

Global health burden of ammonia emissions from fossil-fuel derived nitrogen fertilizer use



Karn Vohra¹, Eloise A. Marais¹, Rebekah P. Horner¹, Aaron van Donkelaar², Randall V. Martin²

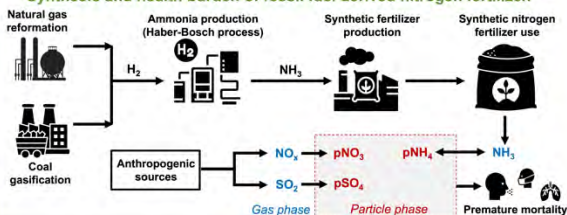
¹ University College London; ² University of Colorado Boulder

POLICY • Evidence-based strategies to enhance nitrogen usage efficiencies without affecting crop yields crucial to benefit public health and sensitive ecosystems.
IMPLICATIONS • Need for contemporary, gridded, time-resolved, and publicly accessible fertilizer NH₃ emissions inventories to refine burden estimates and inform policy.

1. BACKGROUND AND AIMS

- Inefficient use of synthetic nitrogen fertilizers, sourced almost exclusively from fossil fuels, produces large quantities of ammonia (NH₃) that form health-harming fine particulate matter (PM_{2.5}). The impact on global health is unquantified and unaccounted for in fossil fuel end-use health burden assessments.
- Emissions data specific to fertilizer NH₃ emissions are severely limited making it challenging to quantify this burden. Here, we estimate a plausible range of global attributable mortality.

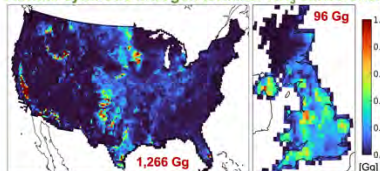
Synthesis and health burden of fossil fuel derived nitrogen fertilizer.



2. EMISSIONS AND GEOS-CHEM MODELLING

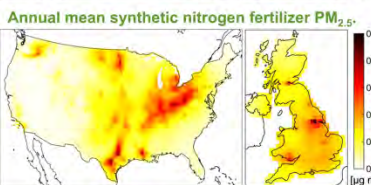
- US EPA National Emissions Inventory 2017 provides NH₃ emissions linked to fertilizer application; For the UK, we use agricultural NH₃ emissions from National Atmospheric Emissions Inventory 2019 and use relative contribution of fertilizer to total NH₃ emissions in each month from Paulot et al. (2014) [doi:10.1002/2013JD021130]

Annual synthetic nitrogen fertilizer NH₃ emissions.



- Emissions hotspots in central plains and California (US) and Northern Ireland and northwest England (UK).

- We run GEOS-Chem model with and without synthetic nitrogen fertilizer NH₃ emissions at 0.25° x 0.3125° spatial resolution.

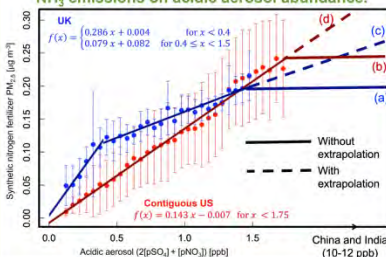


- PM_{2.5} exposure (or population-weighted mean PM_{2.5}) averages ~0.1 µg m⁻³ (US) and ~0.2 µg m⁻³ (UK). Peak values ~0.5 µg m⁻³.
- PM_{2.5} enhancements in regions other than emissions hotspots are in dense populations and large point sources with large acidic aerosol precursor emissions.

3. SYNTHETIC FERTILIZER PM_{2.5} AND ACIDIC AEROSOLS

- We relate PM_{2.5} to 2[pSO₄]+[pNO₃] (moles of NH₃ to balance hydronium ions from sulfuric and nitric acid)
- Relationship valid where total ammonia ([NH₃]+[pNH₄]) exceeds 2([pSO₄]+[pNO₃]); >80% grid cells that have 98% of population

Dependence of PM_{2.5} from synthetic nitrogen fertilizer NH₃ emissions on acidic aerosol abundance.

