

Reducing pharmaceutical pollution along the lifecycle: from drug design to use to waste

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What is in the environment?

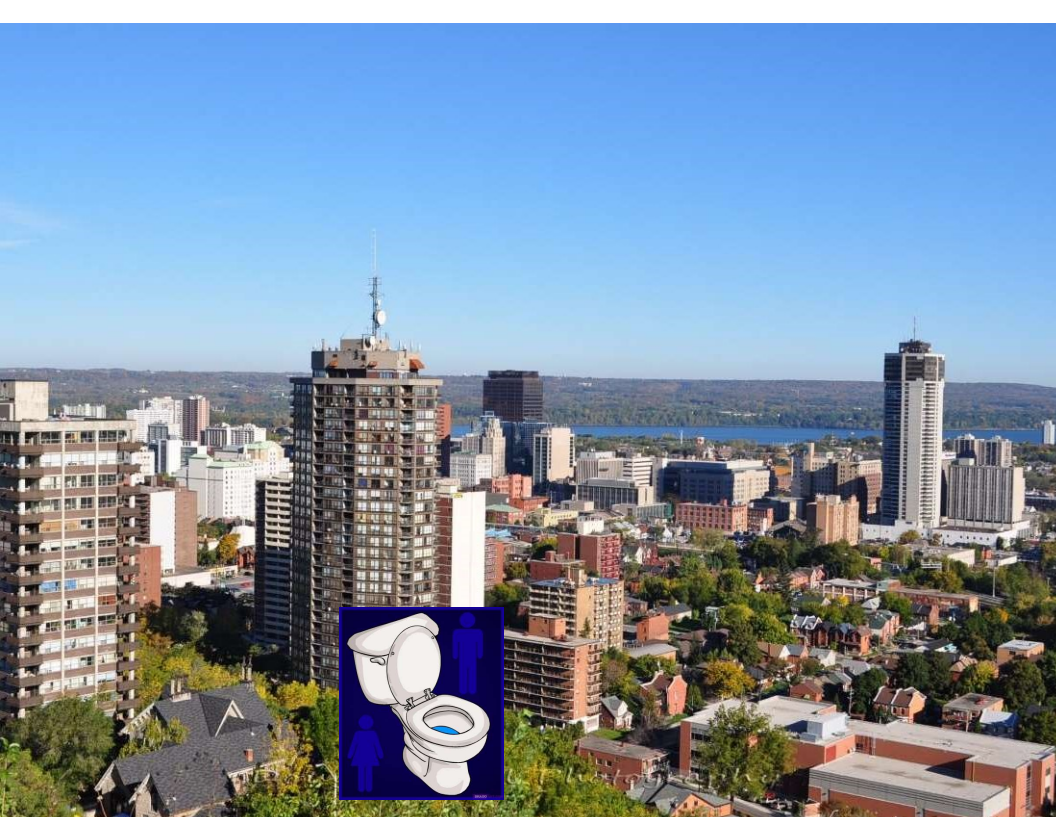
What are the concerns?

What are some solutions?

What is in the environment?

