Contaminants of Emerging Concern (CECs)

Patrick Moran, USGS

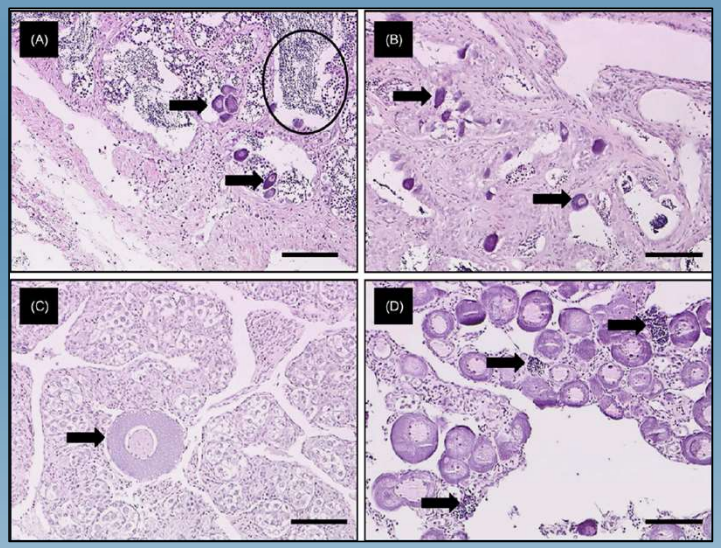
Mark Jankowski, US EPA

USGS science for a changing world

Region 10

Contaminants of Emerging Concern (CECs or CsEC?)

1) Brief History
2) Explosion of Chemical List
3) Mixture complexity
4) Convenience of narrower groups
5) Newer Analytical Chemistry and Toxicology (expands toolboxes)



Hinck, J. E., V. S. Blazer, C. J. Schmitt, D. M. Papoulias, and D. E. Tillitt. 2009. Widespread occurrence of intersex in black basses (Micropterus spp.) from US rivers, 1995–2004. Aquatic Toxicology **95**:60-70.

USGS science for a changing world

Region 10

CECs- History
…began with endocrine disruptors

Chemicals with ability to 'mimic' human hormones, alter endocrine system

Interface, or knowledge exchange, between humans and wildlife learning recognized

…water as common route of exposure

1992 Colborn, Clement- Book, Princeton Sci. Publ. Comp.

"Chemically-induced alterations in sexual and functional development: the wildlife/human connection"

1994- EPA begins using "Endocrine Disruptors" in planning documents

1996 "Our Stolen Future" book Theo Colborn,

Big Splash- introduction by Al Gore, articles in Newsweek, New York Times

1996/1997 EPA provides background documents and "Strategy" document

Early CECs as Endocrine Disruptors

- Many, many compounds seen as having some degree of 'mimic' of endocrine system (both "natural" plant-based, and man-made)
- Estrogen and testosterone 'standards' for pollutant potency normalized
- Often occur at low levels, and as 'mixtures', complex challenge aka "Wicked" problem of how many, from where, combined effect

  Much work still in progress
- Best Example, Estrogen mimics-> Vitellogenin reduction (liver, blood)-> thin shelled fish eggs -> fish population declines
  - Best example- Kidd 2007, Proc. Nat. Acad. Sci., experimental lake Ontario dosed w/ estradiol

But, Endocrine Disruptors as CECs, just one of many CEC examples……

Personal Care Products- triclosan, nonylphenols

Food and Beverage containers- BisPhenol-A, Dioxanes

Pharmaceuticals- progestin, estrogen, carbamazepine

Waste Water compounds- cholesterol, caffeine, sitosterols*

Drinking Water Treatment compounds- trihalomethanes

Pesticides- atrazine, carbendazim

Cars and Roads- PAHs, 6PPD-q

So, we need a new phrase……

…"CECs" so broad, not helpful……

……we may need new Analytical Chemistry

As this list of 'emerging' contaminants grows, so does the challenge of "looking for them" in the environment.

