United States Environmental Protection Agency

Emerging Contaminants and the Ramifications for Environmental Science

Christian G. Daughton, Ph.D.

Chief, Environmental Chemistry Branch

Environmental Sciences Division

National Exposure Research Laboratory

Office of Research and Development

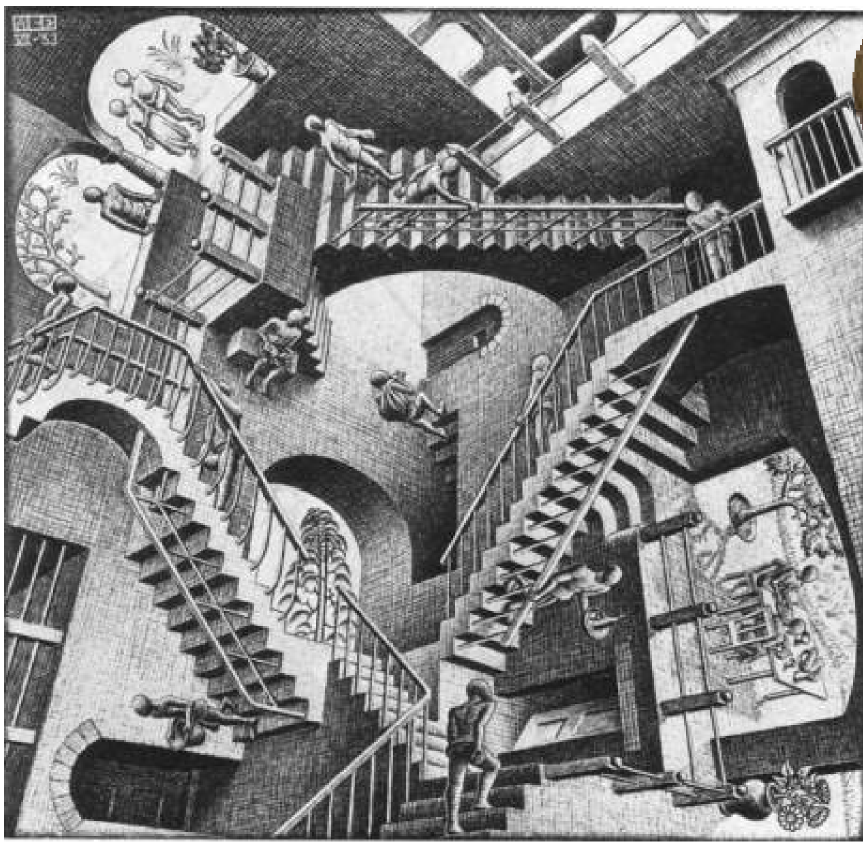
Environmental Protection Agency

Las Vegas, Nevada 89119

daughton.christian@epa.gov

Does anyone know what an *Emerging Contaminant* really is?

Emerging Contaminants …



… depend on one's perspective

What Makes a "Contaminant of Emerging Concern"?

Emerging contaminants (ECs) include more than simply chemicals previously not known to occur in the environment.

ECs also include chemicals already known to occur but now displaying new characteristics not previously suspected or recognized, such as those involving:

- origin or source (e.g., via sweat and dermal transfer)
- location (e.g., "out-of-place" chemicals; "chemical weeds")
- unusual concentrations or levels (e.g., enriched by sorption to plastics in oceans)
- transformation and fate pathways
- exposure routes
- biological effects pathways or endpoints

Slicing the Pollutant Pie

Environmental contaminants can be categorized across many dimensions.

A host of acronyms describe different slices, often breeding confusion.

Acronym Anarchy

EDCs – CMRs– PBTs – vPvB – POPs – OWCs – PPCPs – PhACs – EPOCs – COCs – COPCs – CECs – XOCs – HPVs – PDPs – HDPs – POHOs – SVHCs

ppm – ppb – ppt – ppq
micro – nano – pico

… leads to acronym stupefaction

The Confusing Terminology of Chemical Pollutant Classes

Class or Grouping	***Grouped According to:***
EDC (Endocrine Disrupting Chemical) **CMR** (Carcinogenic, Mutagenic, toxic to Reproduction)	toxicological mode of action or endpoint
PBT (Persistent, Bioaccumulative Toxic) **vPvB** (very Persistent, very Bioaccumulative) **POP** (Persistent Organic Pollutant)	environmental properties
micro-pollutants; **micro-constituents** **trace pollutants/residues**	frequency/level of occurrence
OWCs (Organic Wastewater Contaminants)	location of occurrence
PPCPs (also PhACs, which is a subset)	type of intended usage
priority pollutants and others	regulation
unregulated pollutants	absence of regulation
“chemical weeds”	public perception ("out-of-place chemicals")
emerging contaminants/pollutants **EPOCs** (emerging pollutants of concern) **COCs** (chemicals of concern) **COPCs** (chemicals of potential concern) **CECs** (chemicals of emerging concern)	novelty, fad, timeliness, or new concern
xenobiotics, exotics **xenobiotic organic compounds (XOCs)**	foreign versus endogenous
toxicants, toxins, toxics, perturbogens (agonists, antagonists, activators, repressors, inhibitors, regulators, modulators)	overall toxicity (*note:* "toxins" comprise a special subset of toxicants - those naturally synthesized, primarily proteins; "toxics" is jargon for "toxicants")
HPV (high production volume) chemicals	quantity (manufactured/imported in US ≥1 million pounds/year)
PDPs or **HDPs** (population- or human-derived pollutants/constituents) **POHO** (pollutants of human origin)	source or origin

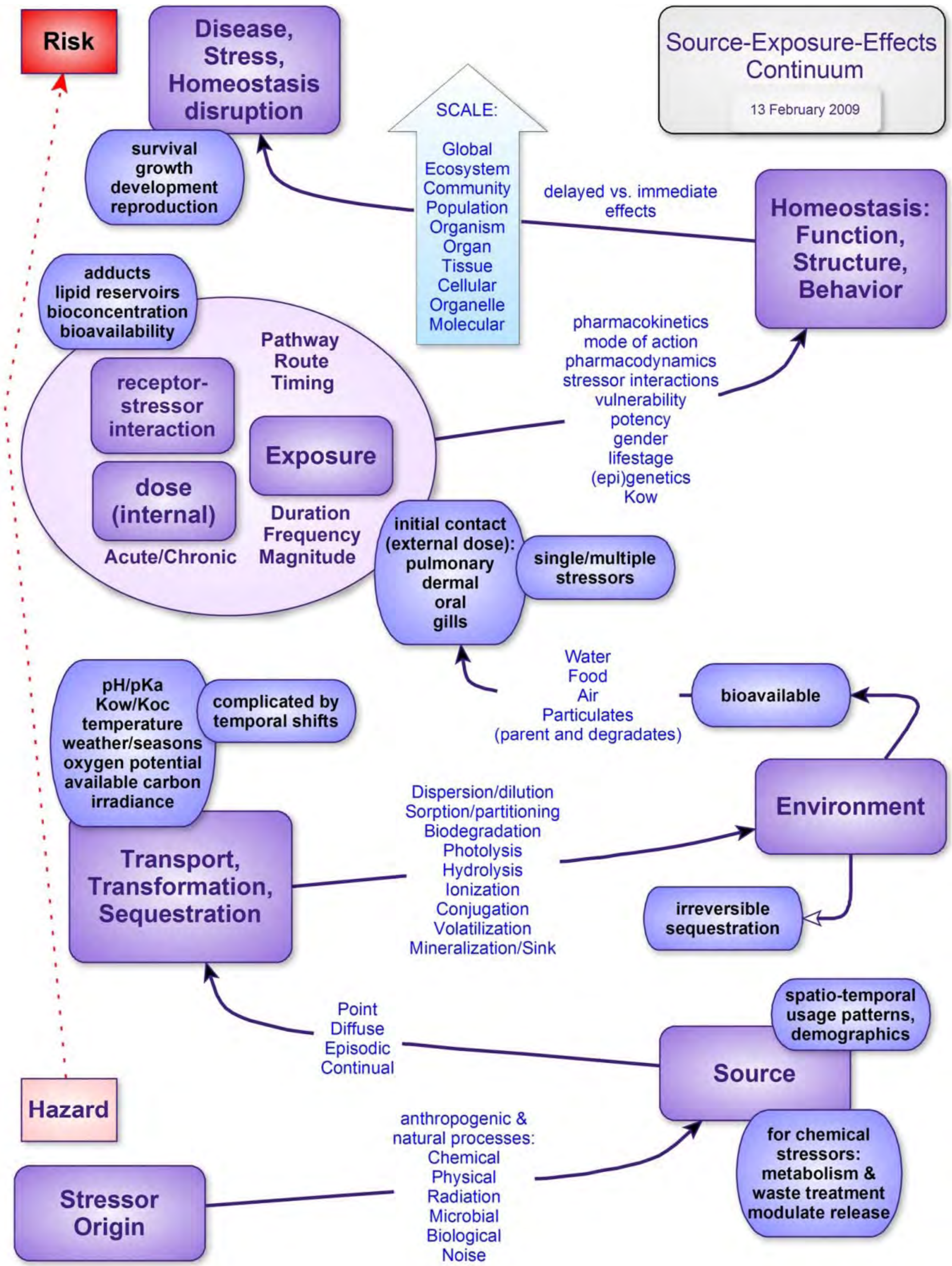
Adapted and extended by Daughton from: *Renewable Resources Journal*, 2005, 23(4):6-23.

