Air pollution: The role of agriculture in Wales

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Take home messages:

- Current levels of air pollution present a major health risk.
- Ammonia emitted as a result of agricultural activities can contribute to particulate matter formation (a key air pollutant), which can have severe health impacts.
- Reducing ammonia emission is a key agricultural production goal, to reduce air pollution levels, and to reduce environmental impact.

Air pollution is currently the single biggest environmental health risk globally. Human activities including industry, transport, agriculture, and others can result in the release of harmful materials to the atmosphere, which can affect the health and wellbeing of human populations, wildlife, and the environment.

Agriculture contributes to air pollution primarily through the emission of ammonia (NH_3). This combines in the atmosphere with other pollutant materials to form particulate matter (see Box 1), which is a key human health threat. In Wales, 93% of NH_3 emission can be traced to agricultural sources. Reducing the amount of ammonia emitted from agricultural activities is therefore a necessary action to reduce levels of air pollution nationally. Agriculture is also responsible for the emission of a range of other pollutants, including nitrogen oxides (NO_X) and non-methane volatile organic compounds (NMVOCs), but these are at relatively low rates of emission compared to other man-made sources.

Currently Wales has some of the worst air quality in the UK. Public Health Wales considers air pollution to be an urgent public health crisis, second only to the impact of smoking. Air quality in Wales is currently governed by various legislation including EU Directives, UK Acts, and Welsh Acts. Air quality management is the responsibility of Local Authorities, which are overseen by the Welsh Air Quality Forum who provide expertise and guidance to ensure statutory requirements are met. These bodies will all work together to deliver The Clean Air Plan for Wales. This initiative aims to reduce air pollution from a range of sources, to improve

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the health and wellbeing of the people of Wales, and to reduce adverse impacts to ecosystems and the environment.

Materials that contribute to air pollution are varied and can originate from a range of natural and man-made sources. Natural sources include dust or wind-blown soil particles, pollen, salt from the sea, and others. Man-made sources are typically emissions resulting from activities such as the burning of fuels for transport, industry, or energy generation. A brief summary of man-made pollutants and their effect can be seen in Table 1. Air pollutants can also be formed in the atmosphere after chemical reaction of other primary pollutant materials, to form secondary pollutants including particulate matter.

Table 1 - Major air pollutant sources and effect.

Pollutant	***Source***	***Effect on health/environment***
Carbon monoxide (CO)	Emission results from incomplete fuel combustion and industrial processes.	Toxic to humans. Can affect lungs and uptake of oxygen, resulting in asphyxiation.
Nitrogen oxides (NO_X)	Emitted from combustion sources. Primarily transport (road, rail, aviation and shipping), but also industrial and energy generation sources.	NO_X gases can exacerbate respiratory illnesses and cardiovascular disease.
Non-methane volatile organic compounds (NVMOCs)	Emitted as combustion by-products, vapour from petroleum distillates, or from the use of chemicals/solvents, from a diverse range of sources, including agriculture, industry, transport and the residential sectors,	Contributes to the formation of ground-level (tropospheric) ozone. Some NVMOCs also have direct toxicological impacts as lung irritants or cancer causing agents.
Particulate Matter (PM_{10} $PM_{2.5}$)	Primary sources: direct emission from fuel combustion, wind-blown dusts and surface erosion. Secondary sources: formation in the atmosphere through chemical reactions of other pollutants (SO_2, NO_X, NH_3) to form sulphates, nitrates and organic aerosols.	Fine particulate matter can travel deep into the lungs and cause a range of issues such as respiratory and cardiovascular illness and mortality. No minimum threshold identified below which no adverse effects occur.
Sulphur dioxide (SO_2)	Emissions arise primarily as a result of combustion of fossil fuels; coal, oil, and diesel.	Can irritate airways and lungs. Combines with water vapour to form acid rain. Contributes to soil acidification

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Lead (Pb)	Historically, emissions are the result of combustion of leaded petrol. Currently, sources are combustion of solid fuel and biomass in industrial and residential sectors.	Toxic element, which can cause a range of health issues. Chronic exposure can affect the blood, kidneys, brain, and central nervous system.
Ammonia (NH_3)	Agricultural emissions are the primary source of ammonia. This includes animal housing and manure management, grassland manure applications, grazing animal excreta, and inorganic fertiliser usage.	Limited direct impact on humans at low concentrations, but after reactions with other materials can become harmful particulate matter. Can have significant effect on terrestrial and aquatic ecosystems, including loss of biodiversity, eutrophication and acidification.

