Air Pollution From Agricultural Emissions and Dietary Change on Public Health in the UK (AMPHoRA)

Research Question:

"What contribution can emission reductions from agricultural production make to improving public health in the UK?"

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The views expressed are those of the author(s) and not necessarily those of the NIHR or the Department of Health and Social Care.

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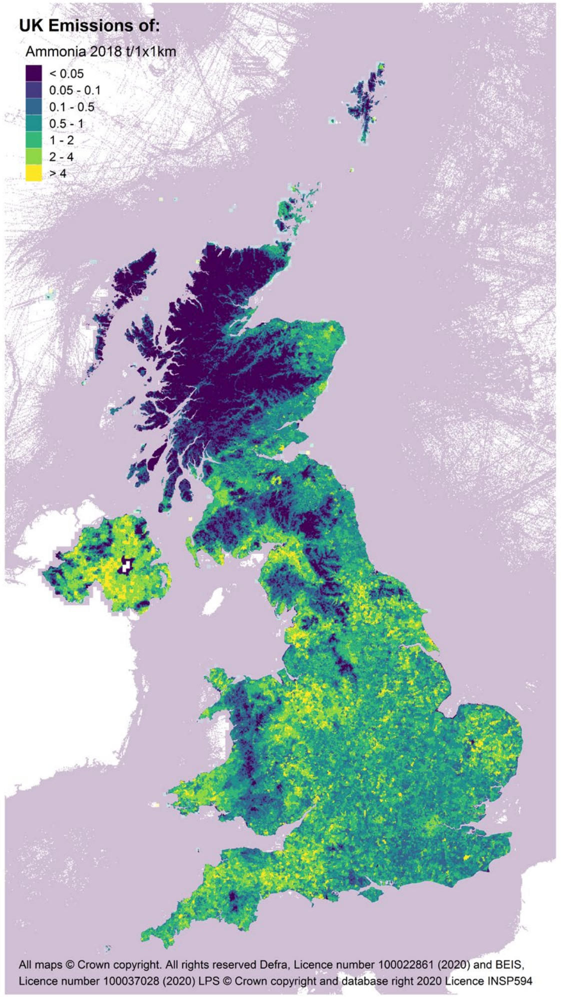

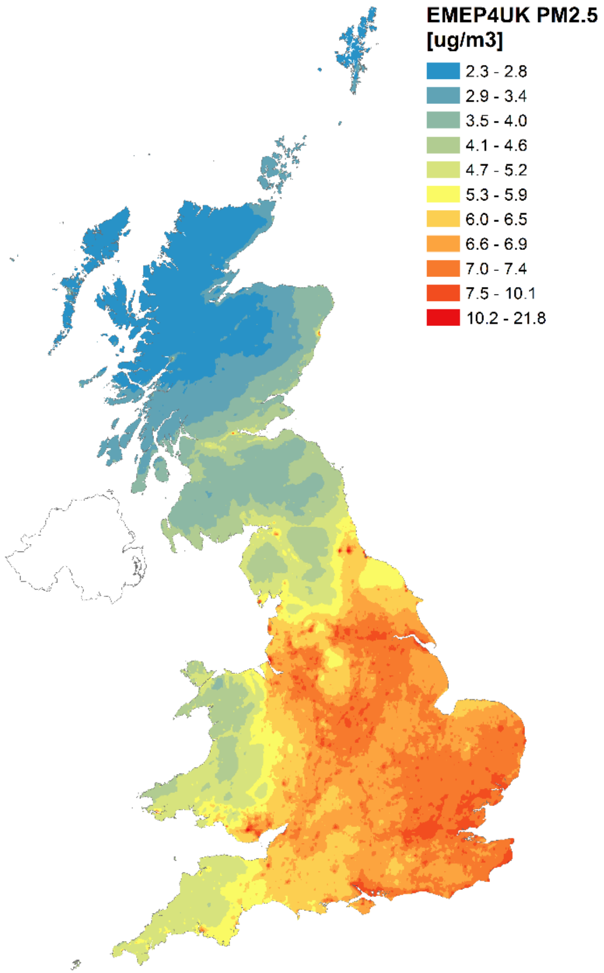

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Key topics addressed in AMPHoRA

- Contribution of **agricultural emissions** of ammonia (NH_3) and other air pollutants to the exposure of UK population to **harmful levels of fine particulate matter** ($PM_{2.5}$)
- Effectiveness of **existing and planned policy interventions** to mitigate emissions and reduce exposure.
- **Public health benefits** in terms of cost savings and improving well-being of vulnerable population groups, patients and the general public.
- **Impacts of interventions** in terms of socio-economic and environmental aspects, accounting for co-benefits and unintended consequences, with a focus on regional and distributional effects.
- Potential **co-benefits of emission and dietary changes for greenhouse gas** (GHG) **emissions**, **biodiversity** and **non-communicable disease prevention**.

Specific objectives (I)

- To convene a **multi-stakeholder group** - comprising government departments/agencies, food and agriculture industry experts, the public, 3rd sector organizations and academics - to **delineate existing and potential future policies with potential to reduce emissions of air pollutants and GHGs** through changes to (i) **agricultural technology and land-use management**, and (ii) **factors influencing dietary patterns**

- To **quantify the impact** in terms of key nutritional constituents and fulfilment of nutritional needs of **interventions aimed at altering patterns of food consumption and UK production** that both help to reduce air pollutant emissions and improve diets for health and sustainability

- To quantify the impact of such policies on air pollutants, GHG emissions, and on population-weighted ambient concentrations of PM, NO_2, and ozone, now and in future, under policy scenarios defined in (1)

Specific objectives (II)

- To **develop and apply models of health impact** capturing the **mortality and morbidity benefits/harms of changes in air quality of food/agriculture interventions** (including both existing and potential future policies), and of the associated dietary changes and environmental impacts where relevant

