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

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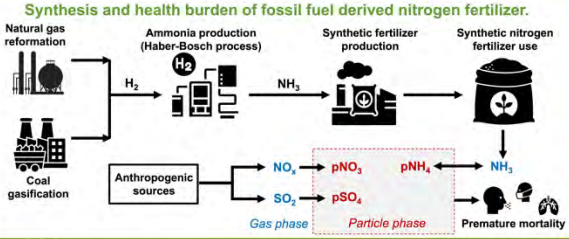
POLICY IMPLICATIONS
- Evidence-based strategies to enhance nitrogen usage efficiencies without affecting crop yields crucial to benefit public health and sensitive ecosystems.
- Need for contemporary, gridded, time-resolved, and publicly accessible fertilizer NH_3 emissions inventories to refine burden 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 (NH_3) 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 NH_3 emissions are severely limited making to challenging to quantify this burden. Here, we estimate a plausible range of global attributable mortality.

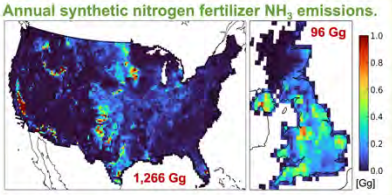
Synthesis and health burden of fossil fuel derived nitrogen fertilizer.



2. Emissions and GEOS-Chem Modelling

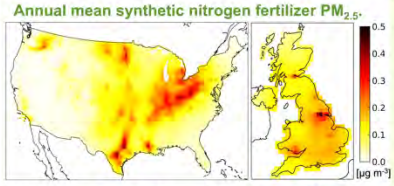
- US EPA National Emissions Inventory 2017 provides NH_3 emissions linked to fertilizer application; For the UK, we use agricultural NH_3 emissions from National Atmospheric Emissions Inventory 2019 and use relative contribution of fertilizer to total NH_3 emissions in each month from Paulot et al. (2014) [doi:10.1002/2013JD021130]

Annual synthetic nitrogen fertilizer NH_3 emissions.



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

Annual mean synthetic nitrogen fertilizer $PM_{2.5}$.

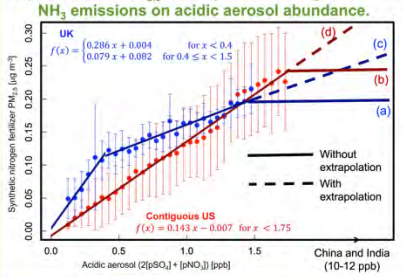


- We run GEOS-Chem model with and without synthetic nitrogen fertilizer NH_3 emissions at 0.25° x 0.3125° spatial resolution.
- $PM_{2.5}$ exposure (or population-weighted mean $PM_{2.5}$) averages ~0.1 μg m^{-3} (US) and ~0.2 μg m^{-3} (UK). Peak values ~0.5 μg m^{-3}.
- $PM_{2.5}$ enhancements in regions 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 $2[pSO_4]+[pNO_3]$ (moles of NH_3 to balance hydronium ions from sulfuric and nitric acid)
- Relationship valid where total ammonia ($[NH_3]+[pNH_4]$) exceeds $(2[pSO_4]+[pNO_3])$; >80% grid cells that have 98% of population

Dependence of $PM_{2.5}$ from synthetic nitrogen fertilizer NH_3 emissions on acidic aerosol abundance.

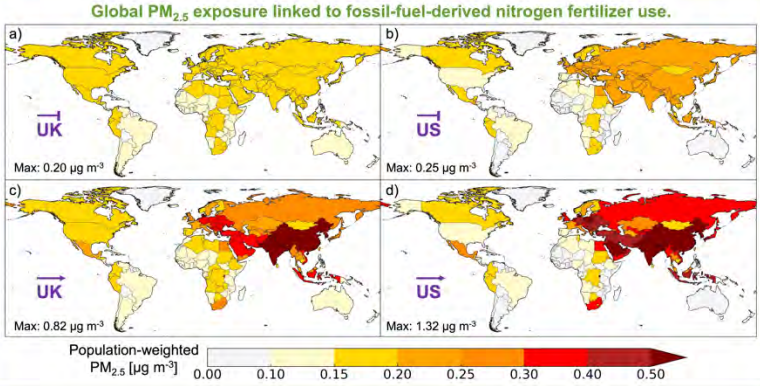


- For the UK, there are 2 distinct slopes and a single linear function for the US.
- Approaches (a) and (b) yield lower-bound estimates and (c) and (d) upper-bound estimates.

4. Exposure to $PM_{2.5}$ from Synthetic Fertilizer NH_3 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.

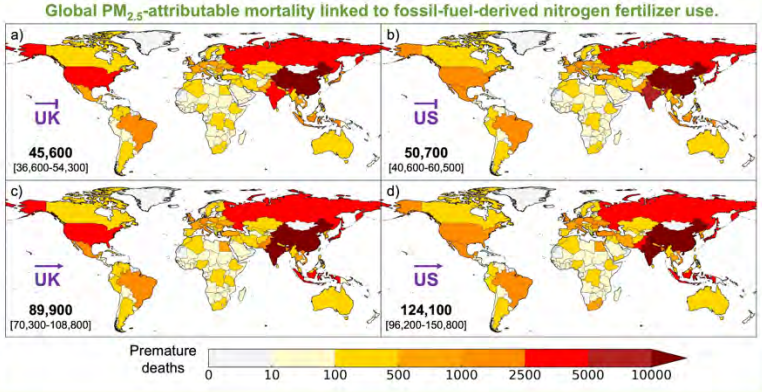
Global $PM_{2.5}$ exposure linked to fossil-fuel-derived nitrogen fertilizer use.



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.

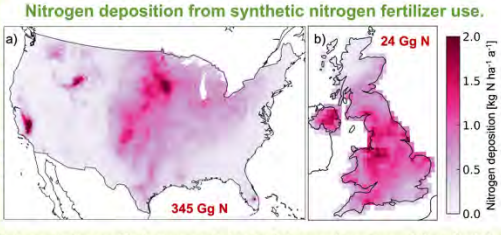
Global $PM_{2.5}$-attributable mortality linked to fossil-fuel-derived nitrogen fertilizer use.



6. Disbenefits to Nitrogen-Sensitive Habitats

- Abatement of acidic aerosols without controls on synthetic fertilizer NH_3 emissions will be insufficient at mitigating environmental harm.
- Annual nitrogen deposition from fertilizer NH_3 emissions is 24 Gg N (UK) and 345 Gg N (US).

Nitrogen deposition from synthetic nitrogen fertilizer use.



- Most emitted nitrogen advected and deposited beyond to neighbouring countries (US) and oceans (UK).

Got any questions?
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Interactive Dashboards

Research findings (air quality trends and premature mortality)

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