Context of “*Emerging*”

The term "emerging" can be applied to any part of the continuum of the risk paradigm – spanning stressors to exposure and effects. It applies not just to chemicals, but also to any previously unrecognized, unexpected, or under-appreciated aspects of environmental science.

The study of "emerging" contaminants is really one of more carefully examining the interface between humans and the environment; and of continually expanding the conventional boundaries surrounding all facets of the source-to-effects continuum.

The term "ECs" causes confusion because it pertains not just to chemicals themselves but also to the many dimensions associated with their properties and the source-to-effects continuum.



Risk
Disease, Stress, Homeostasis disruption
survival growth development reproduction
SCALE: Global Ecosystem Community Population Organism Organ Tissue Cellular Organelle Molecular
Source-Exposure-Effects Continuum
13 February 2009
delayed vs. immediate effects
Homeostasis: Function, Structure, Behavior
adducts lipid reservoirs bioconcentration bioavailability
Pathway Route Timing
receptor-stressor interaction
Exposure
dose (internal)
Acute/Chronic
Duration Frequency Magnitude
pharmacokinetics mode of action pharmacodynamics stressor interactions vulnerability potency gender lifestage (epi)genetics Kow
initial contact (external dose): pulmonary dermal oral gills
single/multiple stressors
Water Food Air Particulates (parent and degradates)
bioavailable
pH/pKa Kow/Koc temperature weather/seasons oxygen potential available carbon irradiance
complicated by temporal shifts
Environment
Dispersion/dilution Sorption/partitioning Biodegradation Photolysis Hydrolysis Ionization Conjugation Volatilization Mineralization/Sink
Transport, Transformation, Sequestration
irreversible sequestration
spatio-temporal usage patterns, demographics
Point Diffuse Episodic Continual
Source
Hazard
anthropogenic & natural processes: Chemical Physical Radiation Microbial Biological Noise
for chemical stressors: metabolism & waste treatment modulate release
Stressor Origin

Some EPA Perspective

Statement of **Peter S. Silva** (confirmed, June 2009, as Assistant Administrator for the Office of Water) at hearing of Nominations Committee on Environment and Public Works United States Senate:

"... despite the considerable progress we have made in the last three decades, we now see additional challenges have arisen in the areas of non-point source pollution and in new emerging pollutants of concern." (12 May 2009)

"Managing Chemical Risks" is one of EPA's five new priority areas identified by EPA's new Administrator, **Lisa Jackson**:

"It is clear that we are not doing an adequate job of assessing and managing the risks of chemicals in consumer products, the workplace and the environment." (23 January 2009)

Some EPA Perspective

Peter S. Silva (American Water Works Association, Annual Conference and Exposition, 15 June 2009, San Diego)

"There is a growing nexus between the way we supply water and how we face environmental impacts."

"Even direct potable reuse is being considered."

ECs will play prominent roles in these efforts.

"Emerging" *Contaminants*

Most "emerging" contaminants are not new to the environment

- **Two major sources for contaminants that are truly "new" to the environment**:
  - Chemicals newly introduced to commerce (e.g., new approved or unapproved drugs, pesticides, nanomaterials).
  - By-products of new anthropogenic processes (e.g., nanotechnology).
- **Previously unrecognized pollutants can come to our attention as a result of**:
  - New advances in chemical analysis (e.g., "non-target" identification).
  - Ability to detect existing pollutants at ever-lower concentrations (single-molecule detection is now possible).
  - Exploring exposure sources not previously examined (e.g., certain foods as a significant source of acrylamide; estrogenics in plastics; PPCPs in biosolids; alkaloids in pyrolysis products from controlled forest burns).

examples

Old pollutants in new places: organohalogens in dolphin & seal brain; conventional POPs and their metabolites in tissues never before explored.

Old chemicals as new suspects: tungsten: mono-, poly- & heteropoly-tungstates

Toxicants masquerading as "inert" ingredients: polyethoxylated tallow amine used as adjuvant for formulating glyphosate; shows high aquatic toxicity and toxicity in human cell cultures.

Occurring at levels or locations never before observed or suspected: APIs in drug manufacturing waste streams. PPCPs in household graywater. Lipophilic contaminants sorbed to plastics in oceans.

New pollutants: perfluorinated phosphonic acids (in waters); unapproved drugs

Source or origin: marine production of halogenated organics; alkaloids in particulates/aerosols from controlled burns in forests (pyrolytic conditions); melamine in infant formula, originating as metabolite of cyromazine, an insecticide used on crops and forage.

Route of transport to the environment (contributing to exposure risk): excretion of drugs via the skin (sweat); illicit drugs in ambient air.

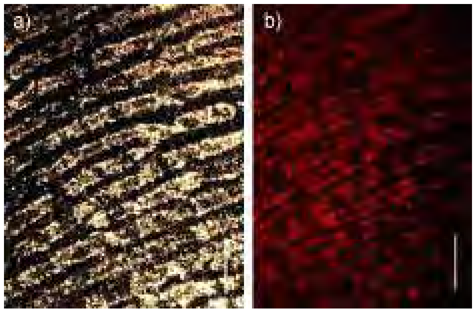
Exposure pathway: interdermal transfer among humans.

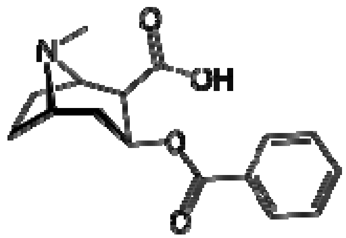
Emerging Contaminants: Humanity's Chemical Footprints and Fingerprints

- Enter the environment by way of diffuse, complex, and interconnected networks fed by myriad numbers of people.
- ECs reflect:
  - The intimate, inseparable, and immediate connections of humans and the environment.
  - The combined actions, behaviors, and activities of individuals.
  - The extensive interconnections and feedback loops between humans and the environment.

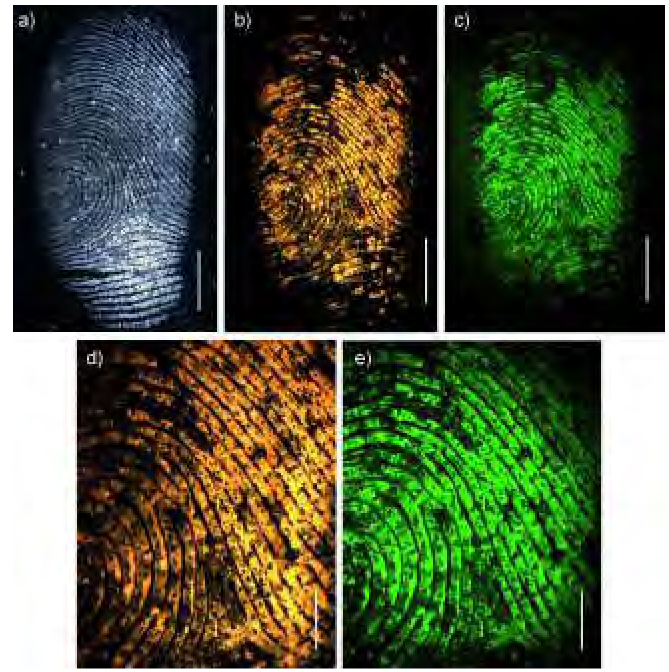
- ECs serve as direct measures of the types, extent, and magnitude of these connections.