Traditionally, had to define and pre-determine what was going to be measured in the lab.

- PCBs- 209 Congeners
- Priority PAHs- 16
- Pesticides- Organochlorines vs. pyrethroids vs. organophosphates vs. glyphosate only

Define and group by Source or by Mode of Action- maybe by both

Each needs their own method, 'standard' and calibration curve in the lab for quantification.

This, "one-by-one" measuring of chemicals assumes we know what's present in sample. (???)

What if we don't really know what is in the sample? ……or what is the 'toxic' agent ?

This was the case with the "pre-spawn mortality" problem that plagued NOAA and USFWS in the Puget Sound for years. = Dave Wark's talk later today.

A sequential, or "by chemical class", process of elimination (using knowledge about sources) is traditional CEC's approach

But- that approach is not 'open' to new chemicals, or previously unknown chemicals

"Open Read" analytical techniques, namely GC-MS Time of Flight new opportunity

(Matrix-assisted Laser desorption/ionization- MALDI TOF MS a powerful tool in USGS method development)

Looking for what we don't know is there……

Pros-

Automation and library improvements in Analytical chemistry databases allow for expanded 'searches' for unknown or 'under recognized' compounds

Strong growth in sharing of electronic notebooks and online "libraries" of MS results

Open to new chemicals, not currently appreciated

Cons-

Labor intensive, slow = expensive

Few commercial labs or skillsets available.

Need to utilize the skillset strategically, for 'key' questions or unknowns.

Current and Future of CECs

- More useful to discuss more narrow groups (…..may not reflect reality)
  - by source = **Pharmaceuticals, Pesticides, Wastewater, Fire Retardants, Roadways**, etc
  - or by Mode of Action = Estrogens, Androgens, Neurotoxicants, Cancer risk, cell metabolism, etc.
    - here- Adverse Outcome Pathways important source to lead our thinking (NIH, EPA, OECD)
      - (430 Pathways described, 5675 Key events documented) see aopwiki.org

Chemical Measurements- will need to utilize both,

- "Traditional" analytical chemistry with fixed schedules, compounds – workhorses
- "Open Read" investigations for those problems with unknown toxicants- partnerships for rare skillset

Mixtures-

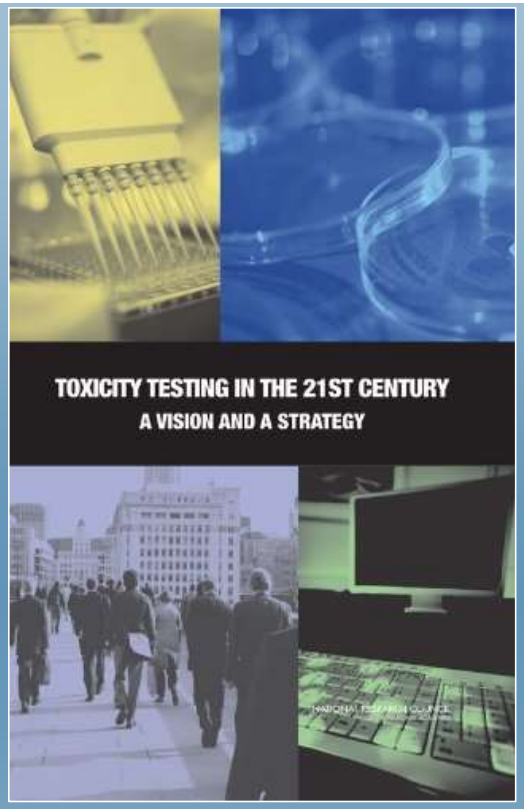
- Will be best addressed Stepwise, by common Modes of Action approaches, groupings
- Basic assumption of potency normalized concentration addition good starting point
  - (more often right than wrong conceptual model)