This story starts in the toilet

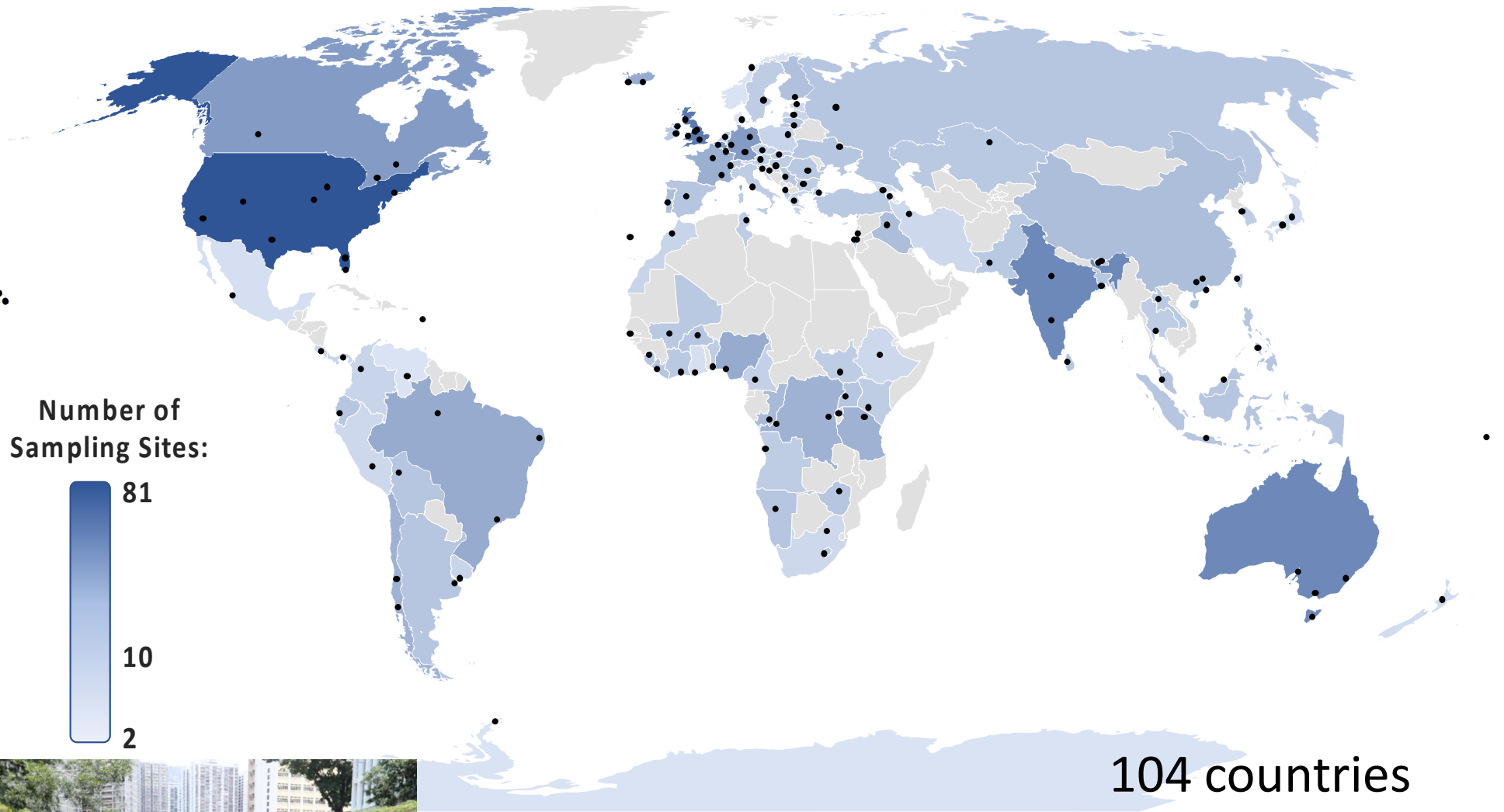




What is in the environment?



What is in the environment?



104 countries
>1000 sites
61 active
pharmaceutical
ingredients (APIs)

Wilkinson et al., 2022, PNAS

What is in the environment?

