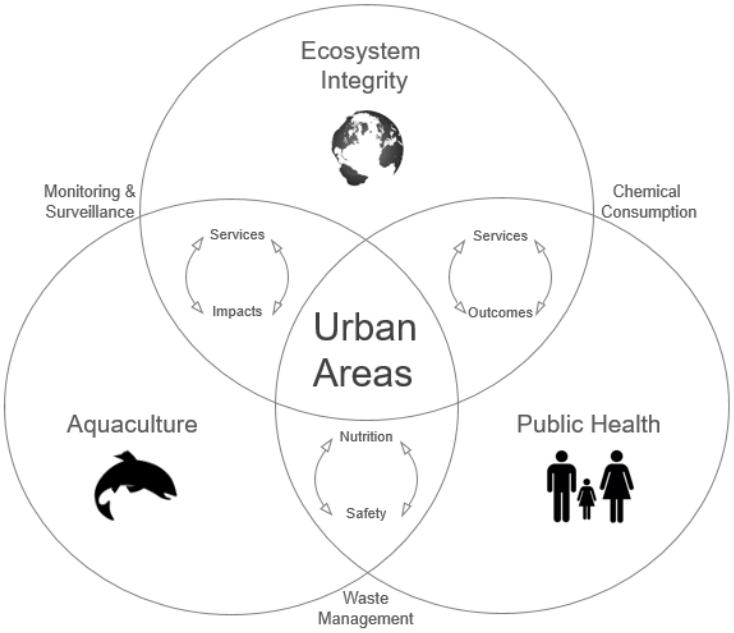
Global Megatrends and Environmental Quality

The Food-Energy-Water Nexus

Sustainable water, air & food – quantity and quality

Given increasing population growth and per capita demand for seafood in Asia, how can we develop sustainable aquaculture practices while protecting environmental quality, particularly in coastal waters?

More People Now Live in Cities than Ever Before...



By 2050:

- By 2025, 2/3 of the global population will live in water-stressed regions (US DoS)
- Global food production must increase by ~50% (~70% by calories; UN)
- Aquaculture growing ~3-5x faster than land based agriculture (FAO)
- 80% of global sewage untreated (UN)

Brooks and Conkle. 2019. *Comp Biochem Physiol C Toxicol Pharmacol*

Environmental Chemistry and Engineering Science

Solution-based Needs for Natural Resources

New approaches and technologies are needed to manage waste and recover resources for human and ecological uses

How can we ensure that the drinking water that is derived from marginal sources (e.g., brackish groundwater in certain aquifers, eutrophic lakes / rivers) is acceptable for human consumption?

Environmental Chemistry and Engineering Science

Solution-based Needs for Natural Resources

New approaches and technologies are needed to manage waste and recover resources for human and ecological uses

What environmental and human health risks should be managed and monitored in water reuse?

Inherent Connections among Human Health, Ecosystems and Environmental Quality

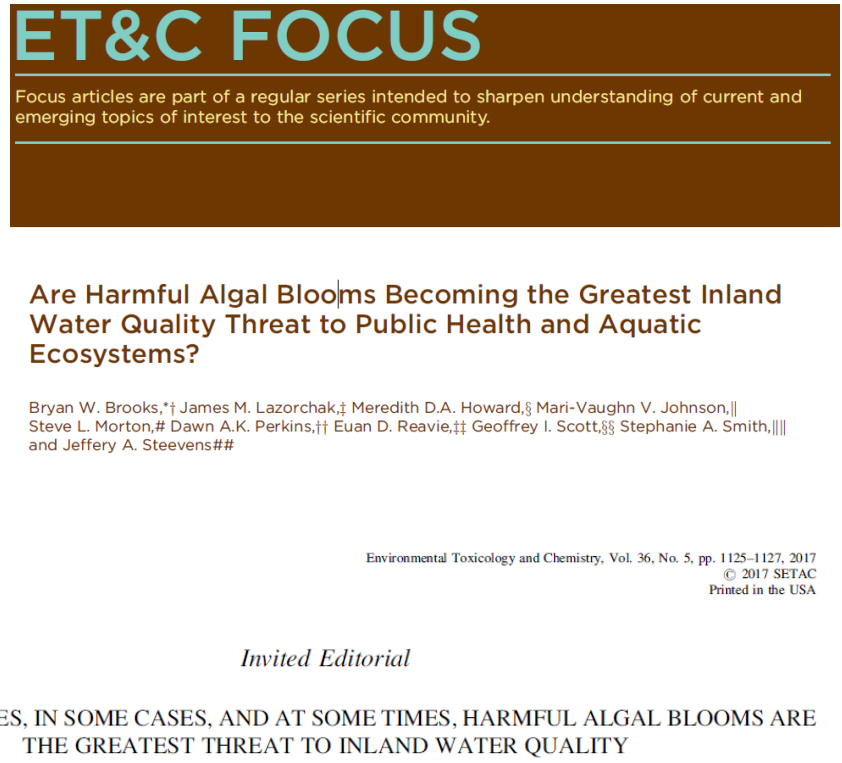
Coupled Human and Ecological Frameworks

Integrative Needs for Public Health and the Environment

Which are the environmental variables that trigger the production of algal toxins in the environment? Does exposure through trophic levels threaten human health?

HABs: Greatest Water Quality Threat?

- Forcing factors include climate change, salinization, landscape modification, nutrient enrichment, water management
- Future needs
  - Predictive models
  - Sensors for blooms and toxins
  - Analytical standards
  - Criteria and standards
  - Adaptive management and remedial interventions



ET&C FOCUS

Focus articles are part of a regular series intended to sharpen understanding of current and emerging topics of interest to the scientific community.

Are Harmful Algal Blooms Becoming the Greatest Inland Water Quality Threat to Public Health and Aquatic Ecosystems?