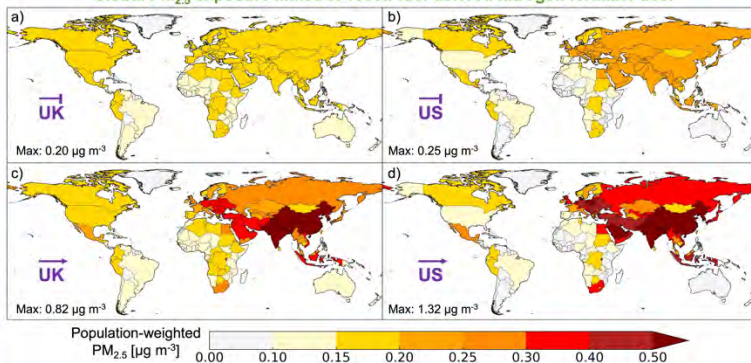


- For the UK, there are 2 distinct slopes and a single linear function for the US.
- Approaches (a) and (b) yield lower-bound estimates and (c) and (d) upper-bound estimates.

4. EXPOSURE TO PM_{2.5} FROM SYNTHETIC FERTILIZER NH₃ EMISSIONS

- We apply the US and UK parameterizations to global 2° x 2.5° GEOS-Chem output.
- Acidic aerosol abundance exceeds max in box 3 so similar exposure for most countries.
- Population-weighted mean synthetic nitrogen fertilizer PM_{2.5} in China and India increases by 3-4 times due to extrapolation to 0.6-0.7 µg m⁻³ using the UK parameterization and 1.0-1.1 µg m⁻³ using the US parameterization.

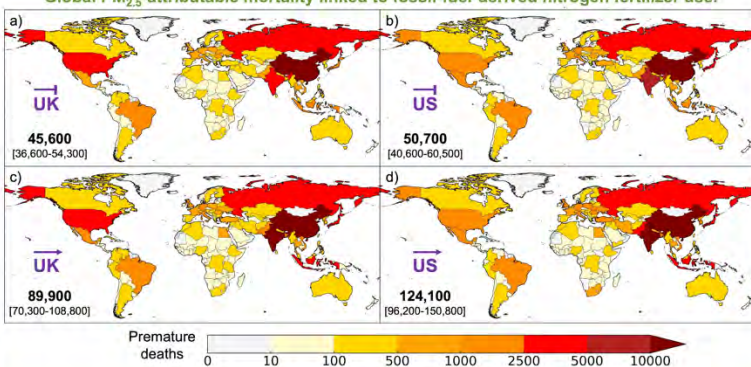
Global PM_{2.5} exposure linked to fossil-fuel-derived nitrogen fertilizer use.



5. SYNTHETIC FERTILIZER PM_{2.5}-ATTRIBUTABLE MORTALITY

- We estimate 45,600-50,700 global adult premature deaths from exposure to synthetic nitrogen fertilizer PM_{2.5} without extrapolation. These estimates double to 89,900-124,100 with extrapolation. Greatest increase in China and India (account for 35-60%).
- This unaccounted health burden is 1-12% of global fossil-fuel end-use health burden.

Global PM_{2.5}-attributable mortality linked to fossil-fuel-derived nitrogen fertilizer use.

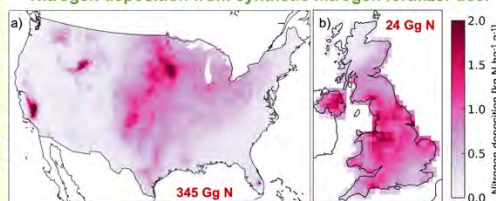


6. DISBENEFITS TO NITROGEN-SENSITIVE HABITATS

- Abatement of acidic aerosols without controls on synthetic fertilizer NH₃ emissions will be insufficient at mitigating environmental harm.

Nitrogen deposition from synthetic nitrogen fertilizer use.

- Annual nitrogen deposition from fertilizer NH₃ emissions is 24 Gg N (UK) and 345 Gg N (US).
- Most emitted nitrogen advected and deposited beyond to neighbouring countries (US) and oceans (UK).



Got any questions?
 Contact me: Karn Vohra
 Email: karnvohra@gmail.com;
k.vohra@ucl.ac.uk
 @kohra_thefog



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