Fingerprints as contributors of environmental contaminants

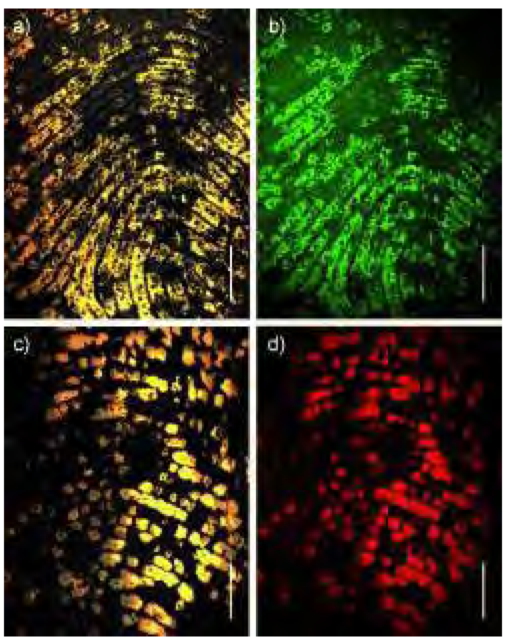


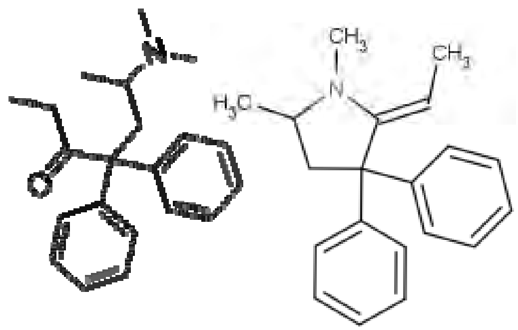


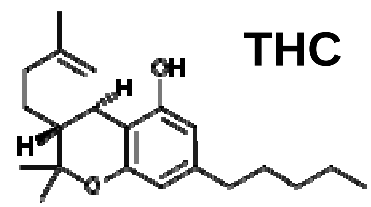
benzoylecgonine



methadone & EDDP







THC

benzoylecgonine (major cocaine metabolite)
EDDP: 2-ethylidene-1,5-dimethyl-3,3-diphenylpyrrolidine (major methadone metabolite)
THC: Δ9-tetrahydrocannabinol (main psychoactive of marijuana)

Hazarika P, Jickells SM, Wolff K, Russell DA (2008) Imaging of Latent Fingerprints through the Detection of Drugs and Metabolites. *Angew Chem Int Ed* 47:10167-10170.

Environmental Life-Cycle of Pharmaceuticals
created by CG Daughton
US EPA, Las Vegas
2 December 2006
transformation/degradation
mineralization
stewardship opportunities
Manufacturer
Commerce distribution
Wholesalers Distributors
Agriculture (e.g., orchards)
runoff
excrement
pets
euthanized carcasses
potential for acute/chronic poisoning of wildlife scavengers
carcasses of medicated animals
physician samples
Physicians
Feedstores
Vet use
domestic animals
airborne dusts (e.g., medicated feed)
occupational human pulmonary exposure
prescribing
CAFOs
Aquaculture
waste residuals pretreatment
humanitarian donations: excess or unusable leftovers
Reverse distributors
unsold product
dispensing pharmacies Rx & OTC
sloughing of antibiotic-resistant bacteria/genes
Waste Treatment (e.g., lagoons)
manure solids
Soil amendment/ disposal
Take-Backs, Mail-Backs, Collection events
atmospheric release (e.g., anaesthetics)
Human consumer use
Gene Exchange multi-drug resistance
naturally occurring bacteria
exposure to resistant bacteria
Incineration
unused/expired leftovers
LTCFs Hospitals Hospice
Leftover medications
Stored awaiting disposal
Diversion Abuse (e.g., pharming)
acute poisonings: accidental & purposeful
diversion by gleaners
Landfill
trash
RCRA Hazardous Waste
release of dermal products from bathing
excretion from oral & parenteral use
Disposal by consumer
trash
Incineration
toilet
toilet or sewerage
Disposal by Coroner's
research of Ruhoy 2006
optional
Law enforcement (controlled substances)
Wildlife exposure (scavengers)
Waste Treatment
groundwater (artificial recharge, colloidal transport)
Aquatic exposure
sediments (sorption)
straightpiping & overflow events
runoff
leachates
landfill
receiving waters
Waste Treatment
Sludge Biosolids
Plant-Made Pharmaceuticals (PMPs)
finished drinking water treatment
"toilet-to-tap"
Soil Amendment
groundwater
Molecular Pharming
drug residues & transformation by-products
Recreation
Advanced Treatment (recycling)
aqueous effluent
PMPs cross-contaminating food supply
irrigation
Wildlife exposure from grazing/ foraging
Chronic, Low-Level, Incidental Human Exposure
Oral & Dermal
uptake by plants & crops
uptake by soil-dwelling organisms

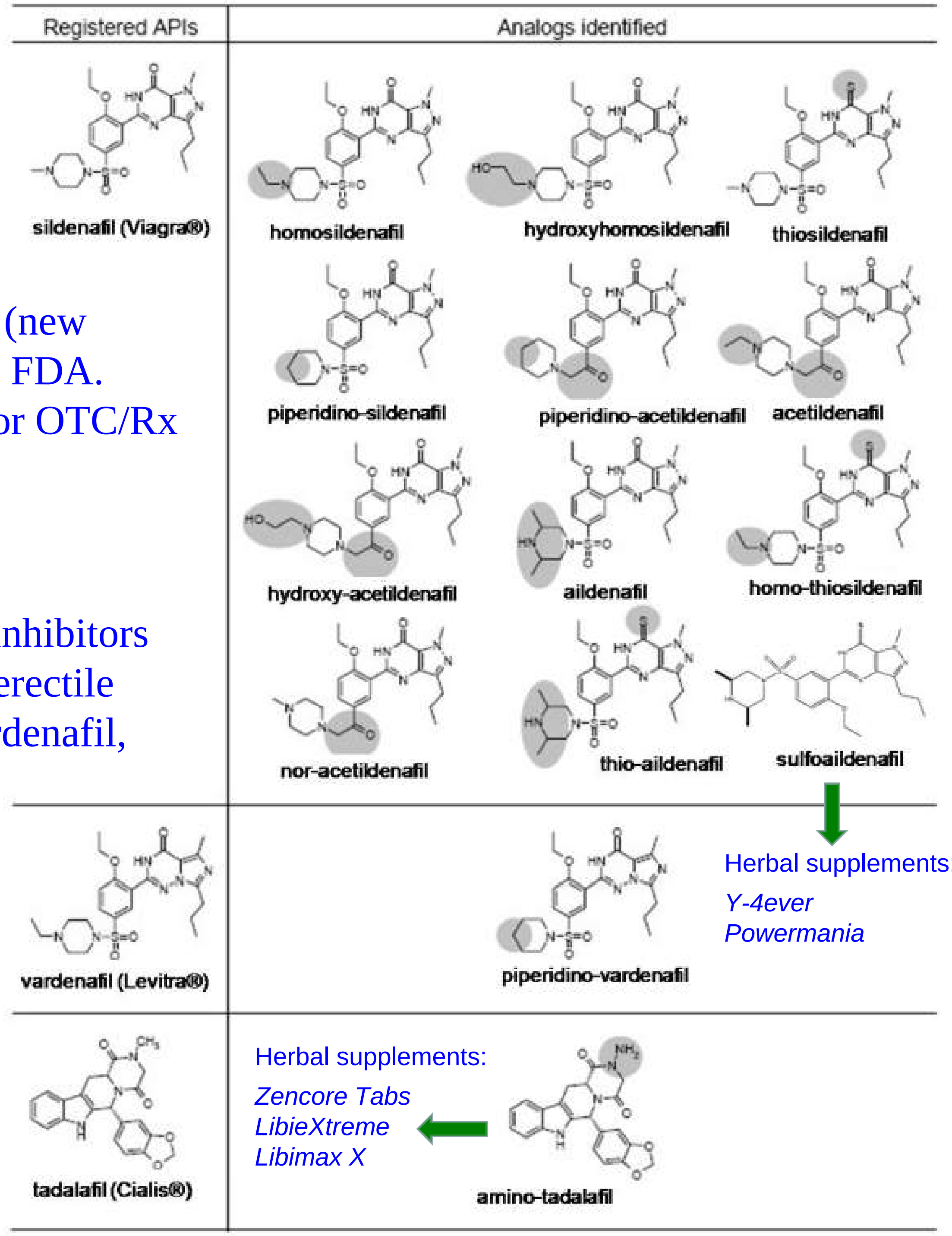
Challenges for environmental chemical analysis:
Complexities in identifying and monitoring chemical unknowns

- **Chiral enantiomers**: long proven important for certain pharmaceuticals and pesticides (e.g., improved profiles for effectiveness and toxicity versus hydrogen analogs). Subject to enantiomeric enrichment via microbial degradation.
- **Nanomaterials**: pose enormous challenges for chemical characterization because of diversity of structures and possible complexity of weathered products.
- **Unapproved drugs**: unapproved analogs of registered drugs; sold OTC in adulterated herbal supplements and in fraudulent prescription medications.
- **Mechanical bonds**: rotaxanes, catenanes, molecular knots

Designer Drugs: Environmental Contaminant Unknowns

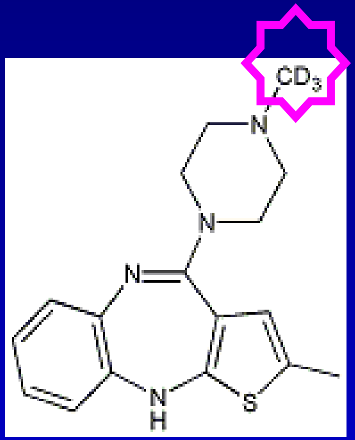
Undeclared drug active ingredients (new molecules) – known or unknown to FDA. Adulterants in herbal supplements or OTC/Rx drugs, often at high levels.