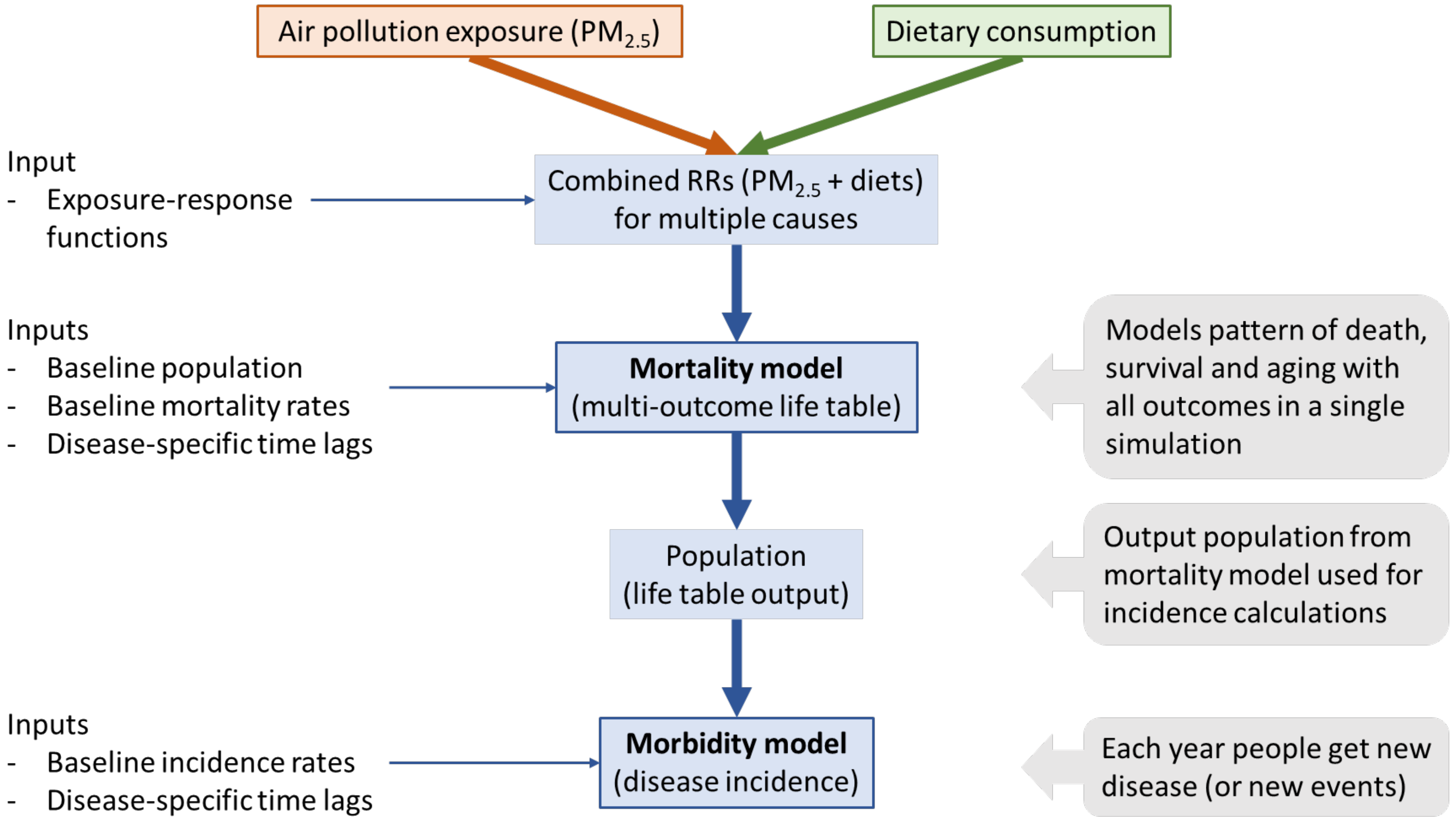
- To **compare policies over time horizons up to 2050** using a multi-criteria assessment framework with assessment criteria **developed with the multi-stakeholder group** (and to include the fulfilment of AP goals, health, health differentials, GHG emissions targets, economic costs)

- To assess the **implications of these analyses for policy development and implementation, patients and the wider public**, taking account of real-world constraints and opportunities, including with the aid of **an iterative cycle of stakeholder engagements**

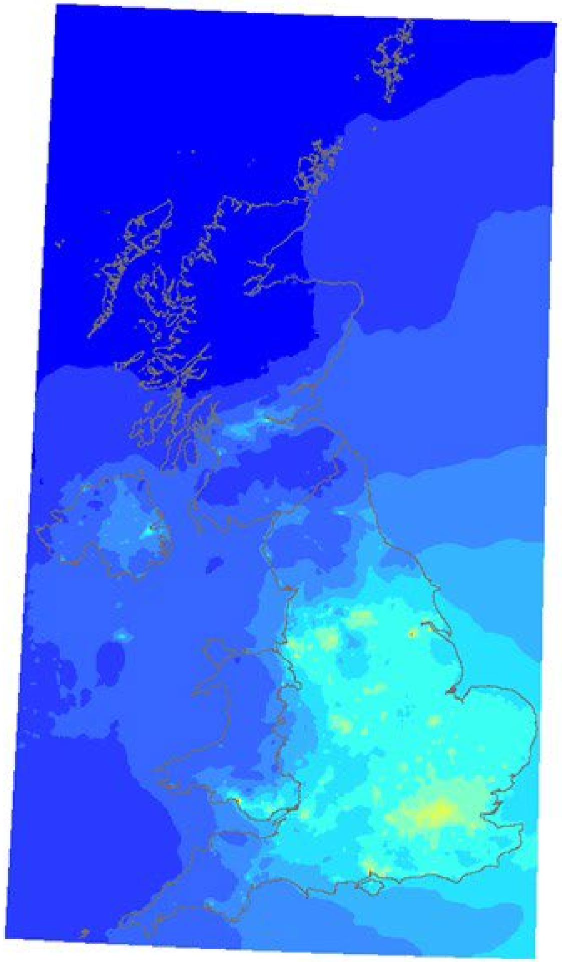
Selected Results – Scenarios considered

Scenario number	Scenario name	Description
1	Present day (2019)	The estimate of ammonia emissions from UK agriculture for 2019 as reported in the UK Air Quality Pollutants Inventory national submission 2021, covering the years 1990-2019.
2	2019 with current agricultural emission measures removed	Current uptake of ammonia mitigation measures is set to zero; comparison with Scenario 1 shows what has been achieved to date through implementation of technical mitigation measures.
3	Current market trend to 2030	A 'Business as usual' projection for the agriculture sector assuming current (2019) rates of implementation of mitigation measures but with livestock numbers and crop areas based on forecasts from the UK Agricultural Market Model (Defra, September 2020)
4	Lower emissions from farms – medium ambition 2030	Medium ambition uptake of mitigation measures on farms based on the Defra Clean Air Strategy proposal
5	Lower emissions from farms – high ambition 2030	High ambition uptake of mitigation measures on farms, improvements in agronomic efficiencies and reductions in food waste (pre- and post-farm gate) based on measures included in the CCC Balanced Pathway to Net Zero
6	Human diet trend to 2030 – no export limits	Livestock numbers and crop areas for 2030 based on UK human dietary trends and market projections, with no limits on export of UK agricultural commodities
7	Human diet trend to 2030 – with export limits	Livestock numbers and crop areas for 2030 based on UK human dietary trends and market projections, but with limits to the quantities of UK agricultural commodities exported
8	Human diet trend to 2050 – no export limits	Livestock numbers and crop areas for 2050 based on UK human dietary trends and market projections, with no limits on export of UK agricultural commodities
9	Human diet trend to 2050 – with export limits	Livestock numbers and crop areas for 2050 based on UK human dietary trends and market projections, but with limits to the quantities of UK agricultural commodities exported
10	Tax on meat and dairy / promote fruit and veg - 2030	A 20% tax on all meat and dairy consumed in the UK, plus a 20% subsidy on the price of fruit and vegetables
11	Increased meat and dairy alternatives - 2030	Based on the results of discrete choice experiments, a 30% switch away from meat and dairy and towards plant-based alternatives was modelled. The switch was assumed only to take place among those already consuming meat and/or dairy.
12	Tax on meat and dairy / promote fruit and veg - 2050	A 20% tax on all meat and dairy consumed in the UK, plus a 20% subsidy on the price of fruit and vegetables
13	Increased meat and dairy alternatives - 2050	Based on the results of discrete choice experiments, a 30% switch away from meat and dairy and towards plant-based alternatives was modelled. The switch was assumed only to take place among those already consuming meat and/or dairy.
14	Medium ambition combination - 2030	Lower emissions from farms, medium ambition, combined with tax on meat and dairy / promote fruit and veg
15	High ambition combination - 2030	Lower emissions from farms, high ambition, combined with increased meat and dairy alternatives

