Ammonia I - AD and digestate management

Introduction

Ammonia (NH_3) is a chemical compound which has significant importance within the natural world. It is a stable colourless gas which, in nature, is produced by nitrogen fixing microorganisms that convert atmospheric nitrogen (N_2) into NH_3[i]. Nitrogen is needed by all living organisms for growth and survival, therefore, organic matter contains large amounts of it in the form of proteins, amino acids and DNA[ii]. When organisms excrete waste or die, the organic matter is decomposed by microorganisms which convert that “organic nitrogen” into inorganic ammonia through the process of ammonification[iii]. There are therefore two biological routes through which ammonia can be released into the environment: nitrogen fixation and ammonification.

Anaerobic digestion (AD) is a process through which organic matter (such as food waste, manure or bakery waste for example) is placed in an oxygen-deprived environment where microorganisms digest and decompose it. This leads to the release of biogas – which can be used for bioenergy purposes – and to the production of digestate, which is the portion of the organic matter which could not be fully digested and converted into gas[iv]. AD-derived biogas is mainly made up of CO_2 and methane, however it also contains other trace gases such as NH_3[v]. Digestate is also rich in mineralised N in the form of NH_4^+ and NH_3[vi].

Ammonia is not a greenhouse gas (GHG). Once released in the atmosphere, the molecules of ammonia only last a few hours before finding their way back to the surface, either in the form of dry deposition (as a gas) or in the form of wet deposition (as ammonium in precipitation)[vii]. As the ammonia deposits back onto the surface, in soils or water bodies, it can accumulate and create a surplus of nutrient in aquatic ecosystems. This phenomenon is referred to as eutrophication. As the habitat’s nutrient content increases due to the high N input, algal growth significantly increases on the surface of the water, leading to light being blocked from reaching below the surface and preventing oxygen from entering the system as well. This leads to hypoxia and eventually to a complete deregulation of the ecosystem and biodiversity loss. Eutrophication also leads to the breakdown of ecosystem services on which human populations rely, such as water quality and pathogen regulation for example[viii]. Ammonia molecules in the atmosphere can also bind to other compounds such as sulfuric acid and nitrate to form particulate matter (PM), which are a form of anthropogenic aerosols. These PMs may cause more direct harm to the environment and to human health[ix]. In 2016, PM pollution was linked to 374,000 premature deaths in the EU[x].

In the UK, ammonia emissions reached 259,000 tonnes in 2020. While these emissions have dropped by 16% since 1980, since records began the main source has remained agriculture and farming, and was nearing 230,000 tonnes in 2020, or around 88% of total ammonia emissions[xi]. Ammonia emissions from farming mainly come from the application of N-based fertilisers (including digestate), manure and slurries on fields. As of 2020, ammonia emissions from all AD-derived digestate represented 5% of total UK ammonia emissions[xii].

In this article, we look at ammonia emissions resulting from AD and from digestate, which is itself often used as fertiliser. We also provide an overview of the current AD regulations which are in place in the UK to manage and mitigate these emissions.

Ammonia emissions from AD and digestate

Anaerobic digestion is a recognised source of ammonia emissions. As microorganisms digest organic matter, they convert organic N into inorganic ammonia or ammonium (NH_4^+) through the process of mineralisation. Some of that ammonia (which is gaseous) can be easily released while the digestate is being processed, stored and applied as fertiliser[xiii]. In addition, due to the typically high pH of digestate, NH_4^+ is further converted into NH_3 in storage, which can lead to more emissions release[xiv]. Although AD was shown to reduce greenhouse gas emissions from the waste it processes (especially methane emissions), ammonia emissions remain high, and sometimes higher than those resulting from untreated waste[xv].

Not only do these emissions lead to environmental issues, as shown previously, they also represent significant financial losses for farmers. As NH_3 is lost from digestate which is destined to be used as fertiliser, the material becomes less nutrient-rich and will, therefore, be less efficient at fertilising soils. This may lead to reduced yields (i.e. less income) and may lead farmers to buy more N-based fertiliser (i.e. increased cost). In addition, the costs of damages to the environment and to human health also contribute to the financial burden caused by these emissions. In the UK, the cost of biodiversity loss has been estimated to be between £0.2 and £4 per kg of emitted ammonia, while the cost of human health deterioration was estimated to be between £2 and £52 per kg of ammonia. By combining the costs of biodiversity loss and human health damage, and if no emissions reduction is acted, it is estimated that these two factors alone cost the UK £700 million every year[xvi].

It is possible to mitigate ammonia emissions from AD and digestate through existing and well understood practices which span the entire AD process, from feedstocks preparation to digestate application. Slurry and manure are widely used as feedstock for AD, especially as they contain diverse populations of microorganisms which help in biogas production[xvii]. However, wastes such as manure, slurry and urea are big sources of natural ammonia emissions. It has been found that acidifying these feedstocks – through natural or chemical acidification – reduces ammonia production within the system. However, whether acidification is done through natural or chemical additives, it often leads to an increase in other GHG emissions such as CO_2 or CH_4, as carbon is added to the system[xviii]. Therefore, there is a trade-off between different types of negative emissions.

Once the AD process is complete, ammonia emissions and nitrogen losses can be further reduced by covering the digestate whilst in storage. Covers vastly limit ammonia volatilisation into air, and prevent rain water from leaking nitrogen out of the digestate, thereby also maintaining high nutrient levels within the digestate which will go on to be used as fertiliser[xix].

