Global cancer risk from unregulated polycyclic aromatic hydrocarbons

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What are PAHs?

Burning of organic matter

- **emission**
- **inhalation**
- **DNA damage**
- **cancer**

Global lung cancer risk results from exposure to PAHs, including local and long-range transport

Highly regulated pollutants nationally and internationally

Shen et al., *Scientific Reports*, 2014
Challenges of assessing and regulating a class of compounds

- Hundreds of different PAHs
- **Benzo(a)pyrene** often used as a proxy or marker for the entire mixture
  - WHO, UK, EU, Canada
  - Previous measurement studies estimate it comprises 40-80% of overall PAH risk
- US EPA prioritizes 16 emitted PAHs
- 4 PAHs used as indicators of emissions for Convention on Long-Range Transboundary Air Pollution (UNECE)

Polycyclic Aromatic Hydrocarbons (PAHs)

- Naphthalene
- Acenaphthylene
- Acenaphthene
- Fluorene
- Phenanthrene
- Anthracene
- Fluoranthene
- Pyrene
- Benzo(a)anthracene
- Chrysene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-c,d)pyrene
- Benzo(g,h,i)perylene
- Dibenz[a,h]anthracene

Plus 100s of other emitted and produced compounds
Atmospheric reactions produce additional PAHs

- Increasing attention in environmental measurement and toxicology to degradation products and PAHs beyond the 16 EPA compounds (including higher molecular weight PAHs)

- Oxidation products can be orders of magnitude (10-1000x) more toxic than parent compounds

What is the relative importance of different PAHs to global cancer risk?
Global models of PAHs include few species.

Friedman and Selin (2012, ES&T): BaP, phenanthrene, pyrene

Shrivastava et al. (2017, PNAS): BaP only

Shen et al. (2014, Sci Rep): BaP only

Global long-range transport and lung cancer risk from polycyclic aromatic hydrocarbons shielded by coatings of organic aerosol

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Shrivastava et al. (2017, PNAS): BaP only
Our approach: A global model to examine the relative impacts of different PAHs

- Global-scale, 3-dimensional atmospheric chemistry and transport model
- Global emissions inventory for 16 PAHs (from Shen et al. 2013)
- Developed chemical mechanism for nitro- and dinitro-PAH formation and included in model (48 species)
- Evaluated vs. global database of atmospheric measurements (plus extensive uncertainty analysis)
- Used animal-based toxicity approach to avoid “double counting” cancer causes from multiple PAHs
  - Compared with epidemiological estimates of cancer risk
Finding #1: BaP is a poor indicator compound

BAP – the PAH usually used to represent the entire mixture

Fluoranthene – another emitted PAH
Finding #1: BaP is a poor indicator compound

Fraction of global cancer risk

- 17%: N-PAHs
- 11%: BaP
- 71%: other emitted PAHs

Compare with 40-80% estimate for BaP from measurement studies

Relative risk differences: BaP suggests 3.5x difference in risk, our method suggests 12x
Finding #2: PAH degradation products contribute substantially to cancer risk ($\gtrapprox$BaP)

Nitro-PYR – the oxidation product of PYR

- Likely even more than we calculate here, as we don’t account for oxy-PAHs and other degradation products, and limited info on toxicity for those included (12 out of 32)
- Unregulated, and largely unmonitored
- Different distribution than parent compounds
Implications: What are the best ways to reduce overall risk?

- Increased scientific and regulatory attention to degradation products and PAHs other than BaP – at global scale
- More measurements needed to quantify exposure
- Monitoring changes in BaP will not be an effective indicator of overall change in risk
- Changed identification of high priority source reductions?
- Better understanding of exposure to mixtures and their impacts