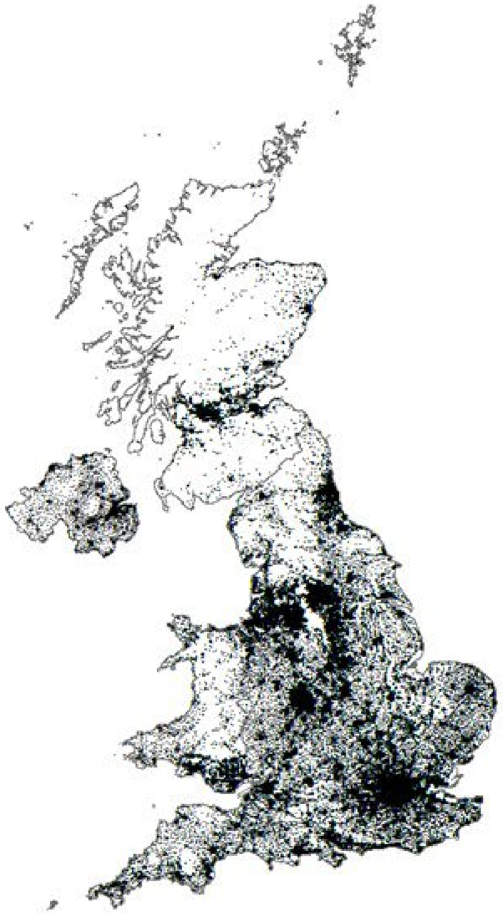
Selected Results – Health Modelling



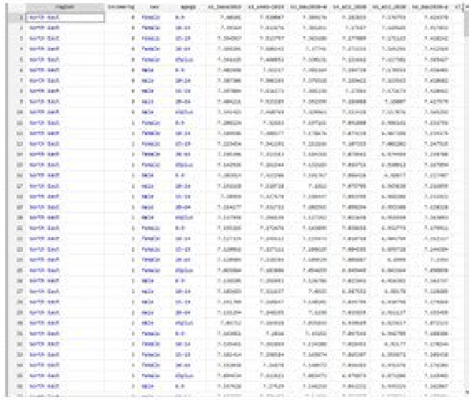
Selected Results – Health Modelling



PM2.5 annual mean
Based on AI1_2030 (S4) by 3x3km



Output Area (pop-weighted centroid)
+ Income deprivation index 2019 (LSOA)



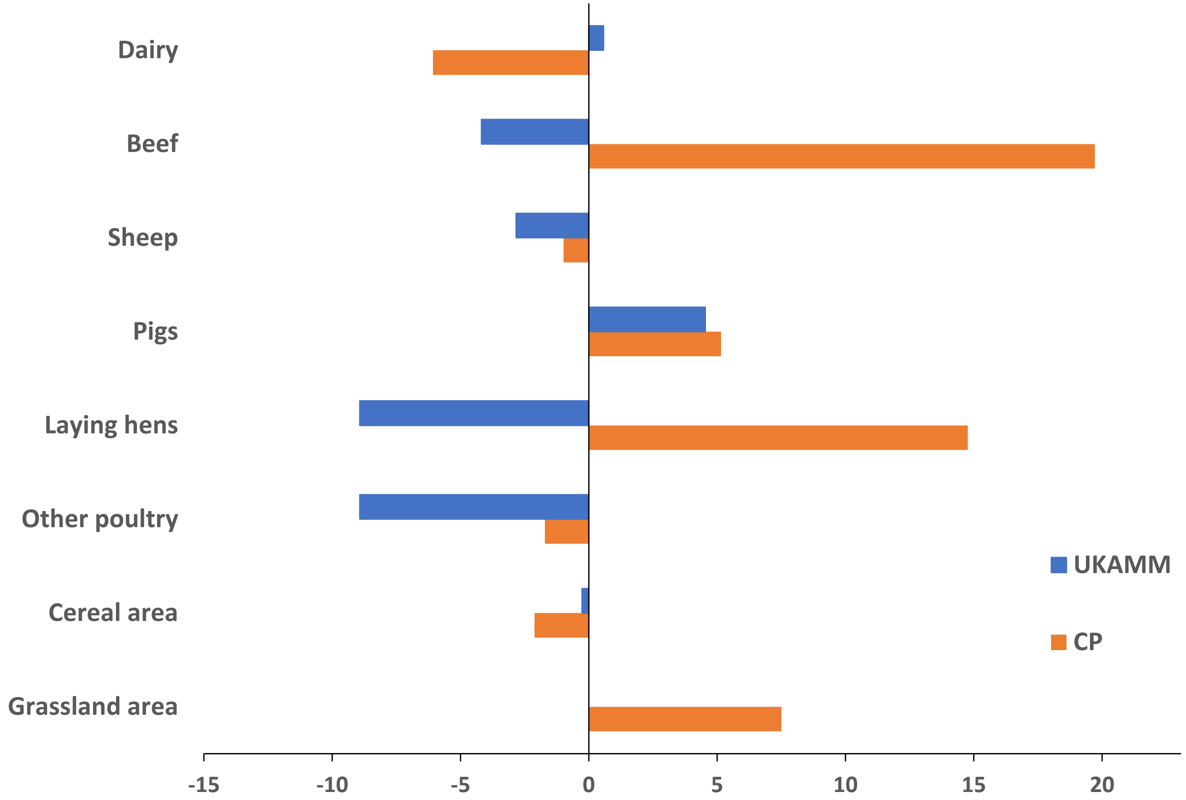
Weighted by sex-age-income-region specific population 2020

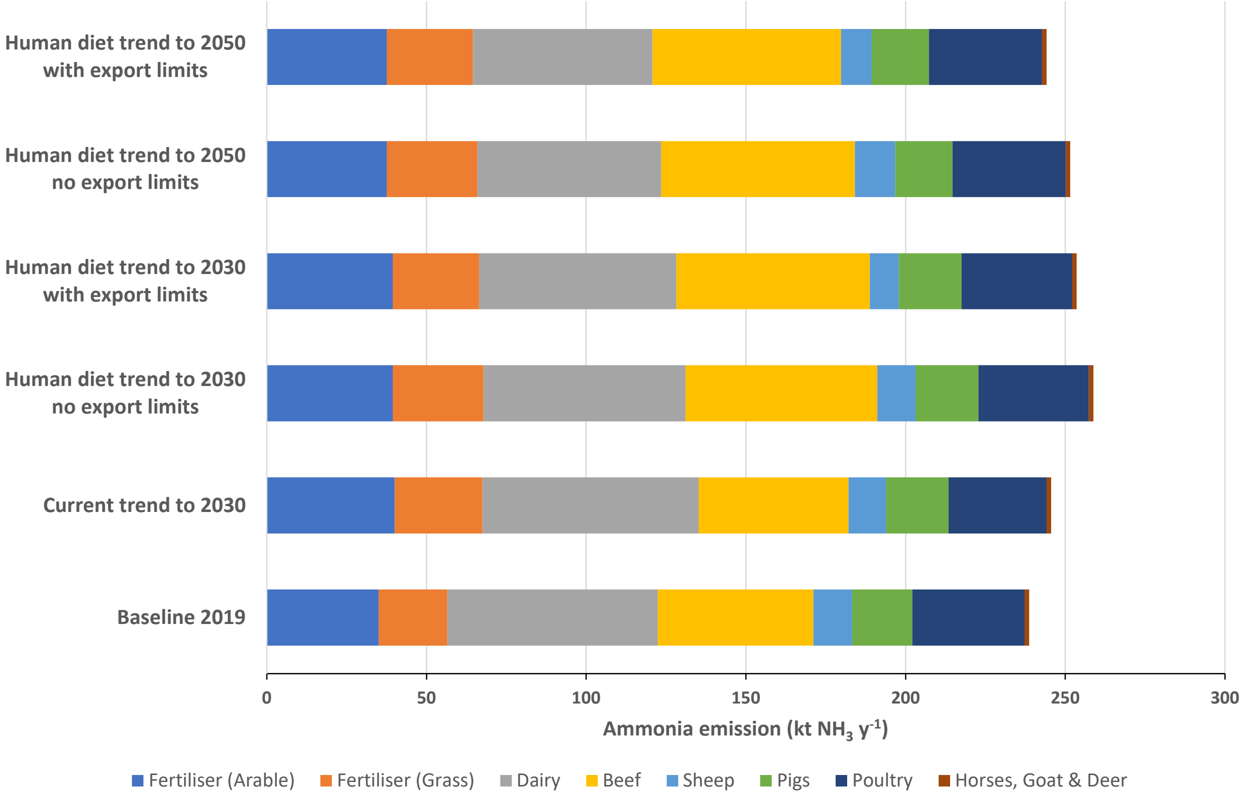
Selected Results – Health Modelling

Receptor	Pollutant	Exposure	Effect
Low and central sensitivity cases			
Health	$PM_{2.5}$	Chronic	Mortality
Health	*$PM_{2.5}$*	*Acute*	*Respiratory hospital admissions*
Health	$PM_{2.5}$	All	Productivity
Health	$PM_{2.5}$	Chronic	Ischaemic heart disease
Health	$PM_{2.5}$	Chronic	Stroke
Health	$PM_{2.5}$	Chronic	Lung cancer
Health	*$PM_{2.5}$*	*Chronic*	*Asthma in children*
Ecosystems	*NH_3*	*Chronic*	*Biodiversity loss*
High sensitivity case: all of the above plus:			
Health	$PM_{2.5}$	Chronic	Diabetes (high sensitivity only)
Health	$PM_{2.5}$	Chronic	Bronchitis in adults (high sensitivity only)
Health	*$PM_{2.5}$*	*Acute*	*Cardiovascular hospital admissions (high sensitivity only)*

Impacts linked to NH_3 emissions addressed in the Defra damage costs, 2022 prices.
Effects in *italics* are not directly addressed by AMPHoRA.