The Universe is Large

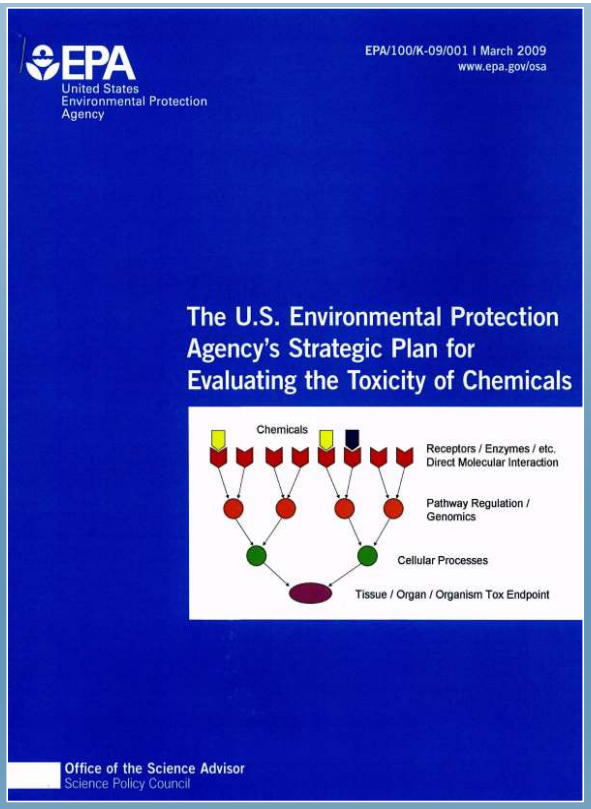
There are 86,000 chemicals in commerce reported to EPA under TSCA. This total excludes pesticides, radioactive materials, food/cosmetics, tobacco/ammo, and trade secrets.

Further, under the American Chemical Society, there are 274,000,000 substances registered. 15,000 chemicals and sequences are added daily. Most will not be produced commercially.

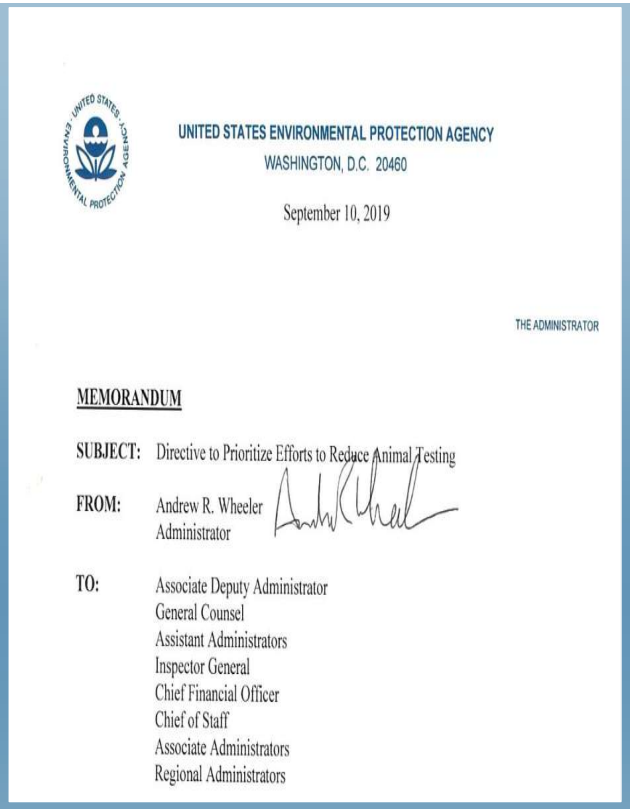
"Traditional" Methods Dominate Risk Assessments



2007



2009



2019

Phasing in NAMs Over Time….