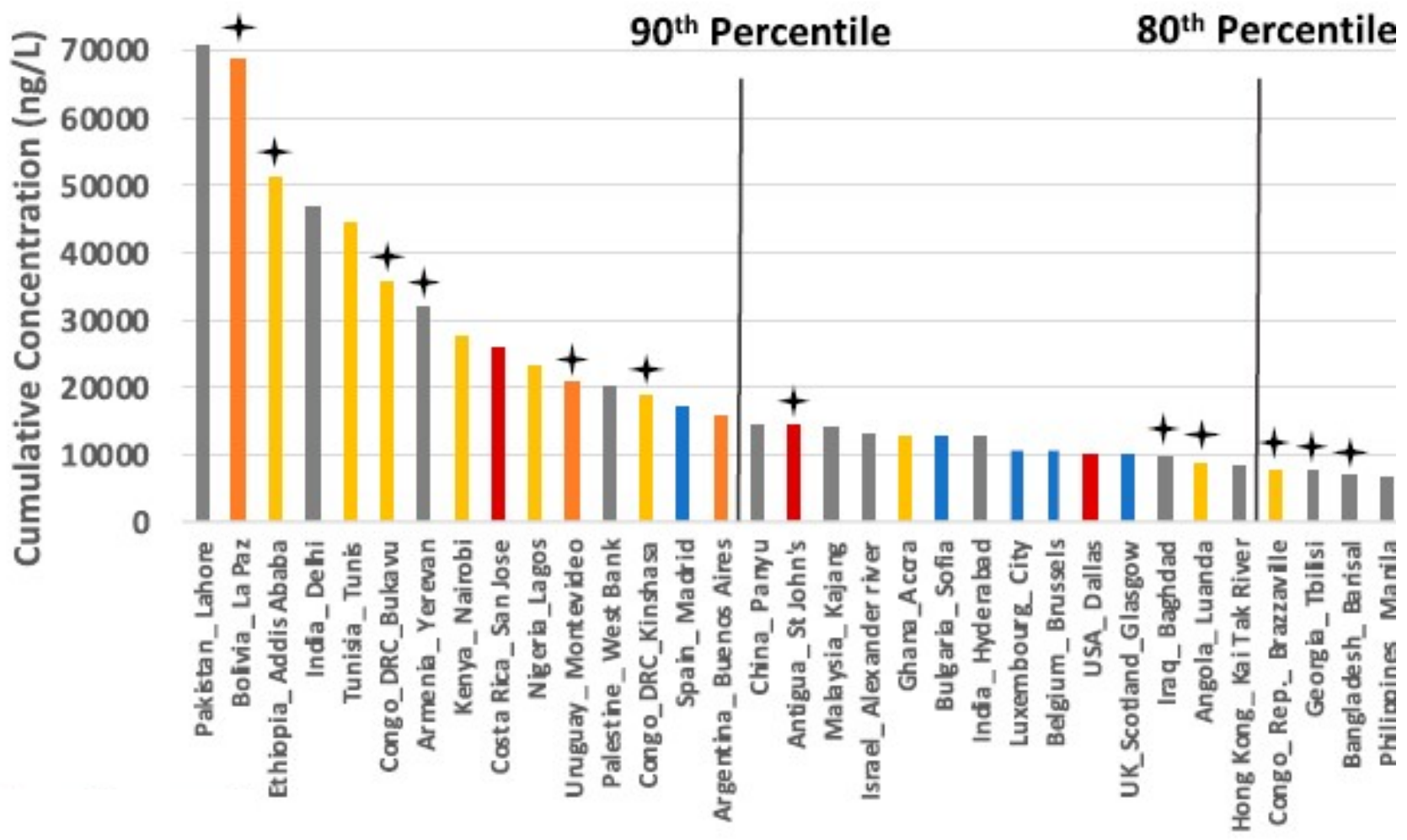


What is in the environment?