Bryan W. Brooks,*† James M. Lazorchak,‡ Meredith D.A. Howard,§ Mari-Vaughn V. Johnson,‖ Steve L. Morton,# Dawn A.K. Perkins,†† Euan D. Reavie,‡‡ Geoffrey I. Scott,§§ Stephanie A. Smith,‖‖ and Jeffery A. Steevens##

SETAC PRESS

Environmental Toxicology and Chemistry, Vol. 36, No. 5, pp. 1125–1127, 2017

Invited Editorial

IN SOME PLACES, IN SOME CASES, AND AT SOME TIMES, HARMFUL ALGAL BLOOMS ARE THE GREATEST THREAT TO INLAND WATER QUALITY

Brooks et al 2016, 2017. *ETC*

HABs: Greatest Water Quality Threat?

- Forcing factors include climate change, salinization, landscape modification, nutrient enrichment, water management
- Future needs
  - Predictive models
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  - Analytical standards
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  - Adaptive management and remedial interventions

NIH National Institutes of Health
Turning Discovery Into Health

NIEHS Oceans and Human Health
Center for Climate Change Interactions

Environmental Chemistry and Exposure Science

Current Environmental Assessment Concerns

New models, analytical tools needed to understanding fate and exposure of historical and emerging contaminants

How do we develop better broad-screening analytical and information processing techniques that do not require pre-selection of target contaminants?

Per- and Polyfluoroalkyl Substances

ENVIRONMENTAL Science & Technology LETTERS

pubs.acs.org/journal/estlcu

Global Perspective

Scientific Basis for Managing PFAS as a Chemical Class

Carol F. Kwiatkowski,* David Q. Andrews, Linda S. Birnbaum, Thomas A. Bruton, Jamie C. DeWitt, Detlef R. U. Knappe, Maricel V. Maffini, Mark F. Miller, Katherine E. Pelch, Anna Reade, Anna Soehl, Xenia Trier, Marta Venier, Charlotte C. Wagner, Zhanyun Wang, and Arlene Blum

Cite This: https://dx.doi.org/10.1021/acs.estlett.0c00255

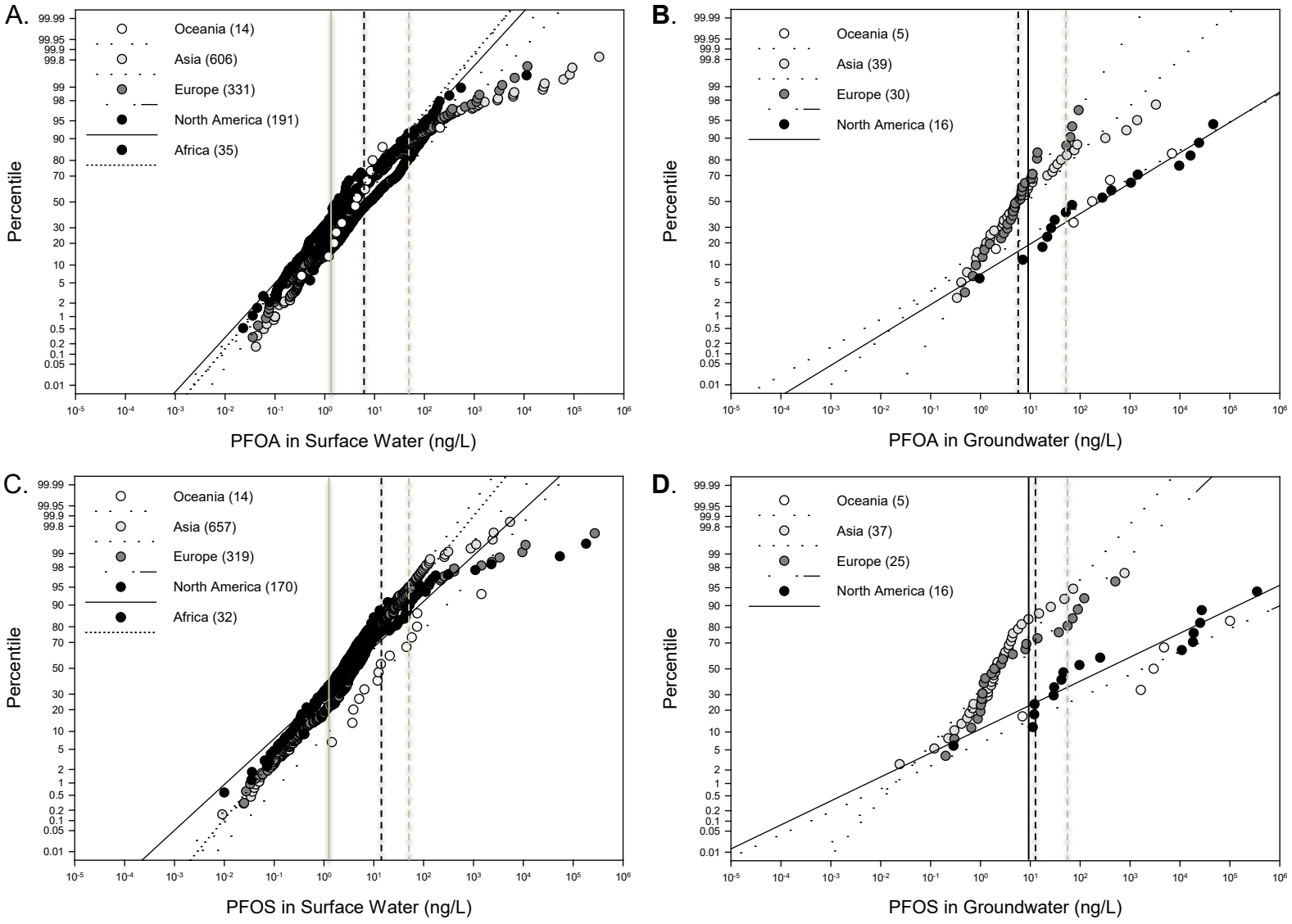
Read Online

"The basis for the class approach is presented in relation to their physicochemical, environmental, and toxicological properties. Specifically, the high persistence, accumulation potential, and/or hazards (known and potential) of PFAS studied to date warrant treating all PFAS as a single class.

We conclude with options for how governments and industry can apply the class-based approach, emphasizing the importance of eliminating non-essential uses of PFAS, and further developing safer alternatives and methods to remove existing PFAS from the environment."