Example: analogs of the approved phosphodiesterase type 5 (PDE-5) inhibitors (used primarily in the treatment of erectile dysfunction), such as sildenafil, vardenafil, and tadalafil.



B.J. Venhuis, D.M. Barends, M.E. Zwaagstra, and D. de Kaste "Recent developments in counterfeits and imitations of Viagra, Cialis and Levitra: A 2005-2006 update," 2007, RIVM (Netherlands National Institute for Public Health and the Environment), RIVM Report 370030001/2007, Bilthoven, the Netherlands, 61 pp; http://www.rivm.nl/bibliotheek/rapporten/370030001.pdf

Challenges for environmental chemical analysis:
Complexities in identifying and monitoring chemical unknowns

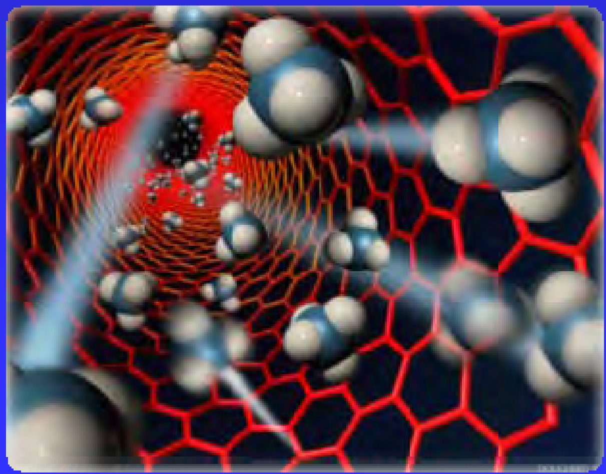


- **<u>Isotopic substitution</u>**: *deuterated analogs* of pharmaceuticals and pesticides long known for altered pharmacokinetics/pharmacodynamics because of kinetic isotope effect.
  - Pharmacologic deuteration yields drugs with greater stability. Can facilitate longer half-lives (increased duration of action from hindered first-pass metabolism); fewer side effects from lower dose, "metabolic switching," and reduced drug-drug interactions.
  - Major unknown for deuterated drugs: alteration of environmental fate & transport?
  - Major new analytical challenge: each API can have one or more deuterated analogs, increasing the numbers of potential analytes. But moreover, these analogs would greatly hinder the identification of each other if they cannot be physically separated prior to mass spectral detection (a result of radically altered isotopic abundances).

Structurally Undefinable Xenobiotics

Importance of Developing the Means to Evaluate and Monitor "Undefinable" Xenobiotics

- The widespread emergence in consumer products of new nanomaterials poses a host of currently unanswerable questions regarding their environmental chemistry and environmental toxicology.
- In particular, the natural weathering or environmental transformation of these materials holds the potential to yield numerous additional, structurally undefinable products.
- Nanomaterials pose numerous, currently intractable challenges to their monitoring in the environment.



It's Been Only 10 Years

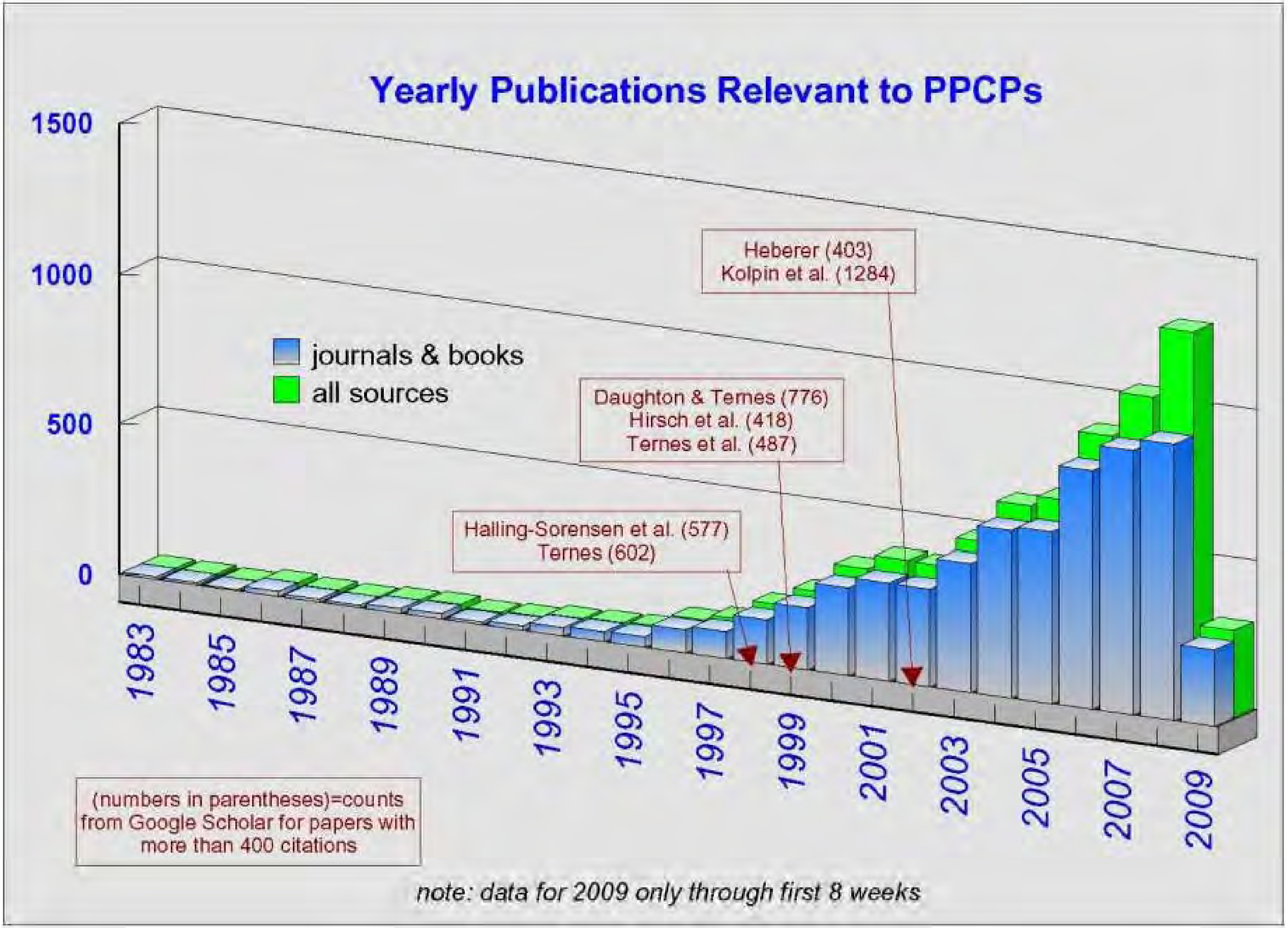
The first published documents to prominently feature the term *emerging contaminants/pollutants* were probably the 1999 report from the 1998 NRC workshop ("Identifying Future Drinking Water Contaminants") and several 1999 government reports by USGS.

The first publication in a journal was in 2001:
Daughton, C.G. "Emerging Pollutants, and Communicating the Science of Environmental Chemistry and Mass Spectrometry: Pharmaceuticals in the Environment," *J. Am. Soc. Mass Spectrom.* **2001**, *12*(10), 1067-1076; doi: 10.1016/S1044-0305(01)00287-2; available: http://www.epa.gov/nerlesd1/bios/daughton/book_jasma.pdf

Emerging Contaminants
- Status Check -

Passage of a decade marks an excellent time to reflect on a number of questions surrounding this rather ill-defined but broadly used term.

- Has the term served us well?
- Do we share a common understanding as to what an "emerging" contaminant might be?
- Is it leading us where we need to be in terms of a scientific discipline?
- What message does it convey to the public, legislators, and regulators?
- Are we perhaps suffering from its overuse – having become an obligatory adjective?
- What about the galaxies of other chemicals that currently evade detection and cannot yet be classified as “emerging”?



Yearly Publications Relevant to PPCPs
1500
1000
500
0
journals & books
all sources
Heberer (403)
Kolpin et al. (1284)
Daughton & Ternes (776)
Hirsch et al. (418)
Ternes et al. (487)
Halling-Sorensen et al. (577)
Ternes (602)
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
(numbers in parentheses)=counts from Google Scholar for papers with more than 400 citations
note: data for 2009 only through first 8 weeks

A More Accurate Birth Date – 150 years ago

George P. Marsh: forerunner to the modern environmental movement. Over 150 years ago, recognized that interconnections pervade all of nature.