Selected Results – Emission Effects of Scenarios

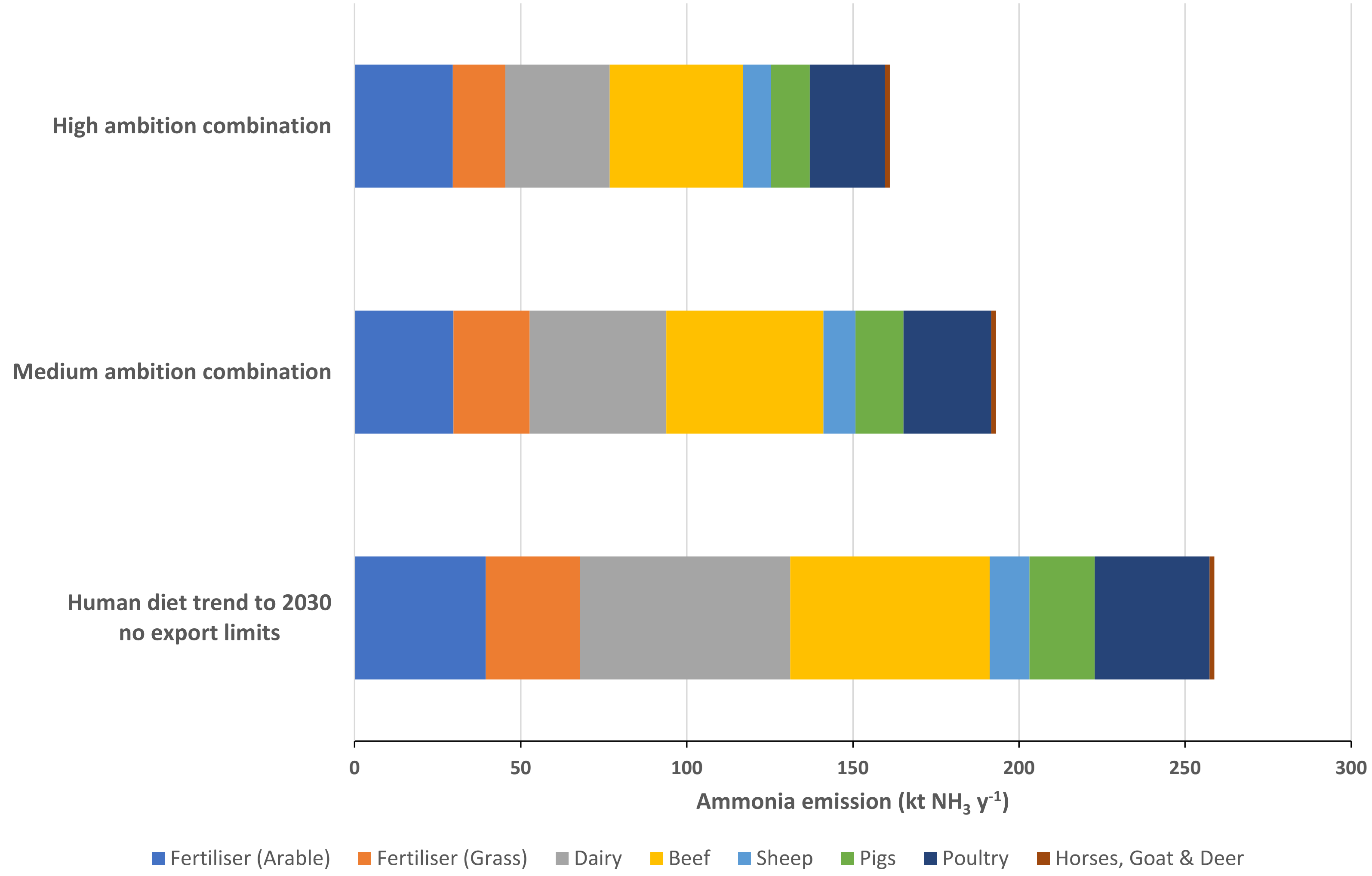




Changes in livestock numbers and land area requirement (as a % compared with 2019) under business-as -usual scenarios for 2030

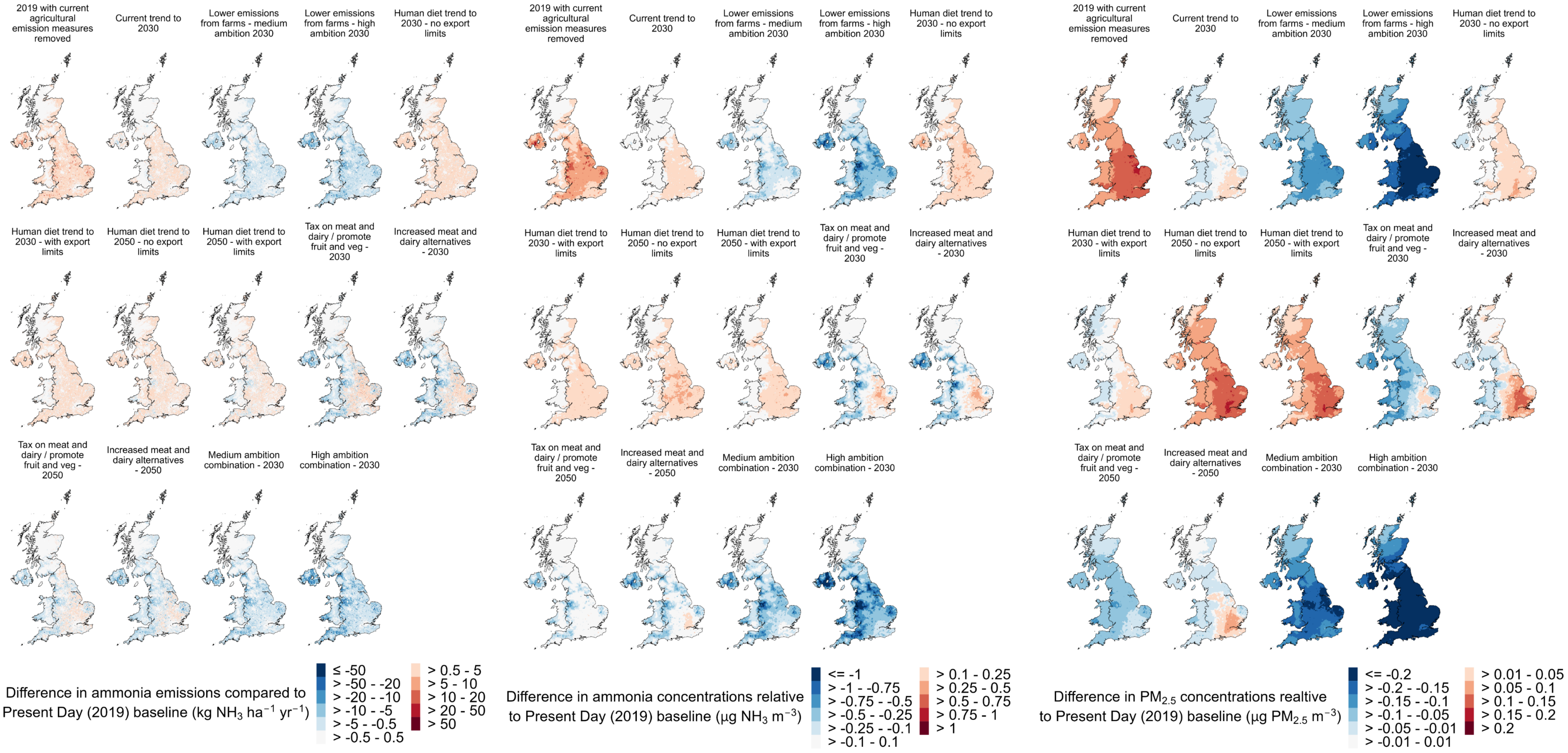
UK Agricultural Market Model projections (UKAMM) and forecast food consumption/ production trends (CP).