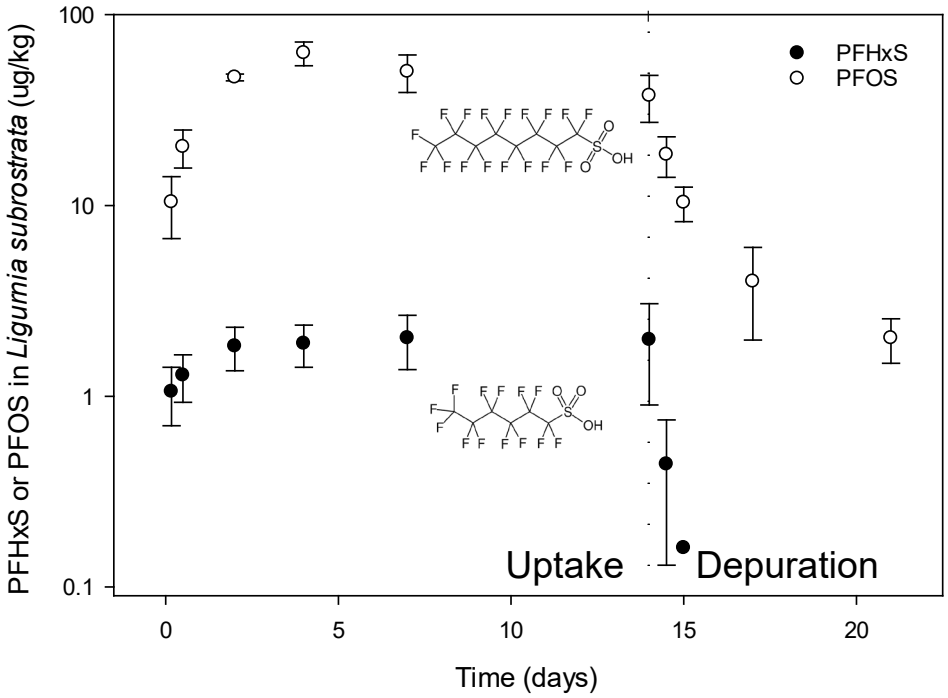
Kwiatkowski et al 2020. *ETC Letters*

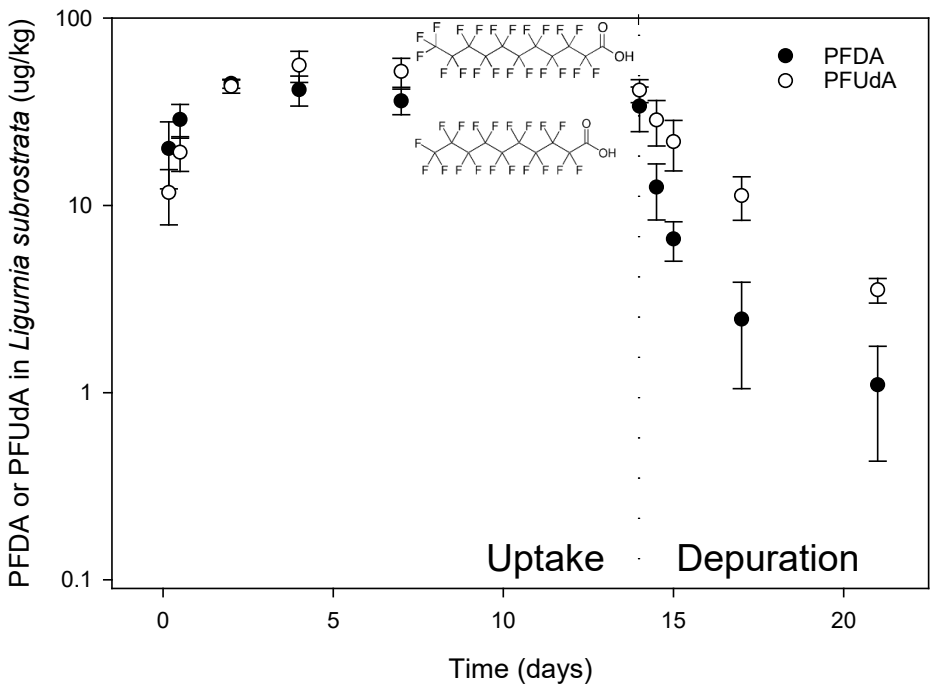
Per- and Polyfluoroalkyl Substances



Sims, Stroski et al. In review.

Per- and Polyfluoroalkyl Substances





Uptake and elimination of A. PFHxS and PFOS, and B. PFDA and PFUdA by the freshwater pond mussel, *Ligurnia subrostrata*. A 14 day uptake period occurred with exposure to PFHxS, PFOS, and PFDA at 10 µg/L and PFUdA at 1 µg/L. The vertical reference line denotes when a seven day elimination period was initiated.

Unionid Pondmussel, *Ligumia subrostrata*

Steevens et al. In preparation

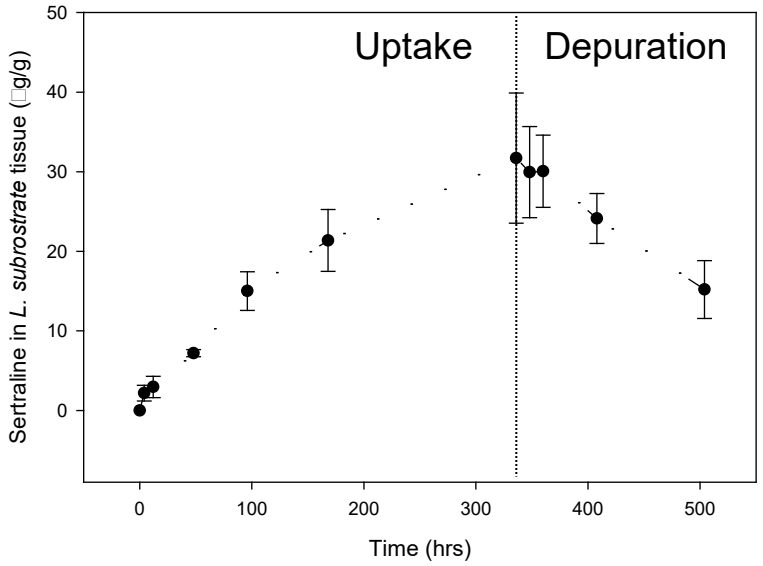
Protecting Biodiversity and Environmental Quality