Birth of the idea of incremental, cumulative impacts from small forces. Foretold the new paradigm of countless point-sources combining to serve as a unified dispersed source: **the significance of the combined but miniscule actions, activities, and behaviors of multitudes of individuals.**

Perhaps the first scientific examination and documentation of the thesis that harm accumulates, regardless of the seeming insignificance of each act of harm.

Marsh GP. 1864. *Man and nature; or, Physical geography as modified by human action.* C. Scribner, New York.

1864: Birth of the idea of incremental, cumulative impacts
[or … *Small Can Be as Big as Big*]

From the chapter:
"**Nothing Small in Nature**."
Marsh GP. 1864.
Man and nature; or, Physical geography as modified by human action.
C. Scribner, New York.

"No atom can be disturbed in place, or undergo any change of temperature, of electrical state, or other material condition, without affecting, by attraction or repulsion or other communication, the surrounding atoms. These, again, by the same law, transmit the influence to other atoms, and the impulse thus given extends through the whole material universe." "…reaction does not restore disturbed atoms to their former place and condition, and consequently the effects of the least material change are never cancelled, but in some way perpetuated, so that *no action can take place in … nature, without leaving all matter in a different state from what it would have been if such action had not occurred*."

Emerging Challenges from Emerging Contaminants

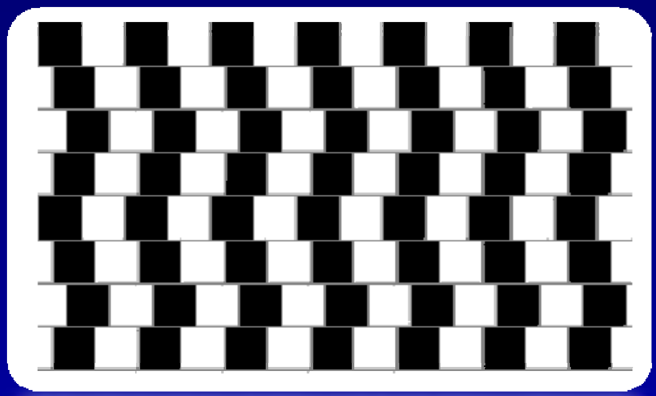
- Increasingly advanced methods of analysis allow peering into the shadows of chemical space with ever-greater magnification and clarity.
- At ever-lower exposure levels, it may no longer be possible to deconvolute a purported effect from its incidence as ambient (natural) background.
- Ever-lower detection limits pose increasingly greater challenges for assessing, communicating, and ameliorating ever-diminishing risks.
- Where do these risks reside within the overall scope of larger environmental concerns?

Complex Mixtures of Chemical Stressors at Ultra-Low Concentrations:

Pose Major Challenges for Measurement and for Assessing Exposure and Biological Effects

What portion of overall risk is contributed by emerging contaminants?

Public Perception



Public perceives only two reasons that ECs occur in the environment:

1. Newly introduced to commerce
2. We failed to detect them up until now

- ECs serve to highlight the fact that the approach to environmental monitoring is reactive rather than anticipatory.
- The term "emerging" can alarm the public, possibly cultivating a negative impression of failure on the part of environmental scientists (but perception does not align with reality).
  - After all, the sole reason that a pollutant becomes known as "emerging" in the first place is simply because of our failure to anticipate or predict (in an ideal world, we should be able to identify and prevent the "emergence" of chemicals).
- Problem is exacerbated with ongoing identification of yet more ECs - with few actions to mitigate or prevent future ones.

The Chemical Universe

We live in a chemical sea of continually changing composition – comprising both anthropogenic and naturally occurring chemical stressors.

Unlike biota, chemical pollutants have no boundaries in their global distribution – "*everything is everywhere*," only the concentrations vary.

The Chemical Universe

The *KNOWN* Universe

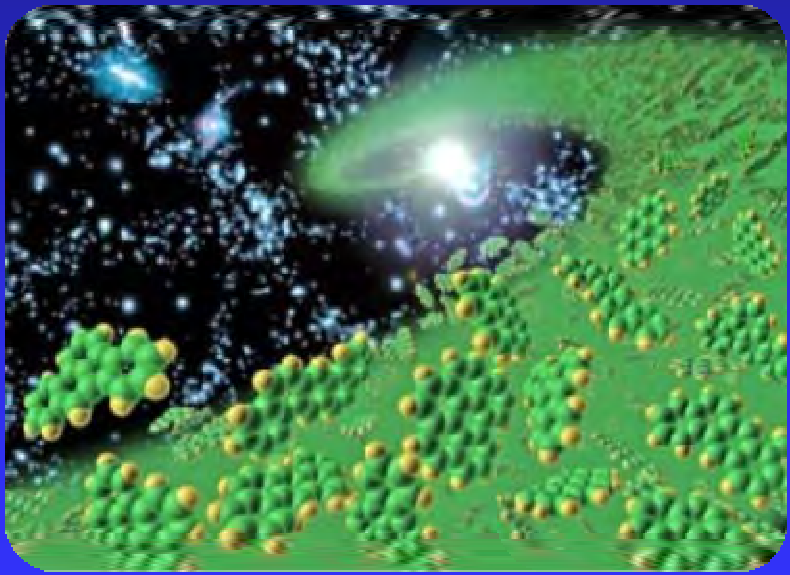
As of April 2010, over 52 million organic and inorganic substances had been assigned CAS RNs.

(indexed by the American Chemical Society's Chemical Abstracts Service in their CAS Registry; excluding bio-sequences such as proteins and nucleotides: http://www.cas.org/expertise/cascontent/registry/regsys.html)

- Of these millions of known chemicals, nearly 40 million were commercially available.

- Roughly only 280,000 are inventoried or regulated by government bodies worldwide - - representing only 0.7% of those that are commercially available or less than 0.6% of the known universe of chemicals.

- Approximately 12,000 new substances are added each day.



The Chemical Universe

The *POTENTIAL* Universe

While the *KNOWN* universe of commercial chemicals might seem large (52 million), the universe of *POTENTIAL* chemicals (those that could possibly be synthesized and those that already exist but which have not yet been identified) is unimaginably large.

How many distinct organic chemical entities could hypothetically be synthesized and added to a seemingly limitless, ever-expanding chemical universe?

By limiting synthesis strictly to combinations of 30 atoms of just C, N, O, or S, **more than 10^{60} structures are possible !**

Expanding the allowable elements to other heteroatoms (e.g., P and halogens) or deuterium, the limits to the numbers of possible structures in “chemical space” defies imagination.

The Chemical Universe

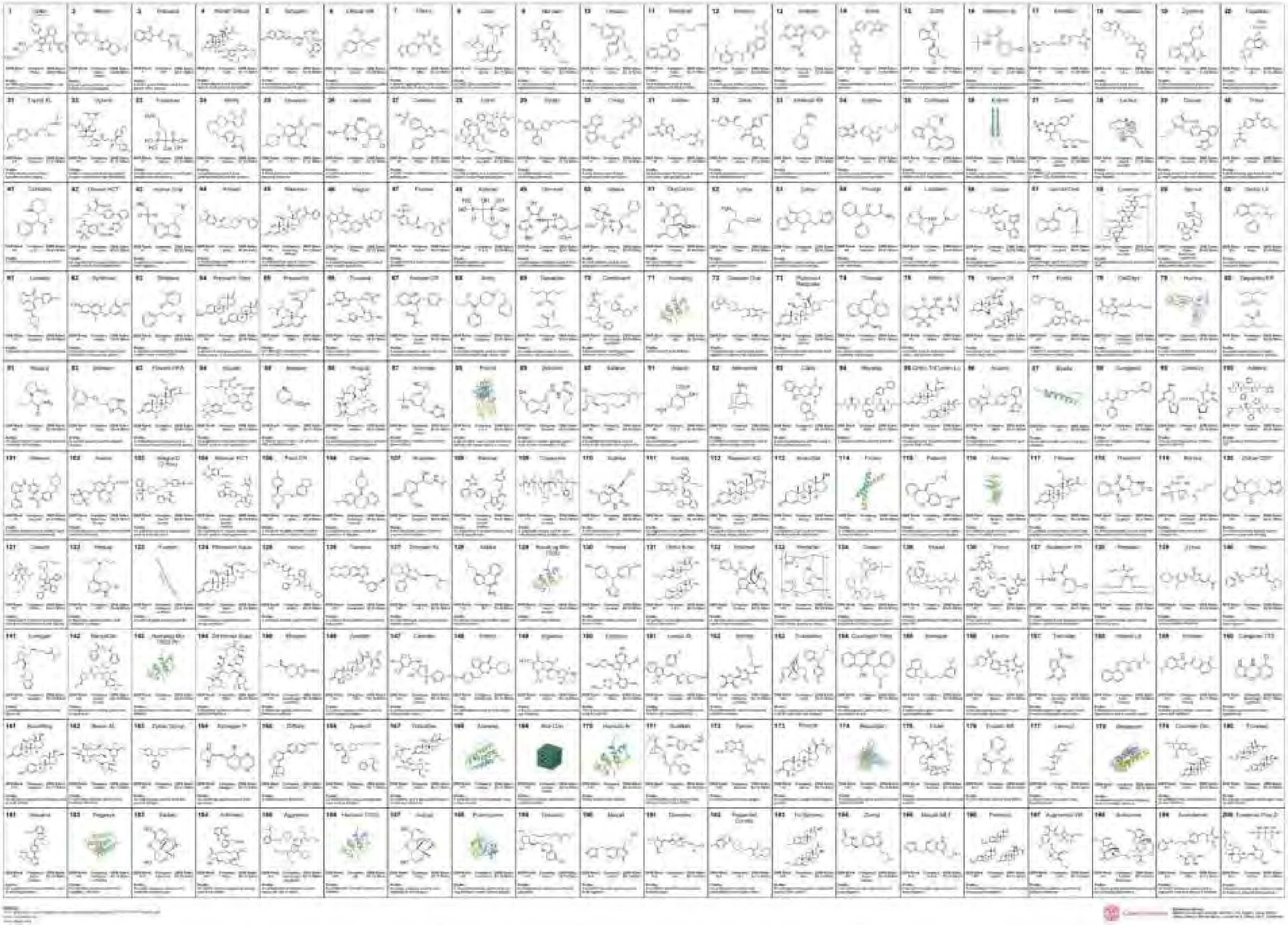
The largest virtual chemical database yet reported comprises small drug-like molecules - - a total of over 977,000,000 structures (Blum and Reymond, 2009).