Selected Results – Emission Effects of Scenarios



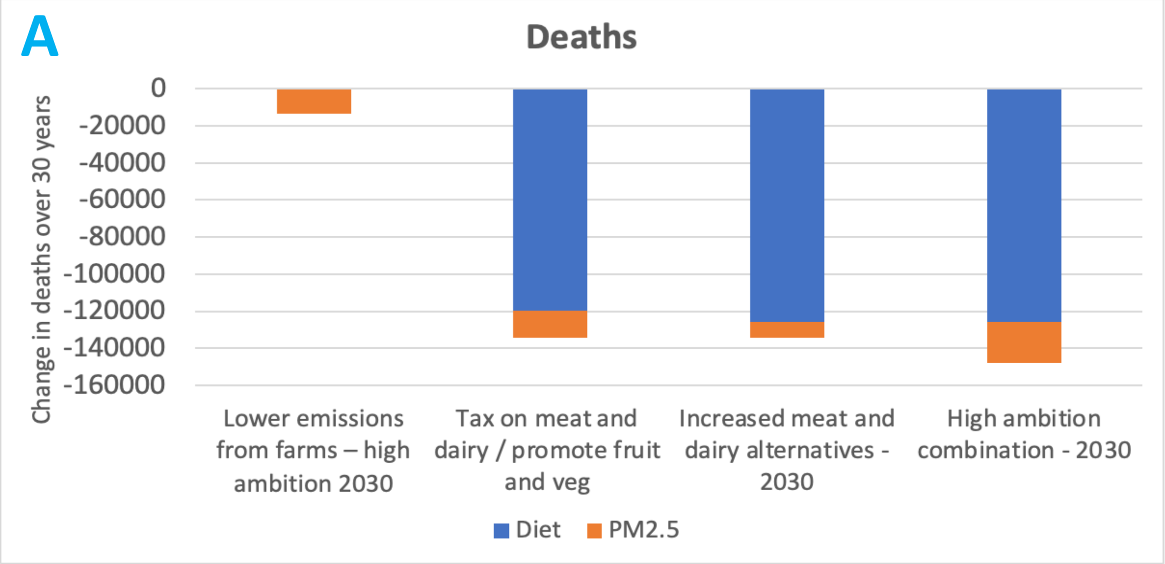
Impact of scenarios combining the on-farm and human diet interventions on ammonia emissions from UK agriculture in 2030

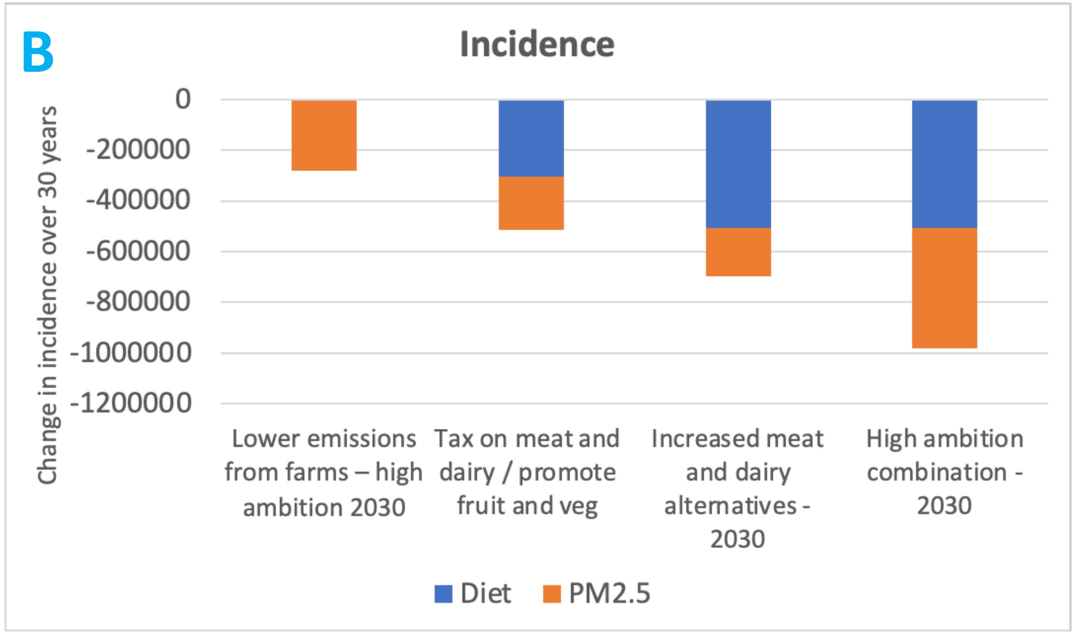
Selected Results – Emissions to Concentrations

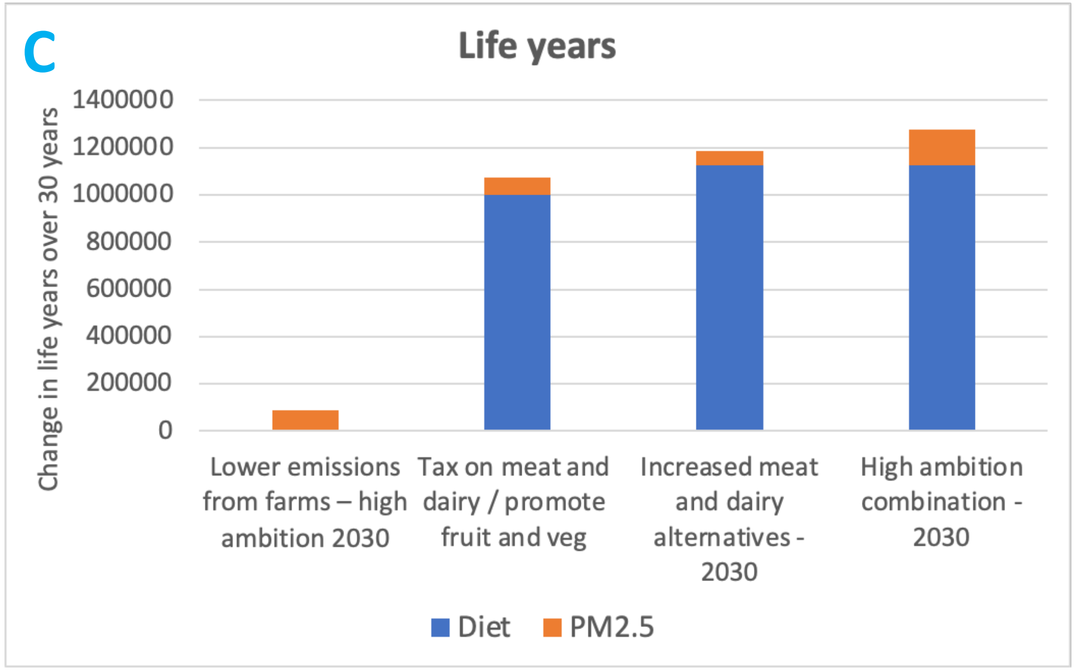


Difference in agricultural ammonia emissions, concentrations and changes in $PM_{2.5}$ concentrations under each scenario relative to the present day (2019) baseline.