Finally, as digestate is applied to soils as fertiliser, a substantial portion of the N within it can be lost through NH_3 volatilisation or through N-leaching after rainfall or irrigation. One method lies in applying the digestate at an active growth stage, when plants take up a lot of nitrogen. This increases the proportion of the inorganic N being taken up by the plants and reduces N loss. Another method relies on the addition of nitrification inhibitors which prevent immobile ammonium being converted into mobile nitrate, and therefore, reduce N leaching and increase the nutrient pool for plants[xx].

With a multitude of practices comes the added complexity of the feedstocks and digestate themselves. Tailoring practices to farms and AD plants would be the ideal way to go, but would be extremely challenging in practice. Nevertheless, the UK government has developed guidance designed to give instructions on how to prevent ammonia emissions from AD and digestate.

Current mitigation regulations in the UK

The EU's 2016 National Emission Ceilings Directive set a legally-binding target for all European Union countries to reduce their ammonia emissions by 6% by 2020, compared to their 2005 levels[xxi]. After the 2020 deadline, it appeared that 16 out of the 28 EU countries failed to reach their reduction target, with the UK missing it by 12% - making it one of the three countries to miss the target by the highest proportion, along with Latvia (15%) and Germany (12%)[xxii]. As per the Directive, EU countries (including the UK, as it left the EU after the Directive was signed) are also legally bound to reduce their national emissions by 16% by 2030, compared to 2005 levels.

In 2018, Defra in collaboration with the UK farming industry, released its Code of Good Agricultural Practice (COGAP) for Reducing Ammonia Emissions in England. The document is intended to provide guidelines and advice to farmers, growers, land managers, advisors and contractors in England to reduce ammonia emissions from a range of farming activities, including digestate storage, handling and spreading. On storing, the COGAP advises that farmers should ensure that there is sufficient storage space, that the digestate and manure be kept covered and kept dry. On the topic of spreading, a carefully planned spreading pattern is recommended so that the digestate is applied at the right time, in the right place and in the right amount, to maximise plant uptake and to limit nitrogen loss. Low-emission spreading equipment is also encouraged. The Code also touches upon limiting ammonia emissions by tailoring and monitoring livestock diet so that nutrient needs are met and not exceeded. Finally, advice is given on livestock housing, noting ammonia emissions can be reduced when housings are kept clean and when urine and faeces are kept apart from each other[xxiii].

In its 2019 Clean Air Strategy, the UK government set out its intent to mitigate all sources of air pollution and to render our air healthier. Although the Strategy does not include legally-binding targets, it positions itself as a guide to inform legislation for years to come. On the subject of ammonia, the Strategy proposes a range of support schemes aiming to provide logistical, technological and financial support to mitigate emissions across all sectors. For AD and digestate, the Strategy announces that it will establish a requirement for all digestate to be stored and covered by 2027. Another future legislation regarding the use of low-emission spreading equipment is also proposed. Finally, the Strategy mentions the possible introduction of new guidelines for digestate spreading practices which have been shown to reduce ammonia emissions from soils in other countries[xxiv]. An updated version of the Clean Air Strategy is expected to be released later this year.

The AD sector is on the rise in the UK, especially thanks to the Green Gas Support Scheme (GGSS) which incentivises biomethane production through AD. Although this is good news for the bioenergy sector, it does create issues regarding the reduction of ammonia emissions. As more AD plants are expected to be built and more waste processed, more digestate will be produced, and more ammonia will be emitted. This illustrates the tricky balancing act that is often required when using biogenic material for the production of bioenergy, and shines a light on problematic emissions other than carbon dioxide. As a result of the potential negative repercussions that the GGSS may lead to, the framework includes guidance on digestate storage and spreading, and on the methods available to stabilise N in the system (e.g. nitrification stabilisers). As per the guidance, food waste, manure and slurry-derived digestate must be stored in tanks or lagoons with fixed or floating covers securely fitted on top. This is a condition that plant operators must follow to receive support under the GGSS. Similarly, when it comes to digestate spreading, the GGSS offers guidance to reduce emissions by using low-emissions spreading techniques and appropriate equipment. Finally, although the GGSS mentions N-stabilisation pathways such as acidification, pelletisation and digestate drying, it recognises that few of them are "advanced enough to provide the evidence necessary to develop robust policy for inclusion on the scheme". As a result, the scheme is funding a study into the long-term implications of such technologies. The results of the study are expected to be made public at the scheme's mid-term review next year[xxv].

Conclusion

There appears to be no lack of evidence for ammonia emissions from farming, and no lack of advisory material on practices known to mitigate these emissions. However, the UK government is yet to introduce legally-binding targets and measures for the reduction of ammonia emissions from AD and digestate management. The 2019 Clean Air Strategy announced the possibility of a legally-binding target stating that all digestate should be stored and covered properly by 2027. This remains to be officially made into law. Storage and cover is already a very widespread practice, however, there needs to be a mechanism ensuring that all farmers practice it and that all the storage options being offered meet the necessary standards.

Digestate and feedstocks are not the only sources of ammonia emissions in the farming sector. N-based industrial fertilisers take up a quarter of the total share of emissions[xxiii]. In a subsequent article, we will cover these fertilisers in more details, mainly focusing on the fossil-derived industrial manufacturing of ammonia, and on the sustainable alternative to it: green ammonia.

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