Restricted to organic molecules containing fewer than 14 atoms of C, N, O, and S (and limited types of Cl-substituted molecules). Excluded likely substituents such as F, Br, I, P, Si, metals, and most Cl.

Database represents the enormously large numbers of chemicals that could possibly be synthesized just from a very limited spectrum of types of elements and numbers of atoms.

Blum, L. C., and J.-L. Reymond. 2009. 970 Million Druglike Small Molecules for Virtual Screening in the Chemical Universe Database GDB-13. J. Am. Chem. Soc. 131 (25):8732-8733.

200 Top-Selling Prescribed Drugs (2006)

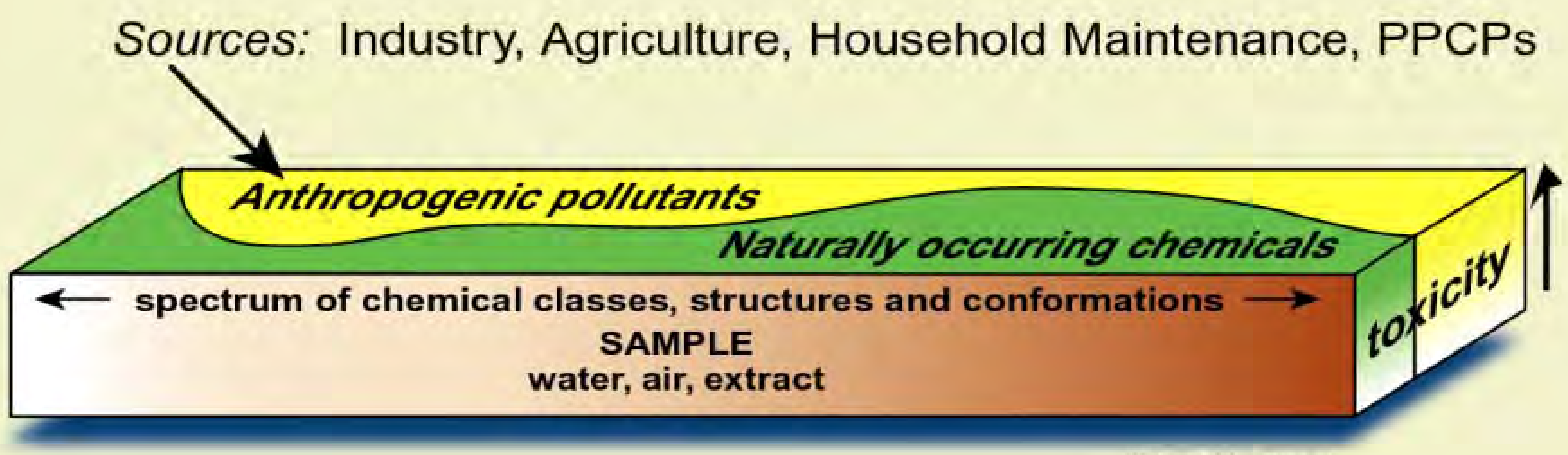


Black Holes in Exploring the Universe Chemical by Chemical

- Traditional chemical-by-chemical approach for evaluating risk of new and existing chemicals is not sustainable (speed, complexity, cost)
- Extensive environmental and toxicological data exist for very few chemicals
- New paradigm will be required to cope with the backlog of existing chemicals and the sheer number of possible new chemicals
- Realization of the critical importance of multi-generational, simultaneous exposure to individual trace levels of multitudes of chemical stressors
- Subtle, delayed-onset effects
- Chemicals cannot be prioritized based solely on commercial volume and conventional toxicity testing
- Assessment of hazard (both virtual and empirical) will require extremely high throughput

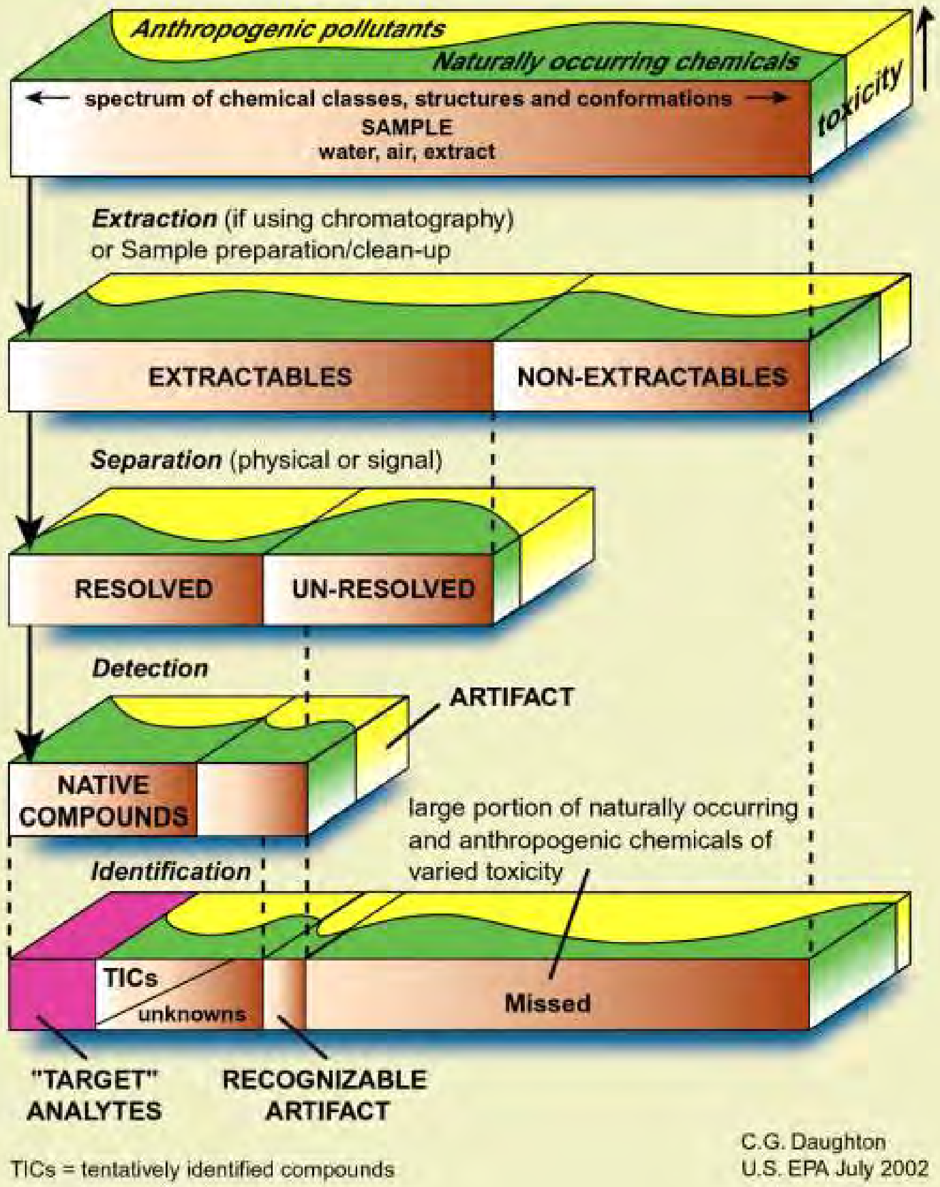
Lessons learned from emerging contaminants will undoubtedly play a major role in the future of risk assessment and risk reduction/mitigation.