Selected Results – Health Modelling







Contribution of changes in $PM_{2.5}$ exposure and diet to the health benefit in terms of [A] deaths, [B] incidence and [C] life years over 30 years by main AMPHoRA intervention scenarios

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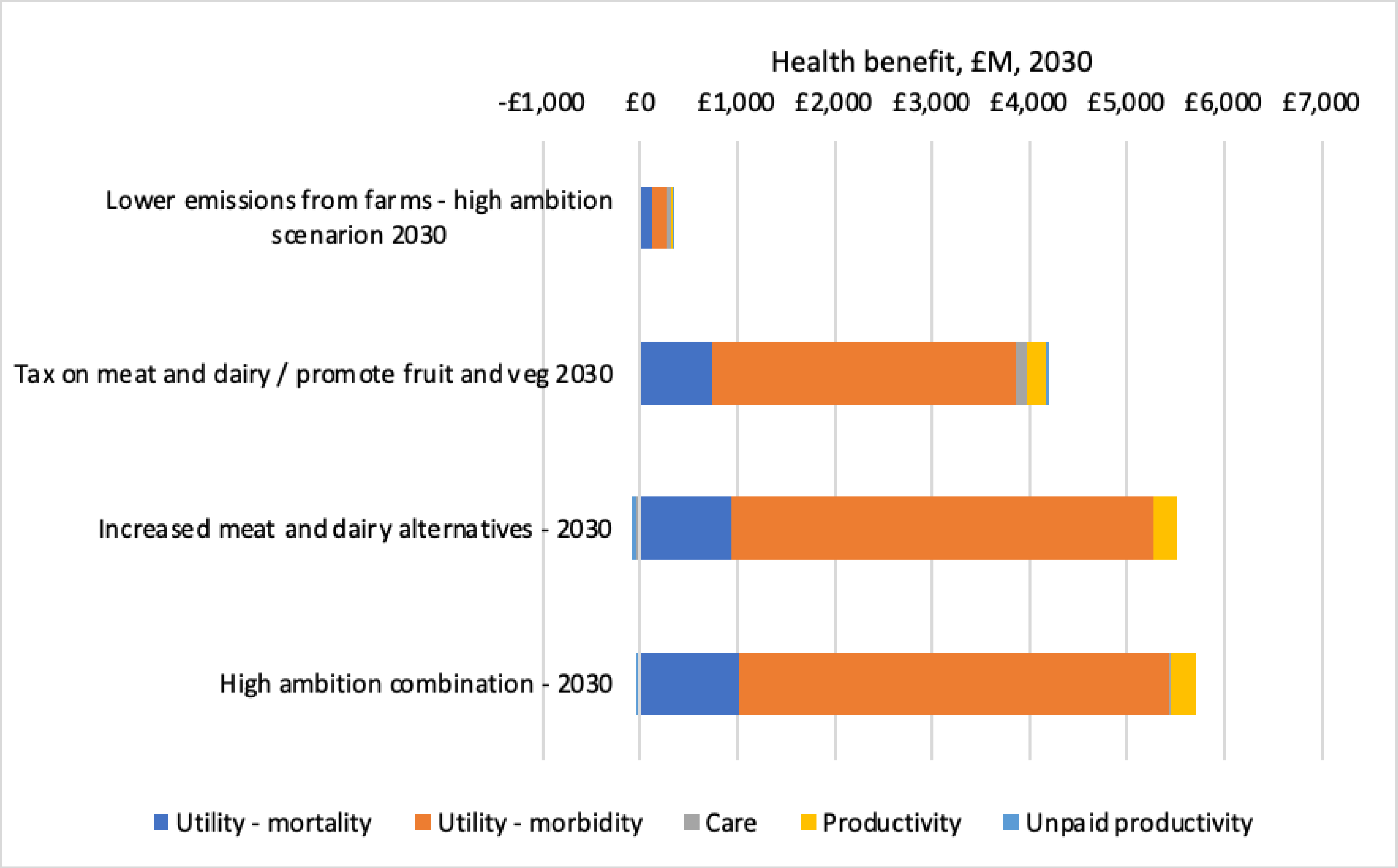
Selected Results – Health Modelling



Health benefits by category in 2030.

Key Outcomes and Conclusions (I)

- The outputs of this study suggest that **dietary changes can bring greater human health benefits than reductions in PM exposure related to agricultural ammonia emissions**.

- The **impacts of ammonia emissions on habitat degradation through nitrogen deposition** and the importance of agricultural ammonia emissions to this are well documented and this study demonstrates the benefits that human dietary changes would have regarding **lower emissions (and hence N deposition) in addition to the human health benefits**.

- Relatively **small dietary changes** (i.e. not total vegetarianism or veganism but merely reducing meat and dairy eating occasions by a small number per week) could **help meet environmental targets and also improve population health**.

- The literature review conducted within this study highlighted, that **health effects of agricultural emissions have not been fully elucidated by the pre-existing research literature**.

Key Outcomes and Conclusions (II)

- Epidemiological studies suggest that **exposure to ammonium-derived PM may exert health effects which could increase the risk of mortality and cardiorespiratory morbidity**, albeit the data is limited and inconsistent.

- There is a need to **better align this evidence with toxicological studies** which suggest that (pure) ammonium nitrate and sulphate have only very modest toxicity.

- Innovative methods are needed to **assess the relative toxicity of agricultural-derived PM** using exposures that more accurately capture the physicochemical composition of real-world emissions than administration of pure ammonium compounds to experimental models. **Direct comparisons to other, more well-studied, sources of PM (e.g. urban PM reference materials, diesel exhaust particles) would be valuable**.

Key Outcomes and Conclusions (III)

- Our results of health modelling based on the investigated scenarios **suggested health benefits in terms of the number of deaths, incidence and life years gained, with the greatest benefits predicted for the older age group**. Most of these benefits were brought about by predicted changes in dietary factors with a lower contribution from changes in $PM_{2.5}$ exposure. However, this needs to be further explored with uncertainty analyses.
- Health benefits of the investigated scenarios showed **inequality among household income groups**: lower income groups receive higher health benefits of the investigated scenarios.
- From an engagement perspective, **building and maintaining successful multi-stakeholder research partnerships** should be considered a key element to build into future research collaborations, especially ideas around community-led efforts, community and agency collaboration, engaging minority groups, engaging young people, citizen science and so forth. Achieving this is in itself a research objective that could be embedded into future research.
- The issues that AMPHoRA researched were very important for community groups and individuals involved in our research partnership.

Pastorino S, Milojevic A, Green R, Beck R, Carnell E, Colombo PE, Misselbrook T, Miller M, Reis S, Tomlinson S, Vieno M, Milner J. Health impact of policies to reduce agriculture-related air pollutants in the UK: The relative contribution of change in $PM_{2.5}$ exposure and diets to morbidity and mortality. Environ Res. 2024 262(Pt 2):119923. doi: 10.1016/j.envres.2024.119923.