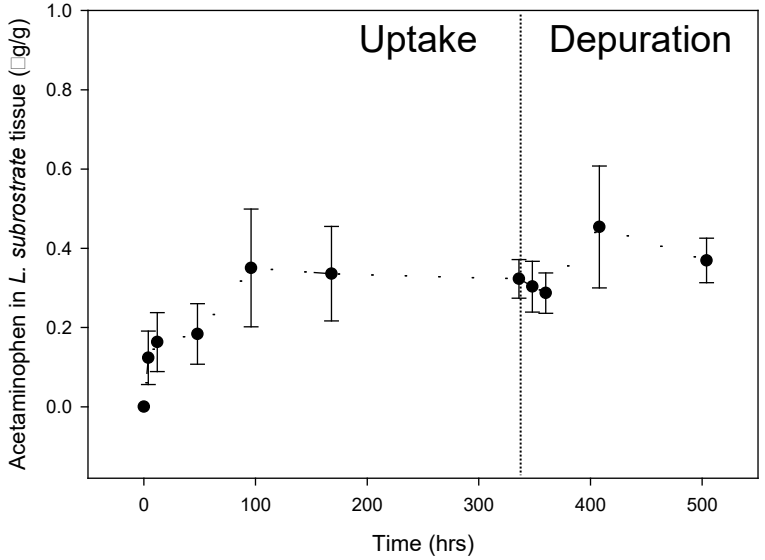
Current Environmental Assessment Concerns

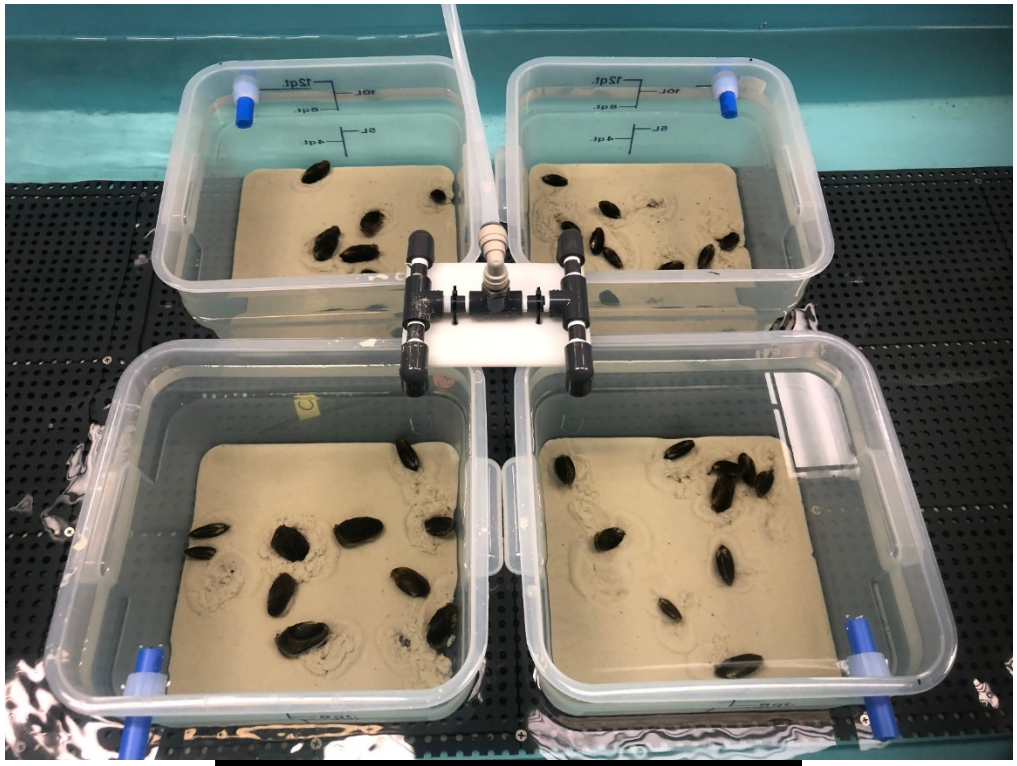
Protection of local species depends on data from model organisms

What is the sensitivity of regional species to contaminants that will allow us to better predict impacts on local ecosystems?

Inanga
Galaxias maculatus







Unionid Pondmussel, *Ligumia subrostrata*

Burket et al. in preparation; www.museum.state.il.us

Inherent Connections among Human Health, Ecosystems and Environmental Quality

Coupled Human and Ecological Frameworks

Integrative Needs for Public Health and the Environment

How can we extrapolate effects data across species using evolutionary conservation of biological pathways?

Comparative Pharmacology?

Ecotoxicology often relied on mammalian toxicology for mechanistic information, to generate hypotheses

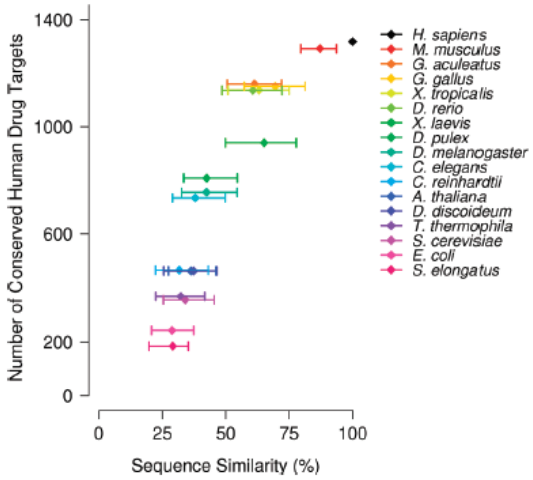
Medicines had been used as positive controls, during basic physiology experiments