Universe of Chemicals in the Environment

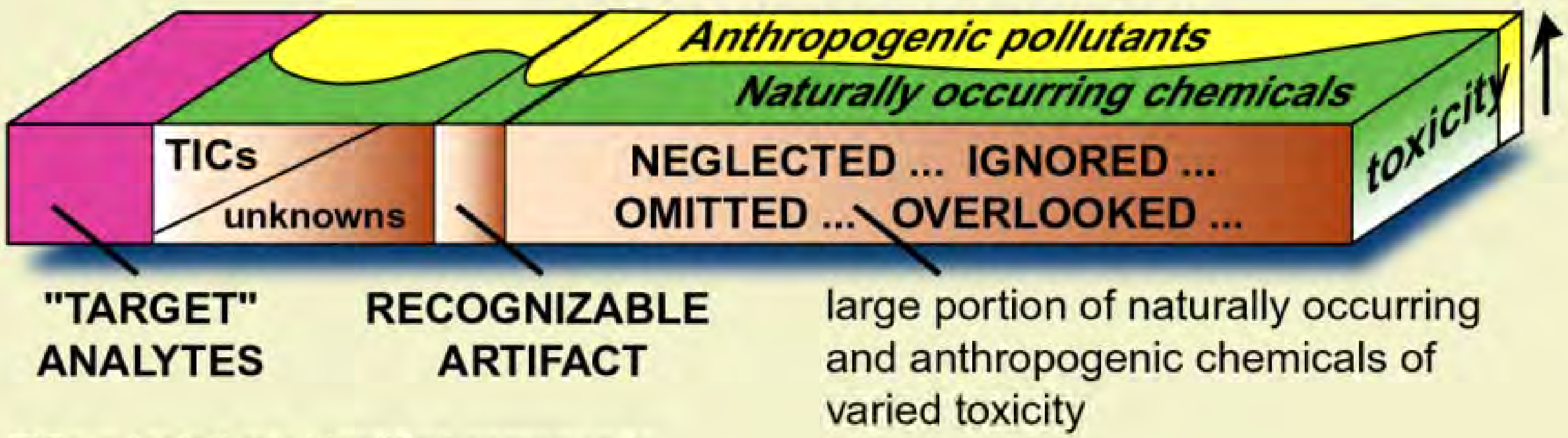


From: Daughton, C.G. "Cradle-to-Cradle Stewardship of Drugs for Minimizing Their Environmental Disposition while Promoting Human Health. I. Rationale for and Avenues toward a Green Pharmacy," *Environ. Health Perspect.* **2003**, *111*(5):757-774; available: http://www.epa.gov/nerlesd1/bios/daughton/green1.pdf.

Limitations and Complexity of Environmental Chemical Analysis



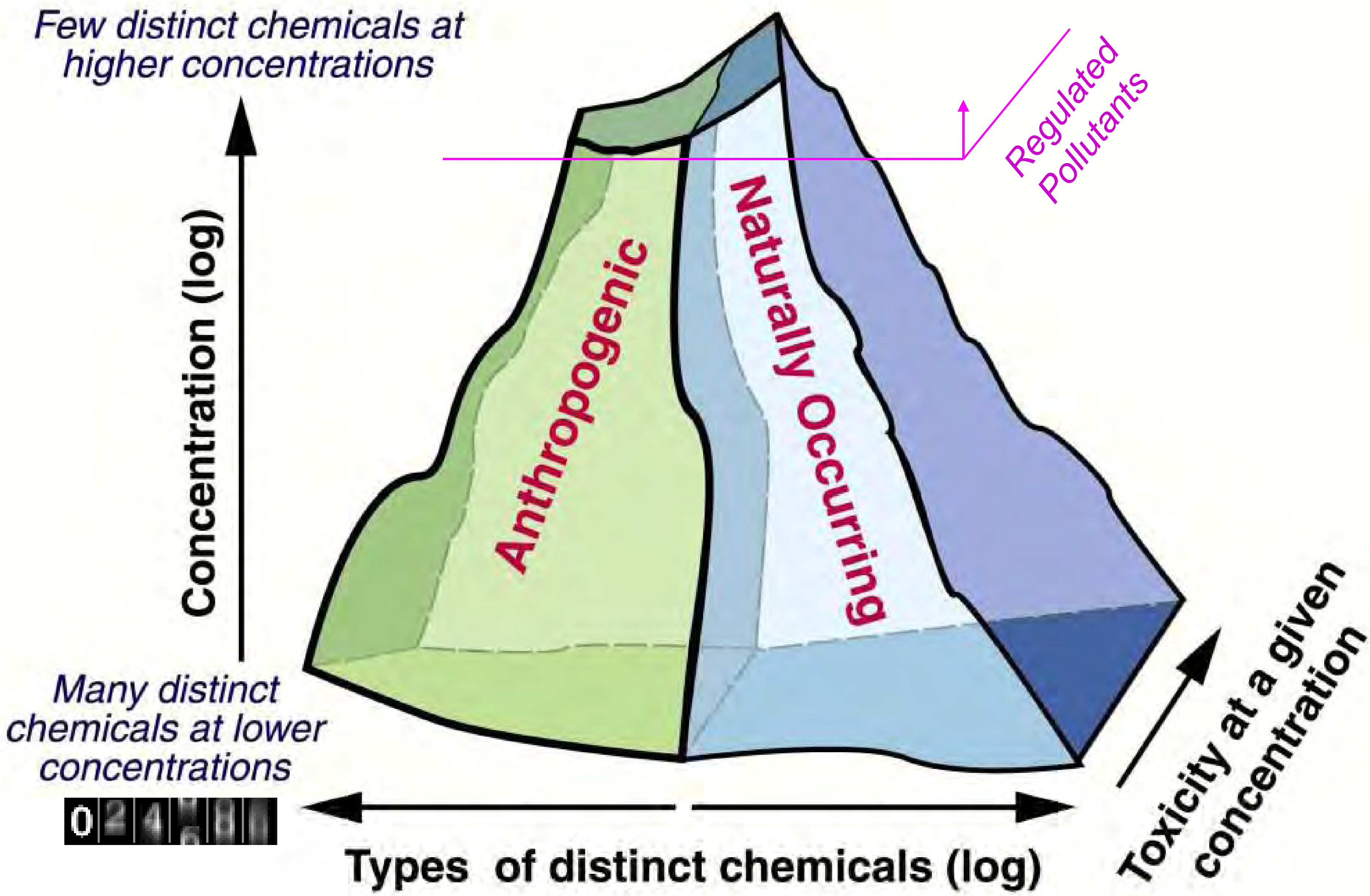
Chemical Analysis Output for a Typical Environmental Sample



TICs = tentatively identified compounds

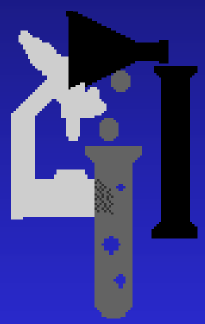
C.G. Daughton
U.S. EPA July 2002

Prevalence/Distribution of Xenobiotic Occurrence



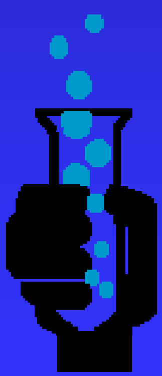
Einstein on:
Environmental Monitoring

"Not everything that can be counted counts, and not everything that counts can be counted." (oft attributed to Albert Einstein)



corollary for environmental monitoring

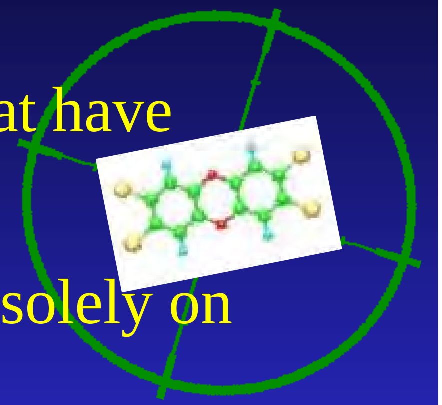
Not everything that can be measured is worth measuring, and not everything worth measuring is measurable.



further truisms regarding *Environmental Monitoring*

- What one finds usually depends on what one aims to search for.
- Only those compounds targeted for monitoring have the potential for being identified and quantified.
- Those compounds not targeted will elude detection.
- The spectrum of pollutants identified in any sample often represent but a small portion of those present and they are of unknown overall significance with respect to risk.