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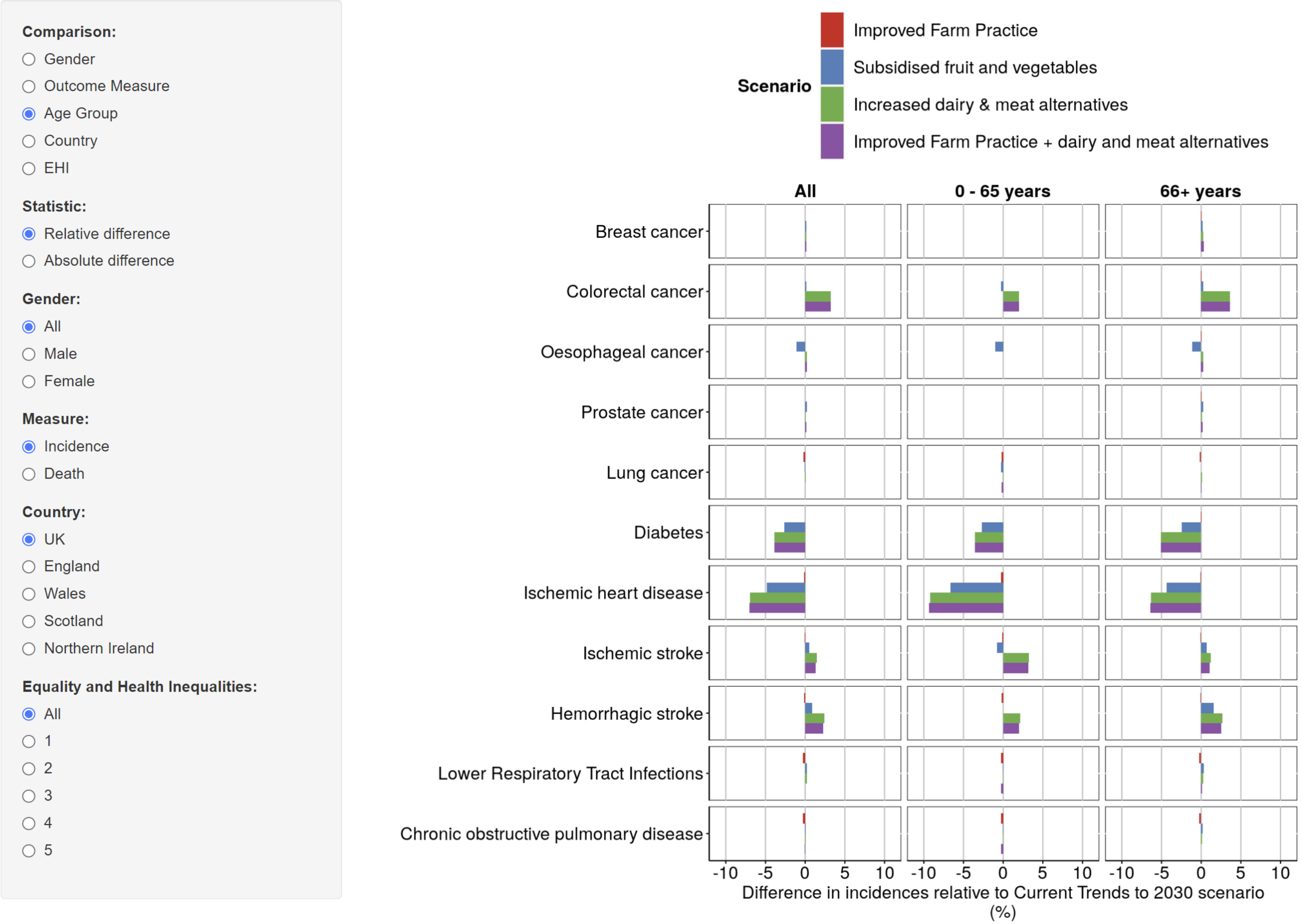
Additional Slides

Selected Results – Data Explorer Tool & Engagement

How are human health outcomes affected?



Screenshot of the prototype AMPHoRA Data Explorer Tool

PPIE Activities – engaging with the public and stakeholders throughout the project

Selected Results – Systematic review

Author (year)	Study design	Country of study	Population	Exposure	Exposure measurement method and duration	Study period
Huang et al. (2019)	Prospective cross-sectional	USA (Georgia). Both urban and rural areas	All children and young adults (0-18 years)	$PM_{2.5}$ 12 source apportionment categories: agriculture, biogenic, coal, dust, fuel oil, metals, natural gas, non-road mobile diesel, non-road mobile gasoline, on-road diesel, on-road gasoline, “other sources”	Daily $PM_{2.5}$ source impacts were quantified using a two-step source apportionment approach: hybrid data fusion of Environmental Protection Agency Community Multiscale Air Quality Modelling System simulations and results from stationary monitoring stations, followed by bias correction	2005-2007
Slawsky et al. (2021)	Cohort Study	USA	5681 participants; 2,497 (43.9%) had coronary artery disease, and 1,652 (29.0%) had a history of MI before index catheterization	$PM_{2.5}$ Traffic-related sources: diesel and gasoline (+secondary organic carbon) Atmospheric secondary species: ammonium nitrate, ammonium sulfate, ammonium bisulfate Others (not reported): biomass, dust, sea salt, coal	$PM_{2.5}$ source apportionment 10 sources at a 12 × 12 km grid resolution. Each participant was matched to a 12 × 12 km grid cell based on their residential address, and daily $PM_{2.5}$ concentrations were averaged to calculate annual mean concentrations for the 365 days before catheterization for each participant and each source. 2002-2010	2001-2010
Jin et al. (2022)	Observational Study	USA (Massachusetts)	787,352 people aged 18 or over	$PM_{2.5}$ 15 components of PM (zinc, vanadium, silicon lead, nickel, potassium, iron, copper, calcium, bromine, sulphate, nitrate, ammonium, organic carbon, elemental carbon)	Novel exposure prediction model Chemical analysis allowed grouping into the following PM sources: heavy fuel combustion, biomass burning, crustal matter, non-tailpipe traffic, tailpipe traffic, secondary particles from power plants, secondary particles from agriculture, and “unclear”. The authors used a weighted quantile sum (WQS) regression model to examine the cumulative associations between $PM_{2.5}$ components mixture and mortality outcomes. The WQS models were fit on 15 PM components and a priori identified source groups for these components. The model estimated the cumulative associations by assigning weights to each component based on their contribution to the associations	2000-2015

Studies fully meeting the inclusions criteria. Abbreviations: CAD = coronary artery disease; CI = confidence interval; ICD = International Classification of Disease; IQR = interquartile range; MI = myocardial infarction; NH_4+ = ammonium; OR = odds ratio; $PM_{2.5}$ = particulate matter with a diameter of 2.5 micrometers or less; RR = relative risk; USA = United States of America; WQS = weighted quantile sum.