Sites Most Contaminated with APIs

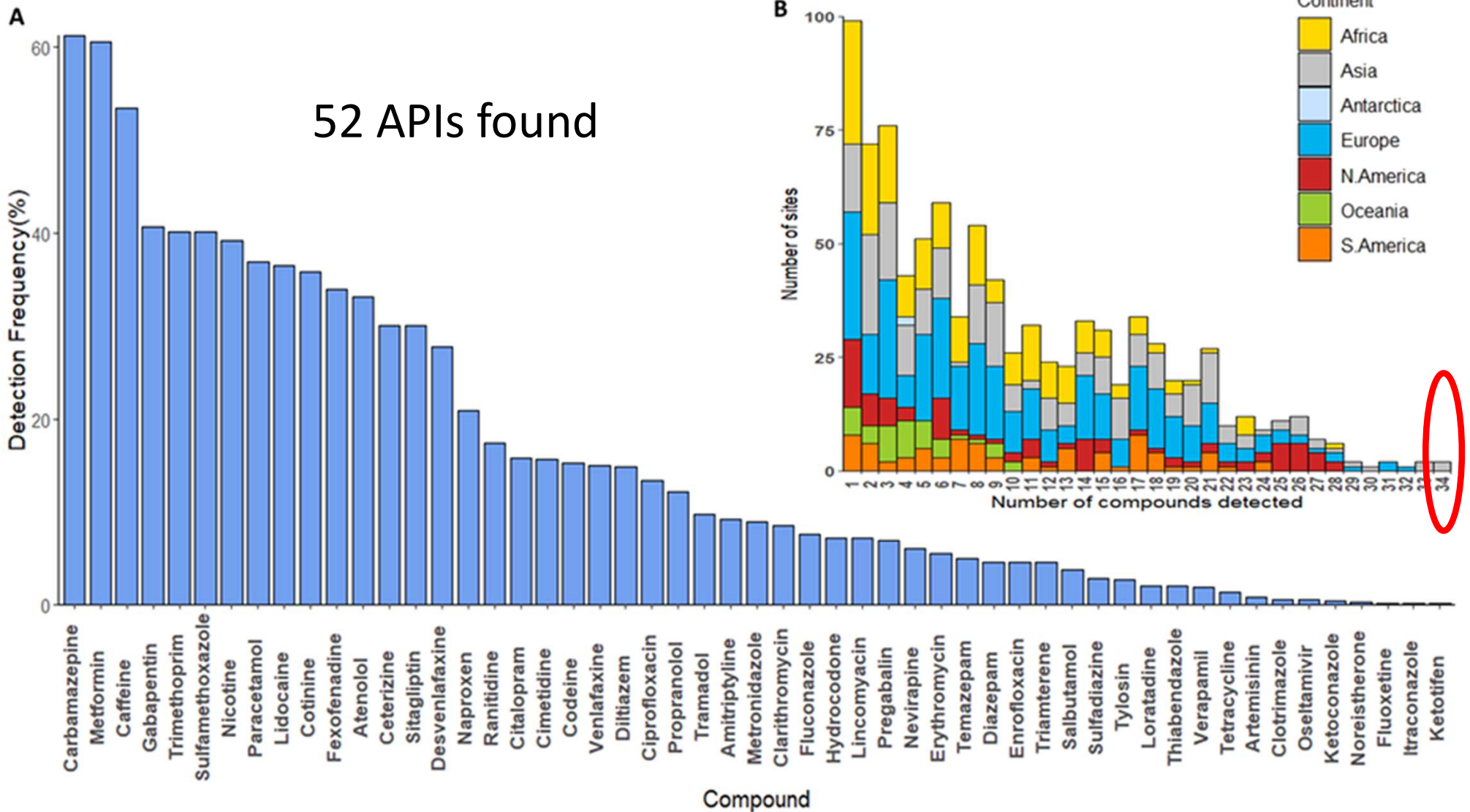


- Africa
- Antarctica
- Asia
- Europe
- North America
- Oceania
- South America
- ✦ Country not previously monitored



What is in the environment?