What is ammonia?

Ammonia is a nitrogen molecule, comprised of one nitrogen atom and three hydrogen atoms bonded together (NH_3). It is a highly reactive and soluble alkaline gas. Ammonia is considered to be reactive nitrogen as it is plant available and ready for uptake, rather than atmospheric nitrogen (N_2), which is inert.

The conversion of inert nitrogen to reactive forms occurs naturally through biological fixation (i.e. by nitrogen fixing bacteria on leguminous plants) or lightning. Reactive nitrogen can also be produced using the Haber-Bosch process, which was developed in the early twentieth century and enables the artificial fixation of nitrogen and the production of synthetic NH_3. This advancement was revolutionary in terms of food production. It is estimated that ~40% of people alive today owe their lives to this process.

As a result of artificial production, which has far surpassed natural fixation, reactive nitrogen is now accumulating in the environment. This has a range of consequences for terrestrial and aquatic ecosystems, and for human health and wellbeing more generally. In the past seventy years, global ammonia emissions have more than doubled. Agricultural activities are the principal cause of ammonia emission globally, accounting for around 81% of output (91% in Wales).

Ammonia output is an issue of growing concern for the UK. In general, emissions of the air pollutant materials, summarised in Table 1, have been reducing in recent decades due to the

influence of legislation and oversight. Conversely, NH_3 has been consistently increasing in the UK and Wales in recent years.

Sources of emission

Ammonia originates from the break down and volatilisation of urea. Volatilisation occurs when the surface concentration of NH_3 exceeds that of the surrounding air. Emissions of NH_3 vary spatially and temporally (seasonally) depending on agricultural practice and factors including climate (volatilisation rate is higher when it is warmer), but emission 'hotspots' are associated with areas of intensive agricultural activity.

The majority of NH_3 emissions from agriculture originates from livestock management or the use of fertiliser. The biggest source in Wales is cattle manure management, which contributes 41% of agricultural emissions. The other sources are manure applied to soils (26.8%), grazing animal excreta (14.5%), inorganic fertiliser usage (10.2%), and other manure management (7.4%). Broken down by livestock type UK-wide, dairy cattle account for 28%, beef cattle 20%, poultry 15%, pigs 7%, and sheep 4% of total emissions.

Ammonia emission rates fell between 1990 and 2007, which is attributed to reductions in animal numbers and declines in the use of fertiliser. However, increased emission from manure management (particularly within the dairy sector) and from increases in the use of ammonium-nitrate and digestate fertilisers, have resulted in rising emission rates since 2007. This presents a range of challenges in environmental terms, as the deposition of reactive nitrogen can result in various impacts including eutrophication, acidification, direct toxicity, and indirect effects such as altering the ability for some organisms to manage stress. In addition, NH_3 can combine with other materials in the atmosphere to become secondary PM (see Box 1). This material is a major air pollutant and can have significant impacts on human health and wellbeing.

BOX 1: Particulate Matter (PM_{10}, $PM_{2.5}$) Formation

Particulate matter (PM) is a general term for a range of solid particles and liquid droplets found in the air. These can be emitted directly from a primary source, or can form in the atmosphere as a consequence of chemical reactions, as pollutant gases react and combine (forming secondary PM). Particulate matter is classified as a material with either an aerodynamic diameter less than 10 micrometres or less than 2.5 micrometres. Due to its nature PM can travel large distances subject to prevailing wind patterns, and can affect areas that are considerable distances from primary sources.

Formation of particulate matter occurs when the emission products from different pollutant sources combine to form secondary inorganic aerosols. Ammonia from agriculture can combine with these materials to form ammonium compounds, including ammonium sulphate ($(NH_4)_2SO_4$), ammonium bisulphate (NH_4HSO_4), and ammonium nitrate (NH_4NO_3). Consequently, reductions in emissions from any one source of pollutant will reduce the amount of overall PM pollution.