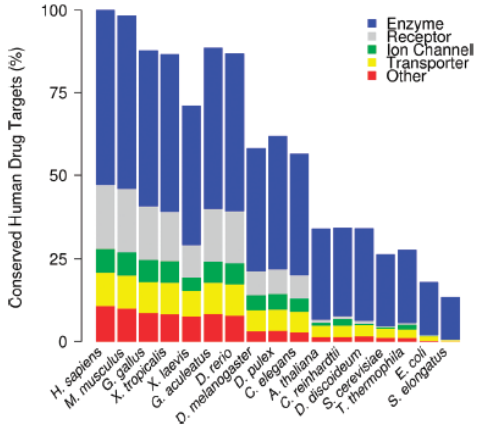
More information is known about pharmaceuticals than any other class of environmental contaminants

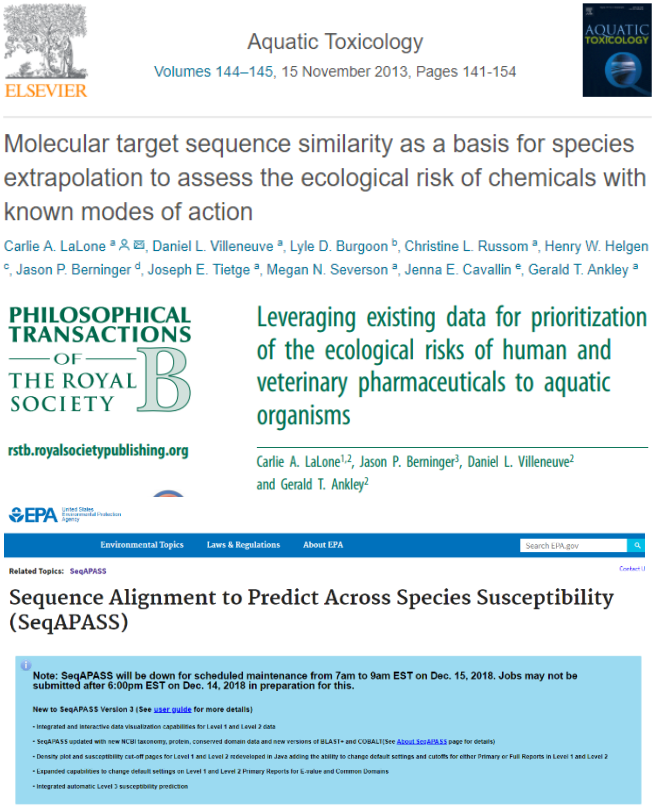
Imagine what we could learn…

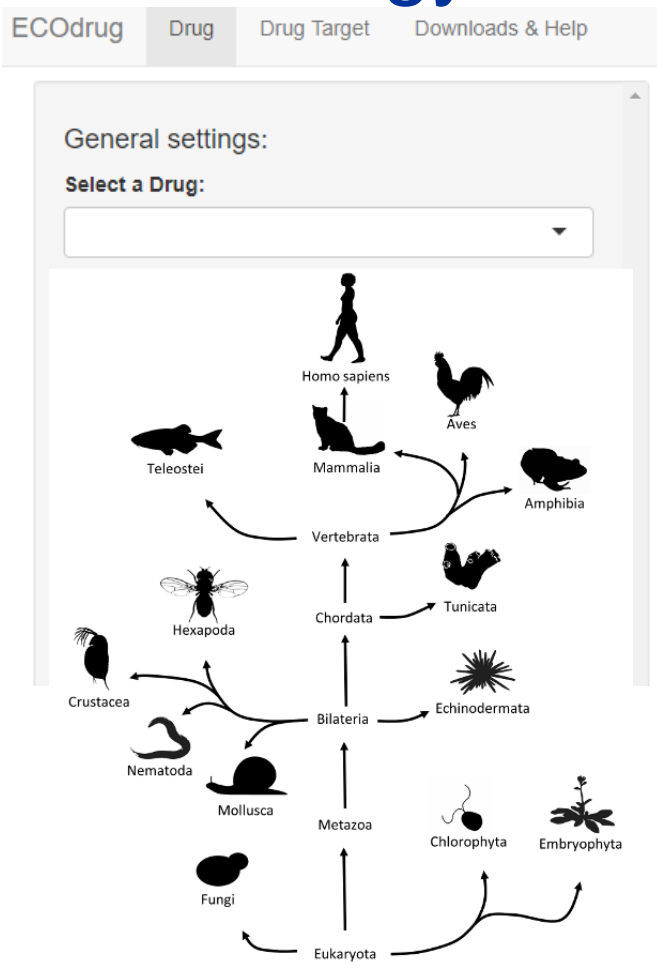
Brooks 2018. *Conserv Physiol*

Comparative Pharmacology & Toxicology



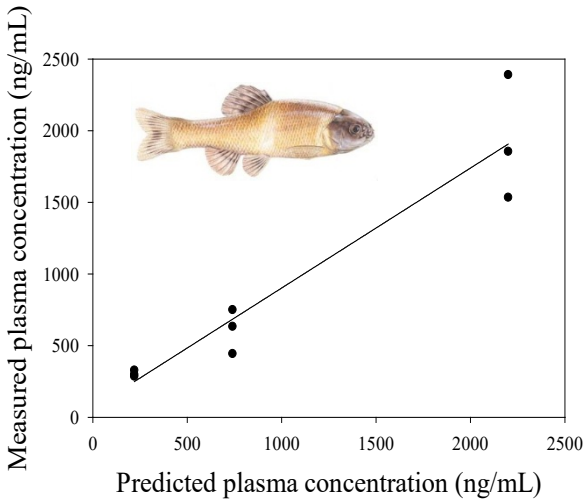


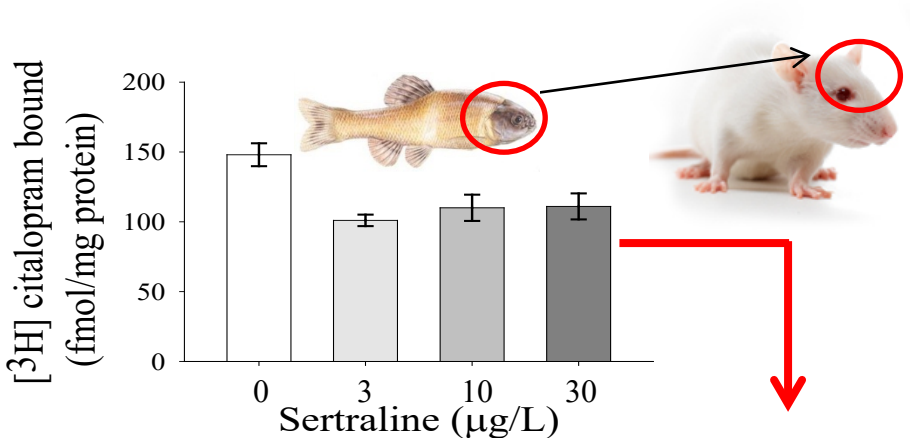


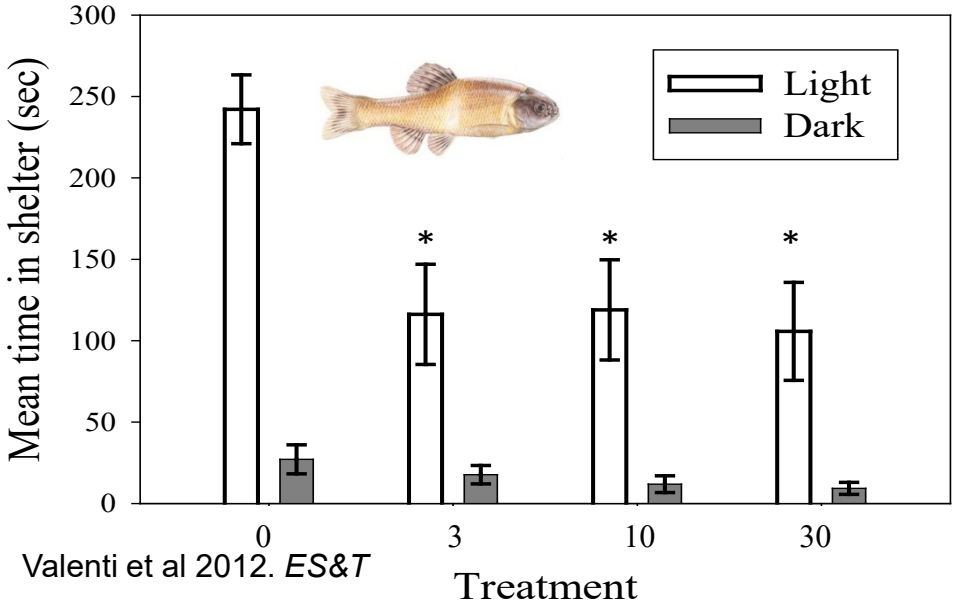


Gunnarsson et al 2008. *ES&T;* LaLone et al. 2014. *Aquat Toxicol;*
LaLone et al. 2014. *Phil Trans R Soc B*; LaLone et al. 2016 *Toxicol Sci:* seqapass.epa.gov/seqapass/
Verbruggen et al. 2017. *Nucleic Acids Research*; Ecodrug.org

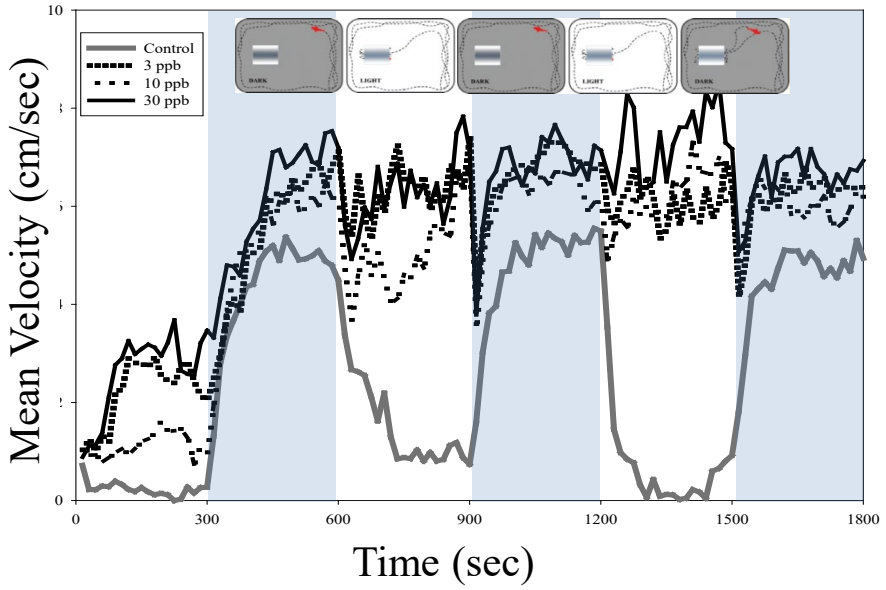
Antidepressant uptake, CNS binding, anxiolytic behavior







Valenti et al 2012. *ES&T*



Sustainable Molecular Design and Environmental Quality

Advancing sustainability through design

Sustainable substitutions, alternatives and the rational design of less hazardous chemicals

How can we design and predict the biological and physico-chemical properties of chemicals during development to minimize environmental hazards?

Coish et al 2016. *ACS Sus Chem Eng*
Corrales et al 2017. *Chem Res Toxicol*
Coish et al 2018. *Toxicol Sci*
Brooks 2019. *Green Chem*

Sustainable Molecular Design and Environmental Quality

Advancing sustainability through design

Sustainable substitutions, alternatives and the rational design of less hazardous chemicals

How can we better manage, use and share data generated from existing testing strategies in order to develop more sustainable and safer products?