Widespread contamination of many pharmaceuticals + complex mixtures

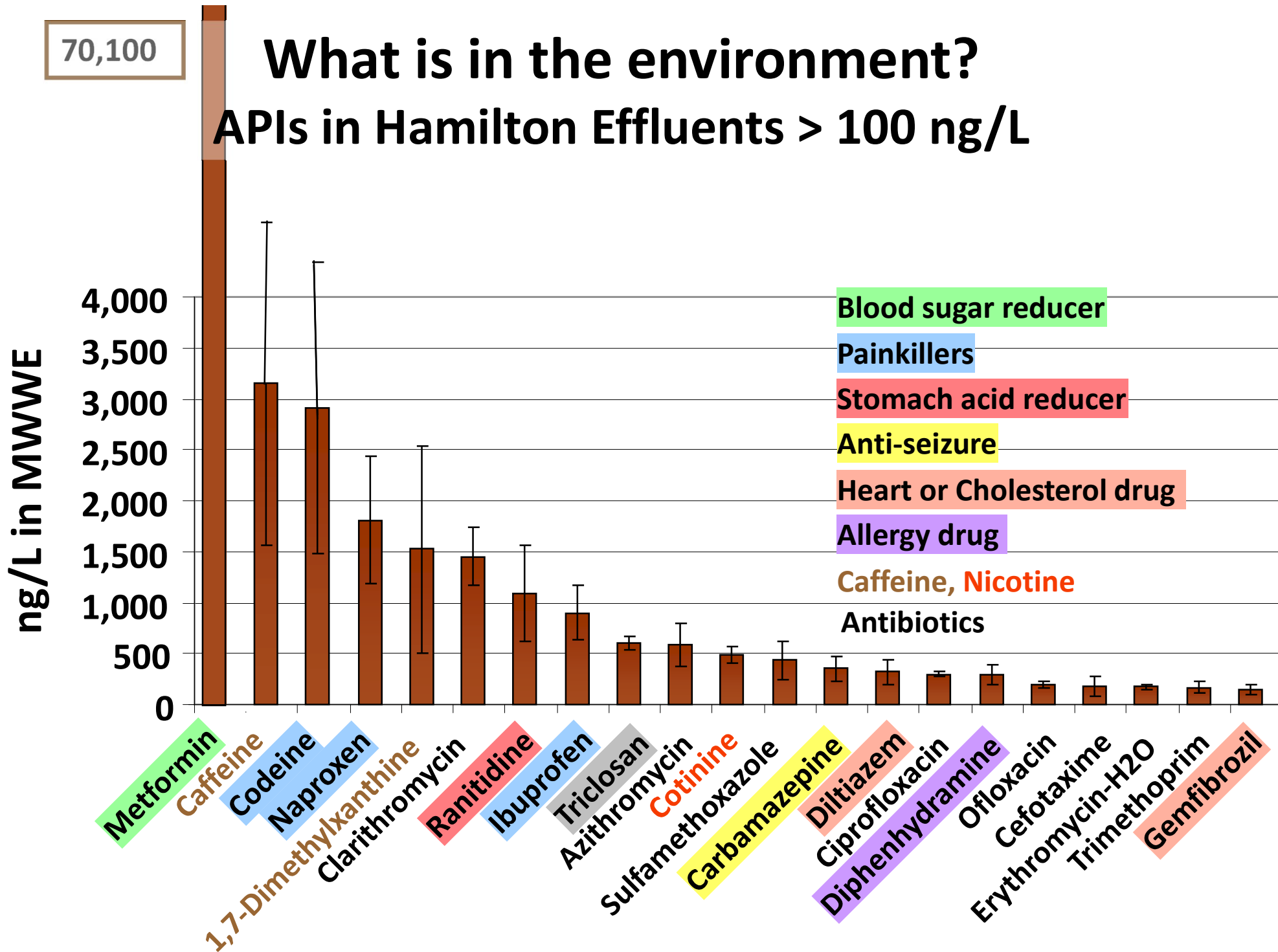


What is in the environment?