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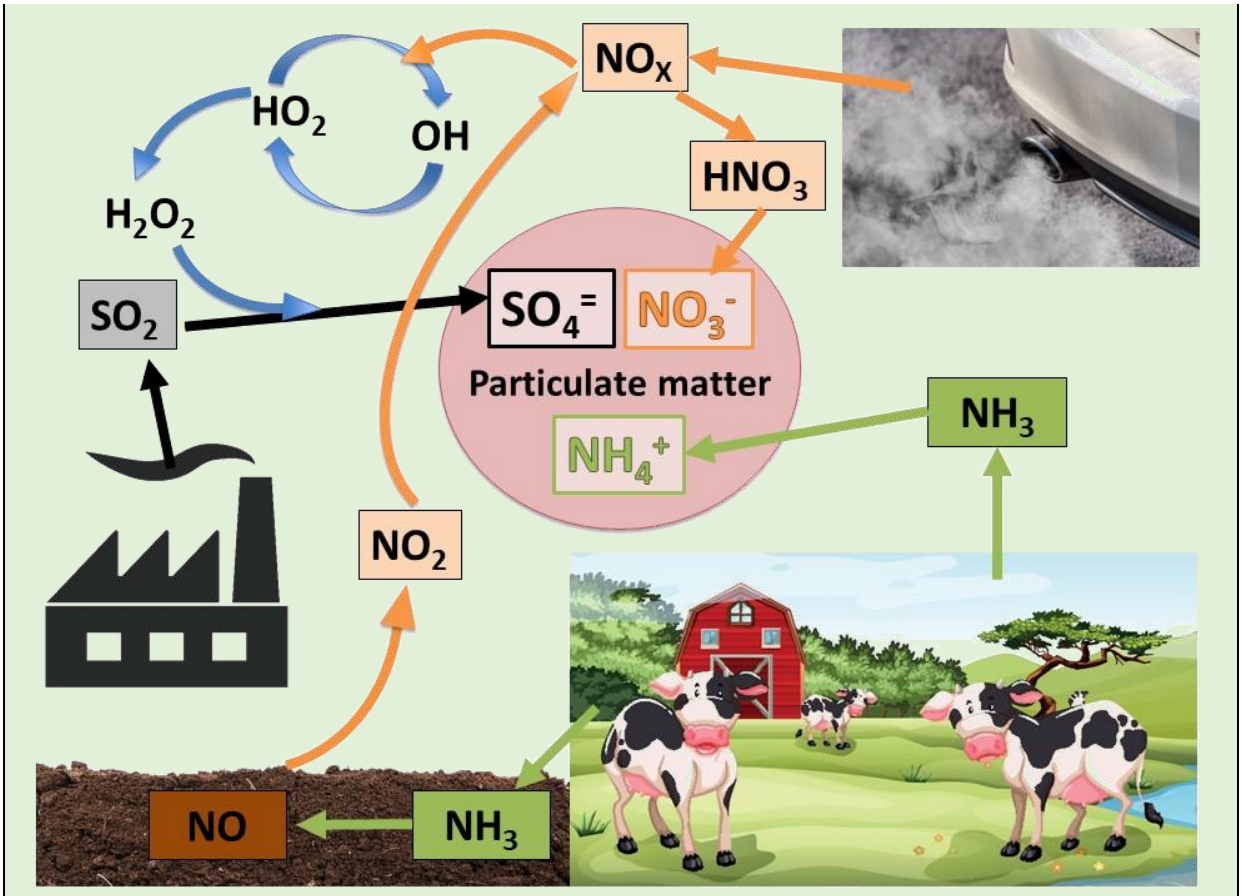

NH_3 can also be chemically transformed in soil to nitric oxide (NO), which is then emitted to the atmosphere and oxidized to NO_2 and HNO_3. As such, NH_3 emission can contribute to PM formation through multiple pathways.

Summary

Ammonia emissions from agriculture are a major source of environmental and air pollution, which is simultaneously damaging to natural systems and human health and wellbeing. In terms of human health, NH_3 at low concentrations is relatively harmless, but this material can combine with other air pollutants in the atmosphere (i.e. nitrogen oxides or sulphur dioxide) to become fine particulate matter. Once in this state, it poses a major threat to human health as it can enter the lungs and cause damage. This can lead to a range of issues including respiratory and cardiovascular illness and mortality.

Livestock agriculture is a major contributor of ammonia pollution. Emission sources occur across the spectrum of livestock agricultural activities, including manure management and direct excretion, and the subsequent use or spreading of manure material. It is possible to modify on-farm management to reduce NH_3 emission, by altering how manure is managed and stored, and subsequently applied to land. Approaches for achieving this are discussed in an accompanying technical article: Air pollution: Agricultural management to reduce ammonia emission.

Reducing the emission of NH_3 is a key goal for UK and Welsh agriculture, to limit the impact to human health and to reduce environmental degradation. Reducing nitrogen loss through this mechanism is also an important strategy for farm business management, as this material is valuable. Thus, greater efficiency in retention and usage relates directly to better farm business efficiency.

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