Coish et al 2016. *ACS Sus Chem Eng*
Corrales et al 2017. *Chem Res Toxicol*
Coish et al 2018. *Toxicol Sci*
Brooks 2019. *Green Chem*

Sustainable Molecular Design and Environmental Quality

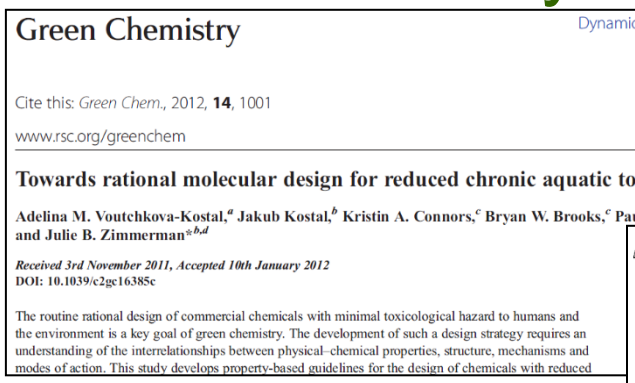
Advancing sustainability through design

Sustainable substitutions, alternatives and the rational design of less hazardous chemicals

How can we implement comparative risk assessment, life cycle analysis, and risk benefit analysis in order to identify and design more sustainable alternatives?

Coish et al 2016. *ACS Sus Chem Eng*
Corrales et al 2017. *Chem Res Toxicol*
Coish et al 2018. *Toxicol Sci*
Brooks 2019. *Green Chem*

Many Opportunities: Sustainable Molecular Design, Alternatives Analyses, Chemical Substitutions



Green Chemistry

Dynamic Article Links

Cite this: *Green Chem.*, 2012, **14**, 1001

www.rsc.org/greenchem

PAPER

Towards rational molecular design for reduced chronic aquatic toxicity†

Adelina M. Voutchkova-Kostal,[a] Jakub Kostal,[b] Kristin A. Connors,[c] Bryan W. Brooks,[c] Paul T. Anastas[b] and Julie B. Zimmerman*[b,d]

Received 3rd November 2011, Accepted 10th January 2012
DOI: 10.1039/c2gc16385c

The routine rational design of commercial chemicals with minimal toxicological hazard to humans and the environment is a key goal of green chemistry. The development of such a design strategy requires an understanding of the interrelationships between physical–chemical properties, structure, mechanisms and modes of action. This study develops property-based guidelines for the design of chemicals with reduced

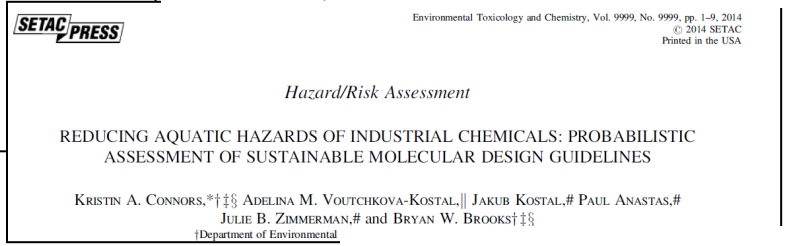
Chemical Research in Toxicology

Article

pubs.acs.org/crt

Toward the Design of Less Hazardous Chemicals: Exploring Comparative Oxidative Stress in Two Common Animal Models

Jone Corrales,[†] Lauren A. Kristofco,[†] W. Baylor Steele,[†] Gavin N. Saari,[†] Jakub Kostal,[‡] E. Spencer Williams,[†] Margaret Mills,[§] Evan P. Gallagher,[§] Terrance J. Kavanagh,[§] Nancy Simcox,[§] Longzhu Q. Shen,[∥] Fjodor Melnikov,[∥] Julie B. Zimmerman,[∥,⊥] Adelina M. Voutchkova-Kostal,[‡] Paul T. Anastas,[∥] and Bryan W. Brooks*[,†]



SETAC PRESS

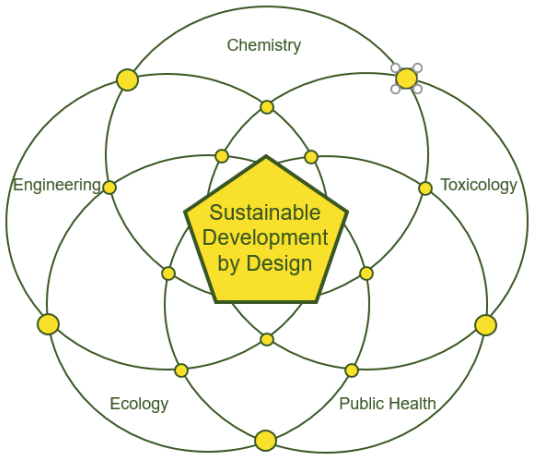
Environmental Toxicology and Chemistry, Vol. 9999, No. 9999, pp. 1–9, 2014

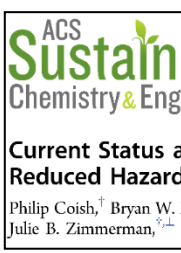
Printed in the USA

Hazard/Risk Assessment

REDUCING AQUATIC HAZARDS OF INDUSTRIAL CHEMICALS: PROBABILISTIC ASSESSMENT OF SUSTAINABLE MOLECULAR DESIGN GUIDELINES

KRISTIN A. CONNORS,*†‡§ ADELINA M. VOUTCHKOVA-KOSTAL,‖ JAKUB KOSTAL,# PAUL ANASTAS,# JULIE B. ZIMMERMAN,# and BRYAN W. BROOKS†‡§
†Department of Environmental





ACS Sustainable Chemistry & Engineering

Green Chemistry

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Cite this: *Green Chem.*, 2019, **21**, 2575

Greening chemistry and ecotoxicology towards sustainable environmental quality

Bryan W. Brooks

Current Status and Future Challenges in the Molecular Design for Reduced Hazard

Philip Coish,[†] Bryan W. Brooks,[‡] Evan P. Gallagher,[§] Terrance J. Kavanagh,[§] Adelina Voutchkova-Kostal,[∥] Julie B. Zimmerman,[⊥,†] and Paul T. Anastas*[,⊥]

The Molecular Design Research Network

Philip Coish, Bryan W. Brooks, Evan P. Gallagher, Margaret Mills, Terrance J. Kavanagh, Nancy Simcox, Grace A. Lasker, Dianne Botta, Stephanie C. Schmuck, Adelina Voutchkova-Kostal Jakub Kostal, Melissa L. Mullins, Suzanne M. Nesmith, Karolina E. Mellor, Jone Corrales, Lauren A. Kristofco, Gavin N. Saari, Baylor Steele, Longzhu Q. Shen, Fjodor Melnikov, Julie B. Zimmerman, Paul T. Anastas ✉