Biasing Our Perspective of Chemical Exposure?



Monitoring studies tend to target those chemicals that have already been reported in prior studies.

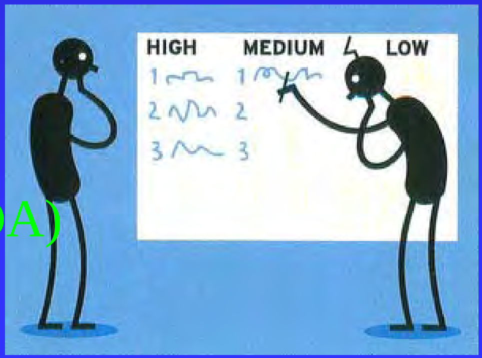
Targeted analytes therefore are often self-selected – solely on the basis of prior positive results.

- Are published data providing a highly biased, selective view of the world of chemical contaminants?
- How large is the chemical world that monitoring activities are overlooking?
- How do we establish how accurate and comprehensive the current picture is?

Weaknesses in schemes for selecting or prioritizing ECs for monitoring or assessing risk

Chemical-by-chemical approaches must account for stressors that:

- have long been present but are not yet known (chemical unknowns, including natural products and degradates from known chemicals)
- are truly emerging (e.g., new illicit chemicals; by-products from new processes)
- have mechanisms of action not yet recognized - with effects not yet evident (e.g., delayed-onset; subtle, cumulative effects; effects hidden within the variance of natural background)
- have no inherent toxicity of their own but which potentiate the toxicity of others (e.g., efflux pump inhibitors)
- while present at low levels, are extremely potent or can combine for additive or interactive effects (e.g., drugs in same therapeutic class, sharing same MOA)



New paradigm needed for addressing ECs?

Limitations and vulnerabilities of target-based chemical monitoring show that an alternative monitoring approach might be more efficacious:

Shift initial focus to biological effects and away from stressors:

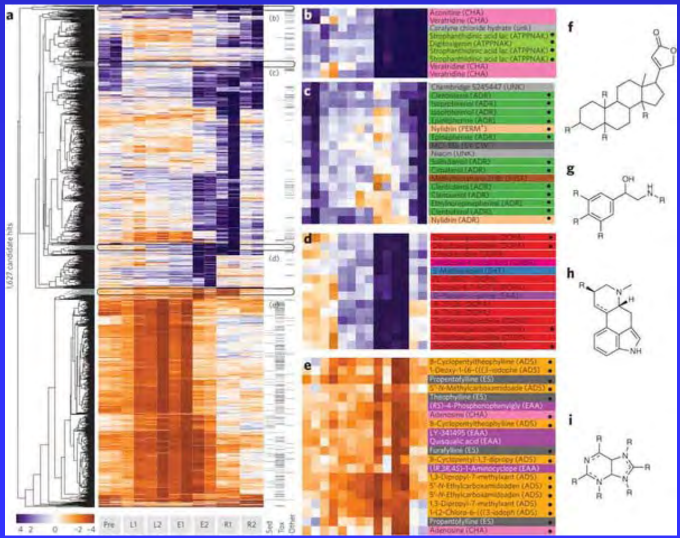
Chemical monitoring places the emphasis on identifying potential stressors to which humans and the environment may or may not ever be exposed - and for which, the potential for effects is largely unknown. *Chemical monitoring often appears to become the end in itself - creating a vacuum for communicating what it might mean.* The historic focus has been on the stressor rather than on outcome or ultimate concern - namely, the potential for exposure and biological effects.

Biological endpoints to inform and guide monitoring:
Given the sheer numbers of ECs that might exist now and in the future, might the power and meaning of target-based chemical monitoring be vastly improved by instead using biology-based screening as the initial survey tool to guide subsequent chemical monitoring?

New paradigm needed for addressing ECs?

Example:

Holistically assess overall potential for adverse biological impact from chemical contaminants with standardized arrays of biology/biochemical assays based on evolutionarily conserved cellular processes whose responses integrate the signals from all chemical stressors present. Examples include cell- or biochemical-based assays (or biomarkers) for measuring inhibition of efflux pumps, endocrine modulation responses, and cellular stress responses.



New paradigm needed for addressing ECs?

Might protecting human health and the environment be served more directly and efficiently by:

Empowering the public: Complexity of the EC issue poses extreme challenges for communication of risk to the public - and prevention or misperception of risk. Critical to involve other disciplines (particularly social psychologists) in the ongoing dialog regarding chemical pollution. Better public understanding of chemical pollution could dramatically facilitate its reduction of elimination.

Designing a sustainable chemocentric society: More efficient use of chemicals and wider implementation of green chemistry practices integrated with pollution prevention and stewardship.

Regardless of whether ECs are ever shown to pose hazards as trace environmental pollutants, actions directed at reducing their entry to the environment via stewardship and pollution prevention (coupled with heightened public awareness) could achieve immediate outcomes. Leveraging would inevitably result, yielding collateral beneficial outcomes extending far beyond those targeted specifically at ECs.

Are we headed in the right direction? What should we expect to achieve?

- Are our priorities in balance with society's expectations and needs?
- Are we focusing on those areas that will yield the most important outcomes?
- Is research sufficiently coordinated and leveraged - internationally?

Possible Major Outcomes from Emerging Contaminants Research

- Improve our ability to assess risk more comprehensively.
- Expand the known universe of chemical stressors. Provide means to identify previously unrecognized or unexpected contaminants.
- Improve the public's understanding of risk - and how all actions can impact the environment.

Possible Major Outcomes from Emerging Contaminants Research

- Catalyze new paradigm for screening and controlling chemical unknowns in complex mixtures that pose actual rather than potential risks.
- Reduce cost and improve speed and efficiency of managing, mitigating, and preventing chemical pollution.
- Develop proactive capability for early warning or predictive ability for identifying newly emerging contaminants.

Questions to Consider

- Is it useful to call well-established ubiquitous environmental contaminants "emerging"?
- Would a term other than ECs be more accurate and useful for "unregulated" chemical contaminants?
- Should such a term also convey a clear meaning for the public and regulators?
- How might progress and success be assessed with regard to research in ECs?

Questions to Consider

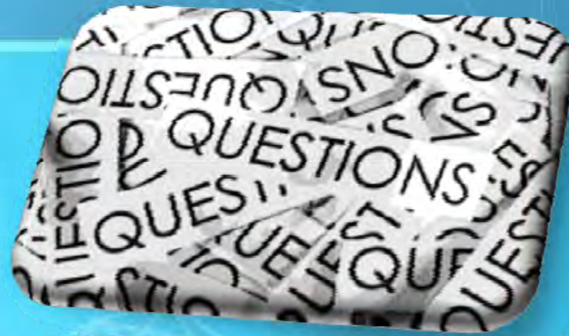
- Can a process be designed to ensure that today's "emerging contaminants" don't persist, becoming tomorrow's concern?
- At what point can a chemical be "graduated" out of the domain of "emerging"?
- Can a proactive system be designed that obviates the need for the term "emerging" in the first place?
- Can stewardship and green chemistry programs be designed to effectively prevent the entry of ECs to the environment?

Final Thoughts

- An individual chemical contaminant can be viewed in a context beyond that of its specific molecular structure and particular toxicological properties.
- Ideally, its presence in the ambient environment might be expected (at the worst) to comport with its value in sustainable use.
- Focus has long been on the individual chemical as an environmental contaminant rather than on preventing its becoming a contaminant in the first place. A sustainable balance might exist between the manufacture and the ultimate uses of any given chemical.

Final Thoughts

- The types and trends in levels of chemical contaminants in the environment serve as direct measures of our progress toward sustainability - from green and virtual chemistry, to smart manufacturing and intelligent consumption.
- Sustainability could be advanced from consumers better understanding their individual roles in both causing (via combined miniscule inputs) and preventing the release of chemicals to the environment. ECs serve to highlight that the environment and humans are intricately interconnected in a complex system that would benefit from examination as an integral whole.



feel free to contact:

Christian Daughton, Ph.D.

Chief, Environmental Chemistry Branch

Environmental Sciences Division

National Exposure Research Laboratory

U.S. Environmental Protection Agency

Las Vegas, Nevada 89119

daughton.christian@epa.gov

702-798-2207

http://www.epa.gov/nerlesd1/bios/daughton.htm *prepared for:*

NorCal SETAC 20th annual meeting

Contaminants of Emerging Concern: Responding to a 21st Century Challenge

University of California, Berkeley

13 May 2010

Christian Daughton, Ph.D.

Chief, Environmental Chemistry Branch
Environmental Sciences Division
National Exposure Research Laboratory
U.S. Environmental Protection Agency
Las Vegas, NV 89119
daughton.christian@epa.gov
702-798-2207

prepared: 3 May 2010