Selected Results – Modelled disease outcomes and ICD-10 codes

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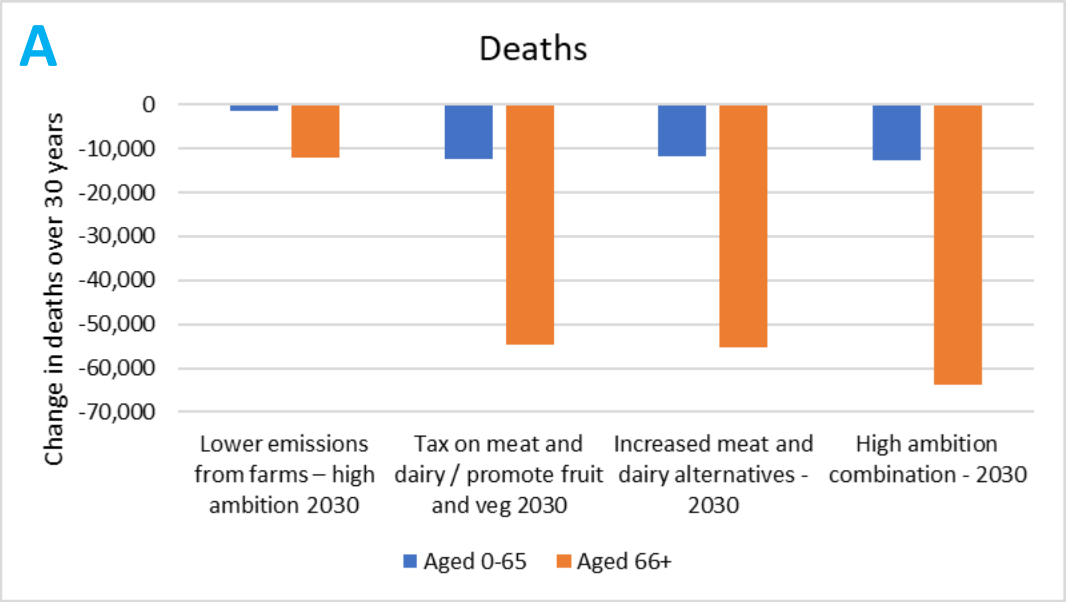
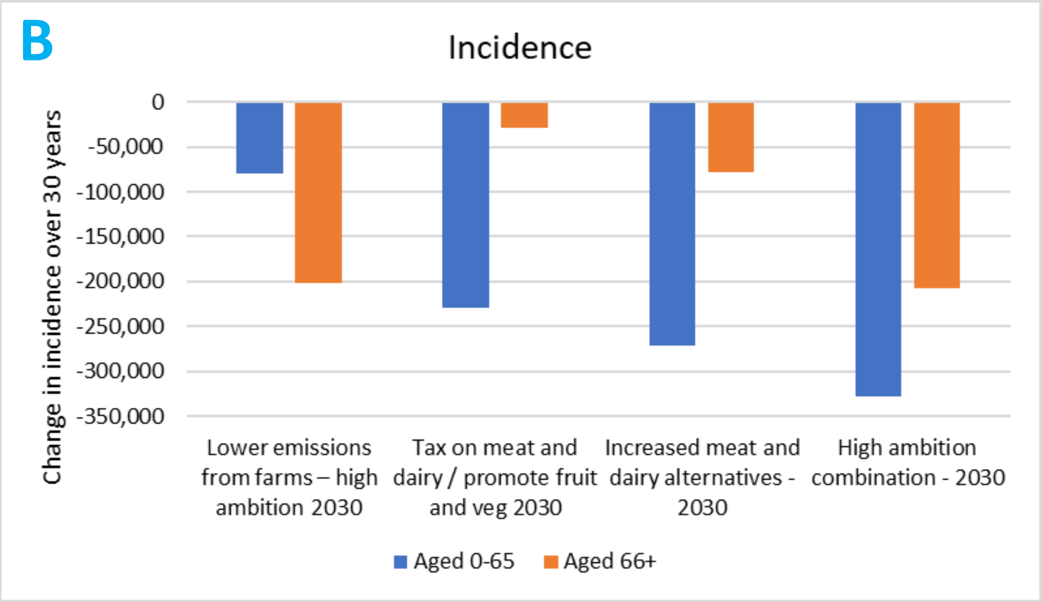
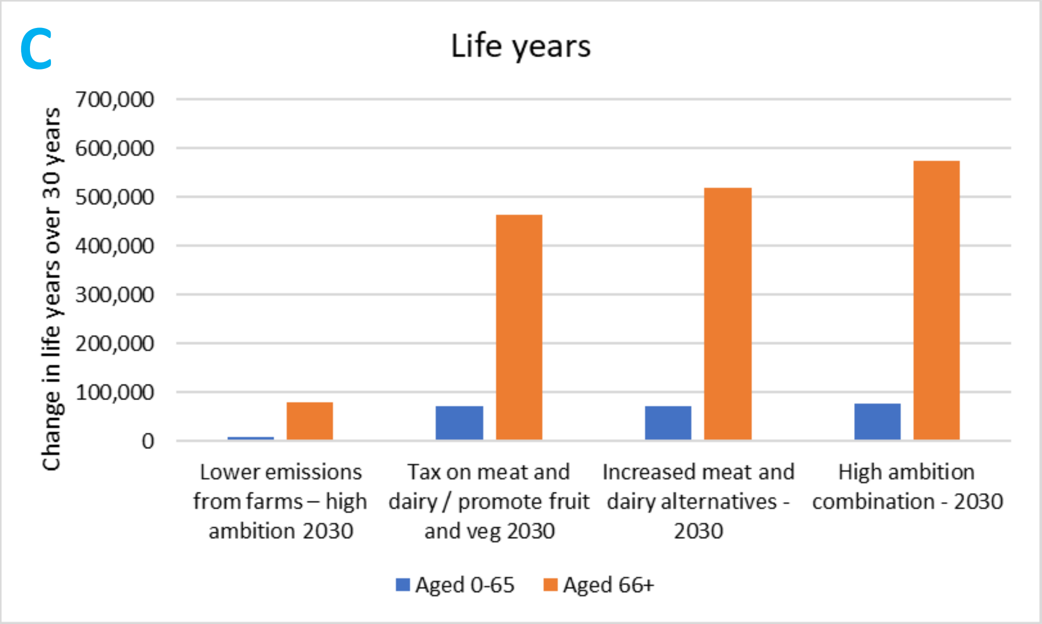
Health outcome	ICD-10 underlying cause of death classification
Ischemic heart disease	I20 – I25.9
Ischemic stroke	G45-G46.8, I65-I66.9, I67.0-I67.3, I67.5-I67.6, I68.1-I68.2, I69.0-I69.3
Haemorrhagic stroke	Cerebrovascular diseases (I60-I63)
Chronic obstructive pulmonary disease	J40-J47Chronic lower respiratory diseases
Lower respiratory infections	09-J18 Influenza and pneumonia J20-J22 Other acute lower respiratory infections
Tracheal, bronchus, and lung cancer	C33-C34.9, D02.1-D02.3, D14.2-D14.3, D38.1
Oesophageal cancer	C15-C15.9, D00.1, D13.0
Colorectal cancer	C18-C21.9, D01.0-D01.3, D12-D12.9, D37.3-D37.5
Prostate cancer	C61
Breast cancer	C50-C50
Diabetes mellitus type 2	E11-E11.1, E11.3-E11.9

Selected Results – Health Modelling





Changes in [A] deaths, [B] incidence and [C] life years over 30 years by age group (0-65, 66+) for each AMPHoRA intervention scenario compared to the Current trend to 2030 scenario.



Selected Results – Systematic review

Author (year)	Study design	Country of study	Population	Exposure	Exposure measurement method and duration	Study period
Joshi et al. (2022)	Short-term time-series ecological study	India (Delhi)	N=1461; number of non-trauma deaths	$PM_{2.5}$ 15 components of PM (organic carbon, elemental carbon, chloride, sulfate, nitrate, ammonium, ammonium-sulfate, ammonium-nitrate, potassium, crustal elements, arsenic, lead, chromium, sodium, noncarcinogens)	$PM_{2.5}$ source apportionment. Ambient PM2.5 and its chemical speciation data were collected periodically for four years between 1 January 2013 and 31 December 2016	2013-2016
Masselot et al. (2022)	Ecological Study	Global. 210 urban areas in 16 countries, the majority in North America, Japan and Europe		$PM_{2.5}$ 7 components of PM (sulphate, ammonium nitrate, black carbon, organic carbon, sea salt, dust)	Average annual $PM_{2.5}$ components mass concentration estimates were extracted for the period 2003-2017 from a global reconstruction model. Each component was then then divided by the sum of all seven components to obtain relative composition and computed the average composition across the whole period.	1999-2017

Studies fully meeting the inclusions criteria. Abbreviations: CAD = coronary artery disease; CI = confidence interval; ICD = International Classification of Disease; IQR = interquartile range; MI = myocardial infarction; NH_4+ = ammonium; OR = odds ratio; $PM_{2.5}$ = particulate matter with a diameter of 2.5 micrometers or less; RR = relative risk; USA = United States of America; WQS = weighted quantile sum.