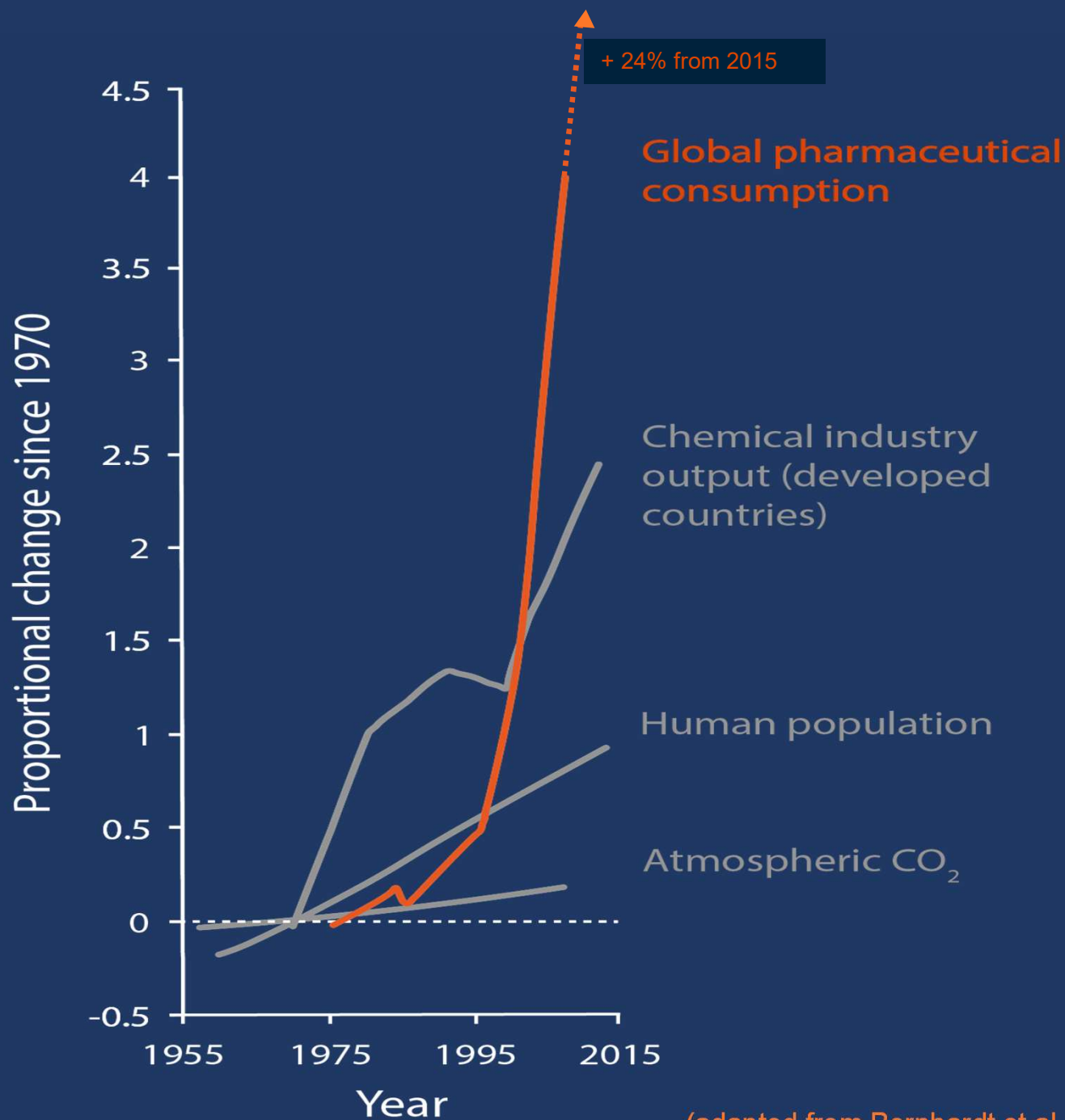
70,100

What is in the environment?

APIs in Hamilton Effluents > 100 ng/L



What are the concerns?



(adapted from Bernhardt et al. *Front. Ecol. Environ.* 2017)

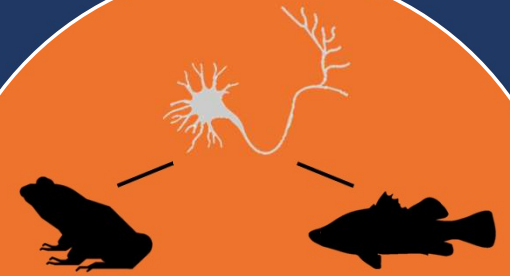
What are the concerns?



Designed to have biological effects at low doses



Persistent in the environment



Drug targets evolutionarily conserved across phyla

What are the concerns?



43.5% of the 1,052 sampling locations had concentrations of at least one pharmaceutical of concern (Bouzas-Monroy et al. 2022 ET&C)

21 APIs of concern

analgesics, antibiotics, antidepressants, anticonvulsants, antifungals, antihistamines, β -blockers, calcium channel blockers, stimulants

What are the concerns (for fish)?

- Blood lipid regulators – lipids
- Diabetes medication – reproduction
- Antidepressants – behaviours
- Anti-inflammatories – growth, reproduction



What are the concerns?