Phasing out Traditional Methods Over Time…

Pre-2007

New Approach Methods (NAMs) can help

Eg:

ToxCast – screens 1000s of chemicals using hundreds of assays

High throughput screening – very fast assays for endocrine, immune, neurological and other acclivities

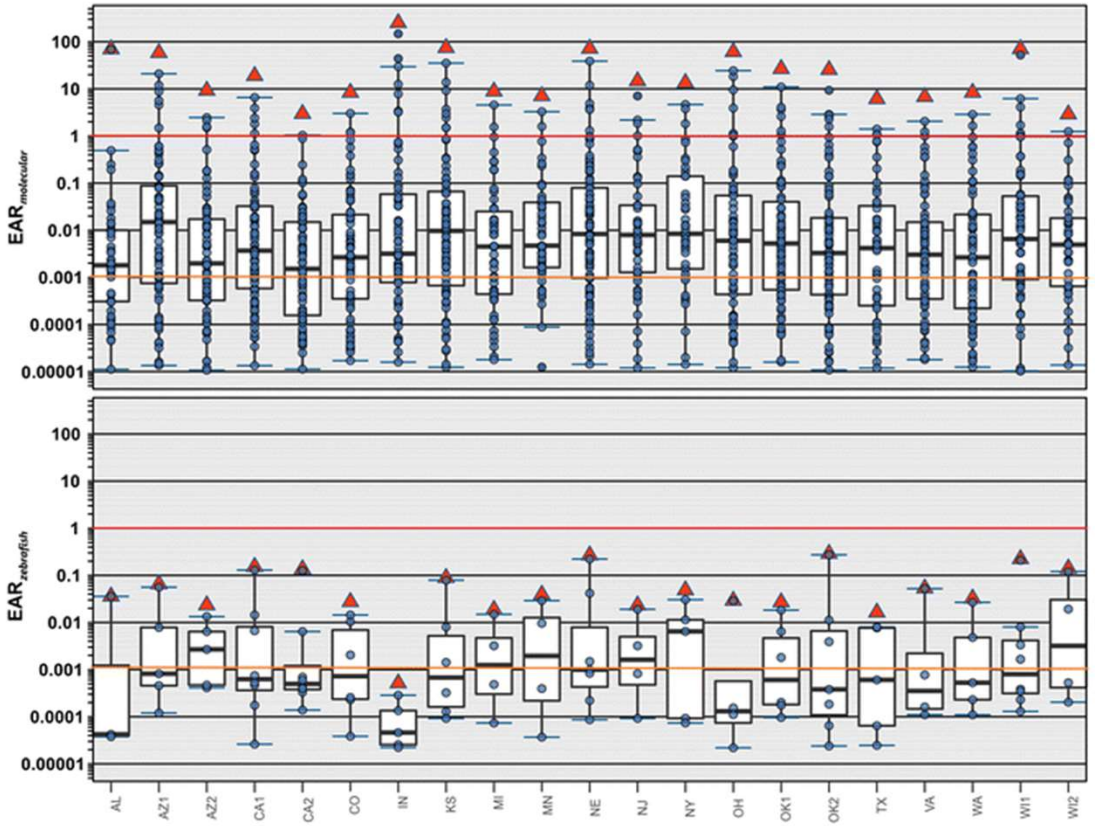
In silico (computer) modeling – uses existing knowledge to predict toxicity

Long Chemical Lists in Samples Can be Compared to ToxCast Bioactivity Data to Prioritize Sites and/or Chemicals…

toxEval

Cumulative and Single Chemical EARs Across US Stormwaters

EAR = Exposure Activity Ratio



Summary

CECs as endocrine disruptors as a recognized problem for decades (at least since the 90s)

Chemical list is long but traditional analytical chemistry is slow

Non-targeted mass spec helps identify the chemical universe and can group into sources/types for further assessment

But toxicity is usually unknown

Non-targeted and targeted New Approach Methods are being deployed to understand toxicity of chemicals and environmental samples/mixtures

Eventual goal is to prioritize our clean-up and other actions for many CECs

Questions and comments welcome

Contact Information

Patrick Moran of USGS (pwmoran@usgs.gov)

Mark Jankowski of EPA (jankowski.mark@epa.gov)