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Extended Research Article

Impact of local and national policies to reduce agriculture-related air pollution through improving diet and farm management: the AMPHoRA mixed methods study

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Scientific summary

Impact of local and national policies to reduce agriculture-related air pollution through improving diet and farm management: the AMPHoRA mixed methods study

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Scientific summary

Background

Agricultural emissions of ammonia (NH_3) significantly contribute to the formation of secondary inorganic aerosols (SIAs), leading to widespread population exposure to ammonium nitrate and sulfate components of fine particulate matter (with a diameter of ≤ 2.5 µm) ($PM_{2.5}$). Unlike nitrogen dioxide (NO_2), SIA exhibits mid- and long-range transport properties, exposing populations to $PM_{2.5}$ far from emission hotspots. Addressing NH_3 emissions and their interaction with sulfur dioxide (SO_2) and nitrogen oxides (NO_x) is complex due to the diverse sources and meteorological dependencies influencing SIA formation. Consequently, policy interventions must consider both local and long-range effects, as local measures alone may not effectively reduce ambient concentrations.

Additionally, human dietary choices and their links to food production, public health and environmental sustainability are subjects of extensive research. This study investigates how modifications in agricultural production and food consumption patterns can mitigate agricultural emissions, reduce associated health impacts and address health inequalities. Specifically, it evaluates interventions aimed at minimising the negative health effects of outdoor air pollution from non-road traffic-related sources.

The UK Clean Air Strategy and the Code of Good Agricultural Practice (COGAP) outline measures to reduce NH_3 emissions from agriculture by 2030. Reports such as the EAT–Lancet Commission on sustainable diets emphasise the necessity of dietary changes to ensure food security, nutrition and planetary health. Implementing technical and managerial interventions in agriculture and modifying dietary habits will influence NH_3 emissions and other pollutants. Comprehensive ex-ante assessments of policy interventions are essential to optimise environmental and human health benefits while safeguarding UK food security and nutrition. Following Brexit, environmental, agricultural and health policy reviews provide opportunities for an integrated approach to maximise public health and environmental and economic benefits. Reducing air pollution exposure, improving diets and enhancing nutrition could yield significant healthcare cost savings across the UK's health system.

State of knowledge

The adverse health effects of $PM_{2.5}$ are well documented. The Committee on the Medical Effects of Air Pollutants has extensively reviewed particulate air pollution and mortality, while the UK Air Quality Expert Group identified reductions in NH_3 and primary $PM_{2.5}$ emissions as the most effective strategies for reducing overall $PM_{2.5}$ concentrations. Agricultural activities accounted for 82% of the UK's total NH_3 emissions in 2016, making agriculture a critical sector for targeted interventions.

International case studies from the Netherlands, Germany and Denmark provide valuable insights into the effectiveness of technical and managerial interventions for NH_3 mitigation. The United Nations Economic Commission for Europe Air Convention's Task Force on Reactive Nitrogen has informed COGAP's recommended interventions, serving as a foundation for an integrated assessment in the UK.

Dietary patterns have well-established links to health and environmental outcomes. The Global Burden of Disease study attributed 11% of the total disease burden in England to dietary risks, with costs to the NHS estimated at £5.8B annually – surpassing costs associated with obesity, smoking and alcohol consumption. Major diet-related diseases include coronary heart disease, stroke, cancer and type 2 diabetes. Furthermore, agriculture contributes 10% of the UK's greenhouse gas (GHG) emissions. Shifting towards healthier diets could reduce GHG emissions by 17% and decrease premature mortality from non-communicable diseases.

While most research on sustainable diets focuses on climate change mitigation, air quality and nitrogen emissions have received comparatively little attention. Studies suggest that reducing animal-based food consumption could lower

nitrogen emissions by up to 40%. The European Nitrogen Assessment has quantified the diverse impacts of livestock on air, water, soil pollution and climate change, reinforcing the need for a comprehensive, integrated approach to assess dietary and agricultural interventions.