Estrogens feminize male fish



Environ. Sci. Technol. 1998, 32, 2498–2506

Widespread Sexual Disruption in Wild Fish

SUSAN JOBLING,^{*,†} MONIQUE NOLAN,[‡]
CHARLES R. TYLER,[†]
GEOFF BRIGHTY,[§] AND
JOHN P. SUMPTER[†]

mented, but geographically (8–14). Most of the chem many orders of magnitude h counterparts, and it therefc exposure will cause signific standing this, it is entirely pc of endocrine-modulating s present in the environmen even synergistic effects.



Male fish with eggs

What are the concerns?

Do we have feminized male fish in Canada, eh?



South Saskatchewan River, AB



St. Lawrence River at Montréal

Wascana Creek, SK



Grand River, ON



Occur where

- 1) Human population high
- 2) Treatment is poorer
- 3) Dilution is lower

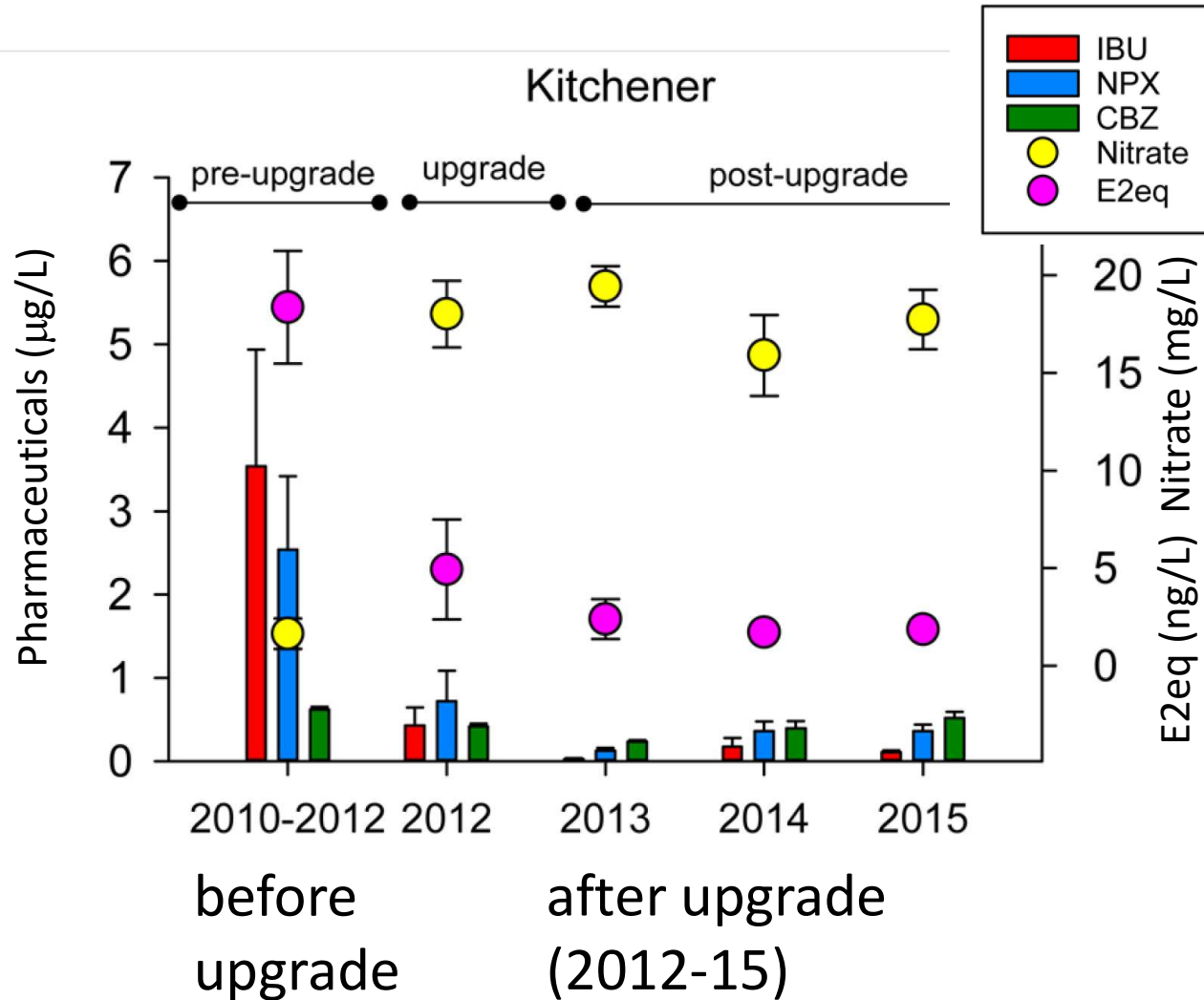


What are some solutions?