Toxicological Sciences, kfx175, https://doi.org/10.1093/toxsci/kfx175

Voutchkova et al 2011, 2012; Connors et al 2014; Coish et al 2016; Corrales et al 2017; Coish et al 2018; Brooks 2019

MoDRN Molecular Design Research Network

modrn.yale.edu

Global Horizon Scanning

Environmental Toxicology and Chemistry—Volume 37, Number 9—pp. 2281–2295, 2018
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Critical Review

Toward Sustainable Environmental Quality: Priority Research Questions for Europe

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Critical Review

Toward Sustainable Environmental Quality: Priority Research Questions for North America

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Environmental Policy & Regulation

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

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Workshop Synthesis

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

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Critical Review

Toward Sustainable Environmental Quality: Priority Research Questions for Asia

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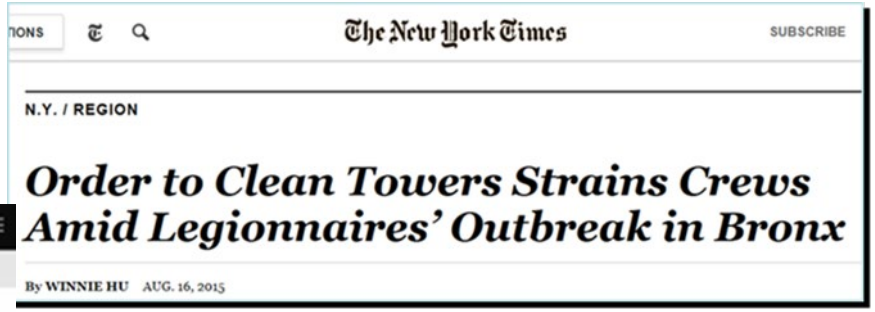
Furley et al. 2018. *IEAM*; Van den Brink et al. 2018. *ET&C*; Fairbrother et al. 2019. *ET&C*; Gaw et al. 2019. *IEAM*; Leung et al. 2020. *ETC*

Some Environmental Health Headlines…



Florida health officials confirm local Zika transmission

What are the key challenges and opportunities facing environmental public health practitioners?

- Environmental health is profoundly local
- 2nd largest public health workforce in the US
- Critical role in food, water and air quality, emergency response, vector control and disaster preparedness
- A “silent” profession until front page problems occur…
- Workforce status, challenges, needs and opportunities are poorly understood
- Fractured health delivery systems among States, Tribes and Territories

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10 Essential Environmental Public Health Services

What are the key challenges and opportunities facing environmental public health practitioners?

www.cdc.gov/nceh/ehs/uncover-eh/index.html

Identifying Needs for Advancing the Profession and Workforce in Environmental Health

An ever-changing landscape for environmental health (EH) requires in-depth assessment and analysis of the current challenges and emerging issues faced by EH professionals. The Understanding the Needs, Challenges, Opportunities, Vi-

Justin A. Gerding, DHA, MPH, Bryan W. Brooks, PhD, MS, Elizabeth Landeen, BA, Sandra Whitehead, PhD, MPA, Kaitlyn R. Kelly, BS, Amy Allen, BS, David Banaszynski, BS, Michael Dorshorst, MEd, Lane Drager, BS, Tannie Eshenaur, MPH, Jeff Freund, BS, Adam Inman, BS, Sandra Long, BS, Jessica Maloney, BS, Tammy McKeever, Tyler Pigman, BS, Nancy Rising, Sarah Scanlan, BS, Jennifer Scott, MS, Colin Shukie, MPH, Gary Stewart, BS, Darren Tamekazu, BS, Valerie Wade, BS, Carolyn White, MPH, and John Sarisky, MPH

See also Künzli, p. 296, and the *AJPH* Environmental Health Workforce & Regulation section, pp. 284–298.

29 Priority Problem Statements to Support the Work of EH Professionals

Gerding et al 2020. *American Journal of Public Health*
www.cdc.gov/nceh/ehs/uncover-eh/index.html

ehp Environmental Health Perspectives

Commentary

A Section 508–conformant HTML version of this article is available at https://doi.org/10.1289/EHP5161.

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

Brooks et al 2019. *Environmental Health Perspectives*
www.cdc.gov/nceh/ehs/uncover-eh/index.html

Initial Conclusions

The UNCOVER EH initiative is:

- Filling an important gap in knowledge about the EH workforce and practice in health departments of the USA
  - 26% of EH professionals plan to retire in 5 years, yet only 6% of students in public health are concentrating their studies in EH
- Describing the variation in EH professional characteristics, education, and practice areas
- Identifying and forecasting current and future grand challenges EH professions are addressing and will face
- Producing information for supporting EH workforce enhancement and development
- Informing strategic EH funding decisions by federal agencies
- Being expanded to examine other geographical regions

Brooks et al 2019 *EHP*; Gerding et al 2019 *JEH*, 2020 *AJPH*
https://www.cdc.gov/nceh/ehs/uncover-eh/index.html

UNCOVER-EH Problem Statements for Decentralized Wastewater

Lack of collaboration during onsite wastewater management policy development ("delegation without consideration") results in gaps in programmatic capacity.

Onsite wastewater management is differentially implemented (e.g., design parameters), administered and assessed.

There is a lack of data to support transitions from prescriptive to performance-based standards for onsite systems.

Adverse health outcomes are presented from aging wastewater infrastructure associated with and because of increasing rural to urban demographic transitions and urbanization.

New onsite technologies lack sustainable onsite wastewater implementation and performance data, including during droughts and flooding, to address emerging threats.

Brooks et al 2019. *Environmental Health Perspectives*
www.cdc.gov/nceh/ehs/uncover-eh/index.html

What are the Key Research Needs for Onsite Wastewater?

Needs for Onsite Wastewater Recycling Research

Unique Partnership with the NOWRA

Steering Committee with Diverse Representation

Phase 1: Survey (completed)
- input from hundreds in business, government, academic, NGOs

Phase 2: Synthesis workshop (this Wednesday)

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