Objectives

The project aimed to:

1. Convene a multistakeholder group, including policy-makers, industry experts, third-sector organisations and academics, to assess existing and potential policies for reducing air pollutants (APs) and GHG emissions via agricultural and dietary changes.
2. Quantify the nutritional impacts of interventions altering food consumption patterns and UK production to enhance health and environmental sustainability.
3. Evaluate the effects of these policies on APs (NH_3, NO_2, $PM_{2.5}$, ozone) and GHG emissions, now and under future policy scenarios.
4. Develop health impact models to assess the morbidity and mortality effects of changes in air quality, agricultural interventions and dietary shifts.
5. Compare policy scenarios using cost-effectiveness and cost–benefit analyses, incorporating health, economic and environmental factors up to 2050.
6. Examine policy implications for implementation, patient health and public engagement through iterative stakeholder consultations.

Methods

- Work package (WP)1: quantified agricultural emission reductions using statistical modelling of production systems.
- WP2: analysed dietary trends and projected future scenarios using autoregressive methods and linear programming.
- WP3: applied spatial data analysis, geographical information systems and atmospheric modelling to simulate pollution dispersion.
- WP4: conducted health impact assessments using epidemiological data, systematic literature reviews and statistical modelling.
- WP5: performed economic valuations and cost–benefit analyses to assess intervention feasibility.
- WP6: integrated findings through participatory research methodologies, engaging diverse stakeholders to refine policy recommendations.

Results

- Dietary changes have greater human health benefits than reducing NH_3-related $PM_{2.5}$ exposure alone.
- NH_3 emissions contribute significantly to nitrogen deposition, degrading habitats. Dietary changes can simultaneously reduce NH_3 emissions and enhance human health.
- Moderate dietary modifications (e.g. reducing weekly meat and dairy intake) could help meet environmental targets while improving public health.
- A 20% meat and dairy tax, coupled with a 20% fruit and vegetable subsidy, could decrease UK meat consumption by 21.5%, while plant-based analogues could reduce it by 30.4%. Fruit and vegetable intake could rise by 3–13.5%.
- 'High-ambition mitigation' scenarios, aligned with the UK Climate Change Committee's Balanced Pathway, could prevent 13,000 premature deaths and 270,000 cases of respiratory diseases over 30 years. Dietary changes combined with NH_3 reductions could avert 67,000 deaths in the same period.
- Older adults and low-income households would experience the greatest health benefits.
- Most farm-level NH_3 mitigation measures yield net economic benefits.
- Reducing GHG emissions amplifies the benefits of dietary and agricultural interventions.
- Engaging a multistakeholder group fostered broader awareness of air pollution, diet and health interconnections in the UK.

Conclusions

The Assessing Mitigation Pathways to Realise Public Health Benefits of Air Pollutant Emission Reductions from Agriculture (AMPHoRA) project has provided a comprehensive, interdisciplinary assessment of the interactions between agriculture, air quality, dietary choices and public health. It has generated extensive data on current and future NH_3 emissions and their health implications while highlighting the need for further research into the direct health effects of agricultural emissions.

By integrating economic, health and environmental analyses, the study underscores the importance of considering dietary changes alongside technical interventions to maximise benefits. Additionally, engaging community stakeholders has reinforced the relevance of these issues at the grassroots level, demonstrating the effectiveness of participatory approaches in environmental health policy-making.

It should be considered that the originally designed project plan was substantially impacted by the COVID pandemic, and throughout the project, adjustments had to be made to account for restrictions, for example, around community engagement. Furthermore, the interactions between the members of the project team were affected by the loss of one of the coinvestigators and the effects of reduced opportunities for direct, effective collaborative working. The project team is heavily indebted to Professor Paul Wilkinson of the London School of Hygiene and Tropical Medicine for his contributions, guidance and input, without which AMPHoRA would not have been possible.

Study registration

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