- Newer Wastewater Systems Effluent Regulations
- 3,100 projects across Canada
- \$3.89 billion invested in Ontario

What are some solutions?

Wastewater treatment plant upgrades improve effluent quality



What are some solutions?

Comment

<https://doi.org/10.1038/s41893-024-01374-y>

The urgent need for designing greener drugs

Tomas Brodin, Michael G. Bertram, Kathryn E. Arnold, Alistair B. A. Boxall, Bryan W. Brooks, Daniel Cervený, Manuela Jörg, Karen A. Kidd, Unax Lertxundi, Jake M. Martin, Lauren T. May, Erin S. McCallum, Marcus Michelangeli, Charles R. Tyler, Bob B. M. Wong, Klaus Kümmerer & Gorka Orive

 Check for updates

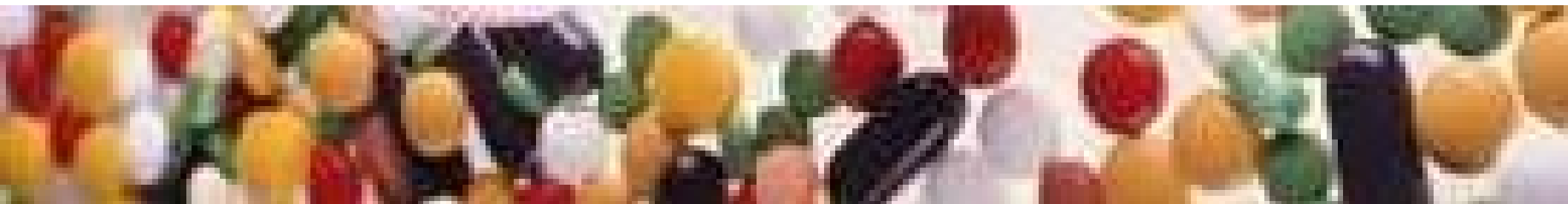
The pervasive contamination of ecosystems with active pharmaceutical ingredients poses a serious threat to biodiversity, ecosystem services and public health. Urgent action is needed to design greener drugs that maintain efficacy but also minimize environmental impact.

We are living in an increasingly medicated world. Pharmaceuticals are indispensable in modern health care, having revolutionized the prevention and treatment of disease, and will remain crucial in the future. Nevertheless, our increasing dependency on pharmaceuticals comes at a major cost. Discharges to the environment during drug production, use and disposal have resulted in ecosystems around the globe being contaminated with mixtures of active pharmaceutical ingredients (APIs), as well as their metabolites, additives, adjuvants, excipients and transformation products. The extent of API pollution was recently demonstrated in a large-scale geographical study that measured 61 different drugs in river water taken from 1,052 locations across 104 countries, spanning all continents¹. Around 42% of the sites



What are some solutions?

Principles of green chemistry



10. Design for Degradation

Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.

Example: [Biodegradable Surfactants](#)

ACS
Sustainable
Chemistry & Engineering

pubs.acs.org/journal/ascecg

Research Article

Reducing Environmental Pollution by Antibiotics through Design for Environmental Degradation

Christoph Leder, Morten Suk, Stefanie Lorenz, Tushar Rastogi, Christian Peifer, Manfred Kietzmann, Daniel Jonas, Marion Buck, Axel Pahl, and Klaus Kümmerer*



Cite This: <https://doi.org/10.1021/acssuschemeng.1c02243>



Read Online

Take Home Messages

- Pharmaceutical pollution of freshwater ecosystems a global issue
- Many locations have levels that pose a risk to aquatic life
- Solutions include
 - Improved wastewater treatment
 - Use of Green Chemistry Principles in drug design

