TFRN/INMS Call for Experts:

Nitrogen Recovery Technologies

Summary:

- Nitrogen pollution represents a major resource loss, highlighting the potential to further develop and promote technologies for nitrogen recovery. In Europe agricultural nitrogen pollution alone represents a lost fertilizer value of €14 billion annually, while globally NO_x pollution is putting €40 billion of nitrogen fertilizer equivalent into the air.
- The overall societal costs of nitrogen pollution are even larger, estimated at €70 to €320 billion annually for Europe and €150 – €1500 billion globally. These costs relate to the impact of air and water pollution on health, ecosystems and climate.
- There is huge potential to develop nitrogen recovery technologies further as a significant contribution to the circular economy, while reducing environmental pollution at the same time.
- Technological options for nitrogen recovery include from both liquid and air streams flows, including from excess manure and waste water discharges (liquid) and from combustion sources (air).
- The Task Force on Reactive Nitrogen (TFRN), in partnership with the International Nitrogen Management System (INMS) plans to produce a short report during 2018 on the state of emergence of these technologies and their potential for further development in the future.
- It is anticipated that the report will focus on a) scale of available resources that might be recaptured, b) state of the emerging technologies, c) estimation of the potential for future N recovery as a contribution to the circular economy, d) emerging policy landscape and the case to develop enabling mechanisms. The anticipated scope in the first instance is the EU, set within a UNECE and global context.
- Experts are invited to join a TFRN / INMS working group to prepare the report. Potential experts should indicate their interest through a web form at the TFRN website (http://www.clrtap-tfrn.org/content/tfrninms-call-experts-nitrogen-recovery-technologies). It is proposed to appoint a chair to lead preparation of the report, members of the working group, and identify agreed reviewers. The form will allow you to indicate your expertise and proposed contribution.
- The working group is expected to work mainly electronically, but may also meet in person alongside relevant 2018 TFRN / INMS meetings.

Background

Potential for Nitrogen Recovery in EU27: Nitrogen pollution has been estimated to have major societal costs while also representing a huge waste of valuable nitrogen resources. The value of European nitrogen pollution was first estimated by the European Nitrogen Assessment (ENA). Using a willingness-to-pay approach, the ENA estimated nitrogen pollution of air, water and soil to have societal costs worth between € 70 and € 320 billion per year (Brink et al. 2011). In this calculation, the focus is on the costs of the adverse effects on health, ecosystems and climate.

Another way to value nitrogen pollution is simply as the fertilizer value of the nitrogen lost. While this does not account for the value of pollution impacts, it indicates the resource available to benefit farmer profits, if it could be avoided. Based on the ENA values, nitrogen losses from EU farming are valued at €14 billion annually, equivalent to 25% of the Common Agricultural Policy (CAP) budget, or 10% of the entire EU budget (Sutton et al., 2017). [[Will, please add the references at the end. This is the Aarhus paper]]

While these figures provide a major motivation to recover nitrogen losses, the challenge does not only apply to agriculture. Nitrogen losses also occur from combustion processes and waste water treatment. For example, the fertilizer value of global emissions of nitrogen oxides (NO_x) to air is around $40 billion per year (Key Action 6, Sutton et al., 2013). Current technologies focus on denitrification of NO_x to inert N_2, which represents a major loss of resource, with hardly any of this being recycled into useful products. Just as the 'arc process' focused in the 19th century on deliberate production of nitric acid, inadvertent release of NO_x could be recapturing nitrates for use in fertilizer and other products.

In 2016, the *'Rural Investment Support for Europe Foundation'* (RISE) produced a report outlining potential opportunities of nitrogen recovery (Buckwell and Nadeu 2016). The report provides an overview of methods used to recover nutrients in EU27 countries from three key waste streams; manure, sewage sludge and food chain waste. It estimated that 2.0-5.0 Mt of nitrogen is not being recovered nor returned to land from these three waste streams, representing 18-46% of the 10.9 Mt of mineral nitrogen currently being applied to fields in the EU27 (Buckwell and Nadeu 2016).

Key Waste Streams for Nitrogen Recovery: Nitrogen is currently recovered from manure, wastewaters, sewage, and food waste. Technologies to recover nitrogen from NO_x outputs from stationary industrial sources remain largely at the level of research and development. In addition, there is potential to consider ammonia recovery and nitrogen recovery from gaseous and particulate matter emission to the atmosphere (summarised in table 1).

Goal of the Report: To assess the opportunities provided by current and developing technologies to recover nitrogen from waste streams, and highlight investment potential to bring technologies into competitiveness. Provide evidence to support discussions on how society might invest in these technologies.

Anticipated Output: The report would aim to describe the 'state of the art' knowledge on nitrogen recovery technologies, with earliest drafts by June 2018. The report itself would be anticipated to be produced by end 2018. It is not anticipated to repeat the many details already provided by the RISE report (Buckwell and Nadeu 2015). Rather goal is to highlight the major emerging methods and provide directions for further information on the details. Key issues are to summarize and compare the technology readiness of different approaches, and highlight the opportunities and priorities for future investment.

Relevant aspects could include providing the'big picture' view of recovery technologies, accompanied with an assessment of logistics for implementing each method, legal framework and national policies supporting/blocking recovery, economic assessment and valorization routes (including capital expense and operational costs) for each method, and investment potential to bring technologies into competitiveness at national, regional or global scales. In addition, building upon the RISE report, the working group could provide further guidance on nitrogen recovery technologies (including recovery of NO_x, ammonia or nitrogen capture from particulate matter).

Outline prepared by Will Brownlie and Mark Sutton,
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Table 1. Overview of current and emerging nitrogen recovery methods by waste stream.

Waste stream	**Overview of N recovery method**	**Output products**	**Challenges**	**Current and emerging technologies**
Manure	De-watering, concentrating and converting manure into a stable product that can be easily stored, transported and applied. Manure recovery processes use two types of substrates: raw manure or digested manure. Initially, a liquid and solid separation is typically performed. The liquid fraction (i.e. mineral concentrate) can undergo ammonia stripping or be directly used as fertiliser in fields. The solid fraction may follow a digestion process or be composted (Foged et al. 2011).	Manure compost is the main market oriented product derived from manure, next to dried manure pellets and separation solids (Sommer et al. 2013). Other products valued for their nutrient content but produced in lower quantities are liquid mineral concentrates, ashes and char (Sommer et al. 2013). Most of these manure products can be directly applied to fields and will produce a fertilizing effect or a soil improver effect.	Removal of heavy metals, pathogens, pharmaceuticals and complex organic compounds from wastes.	• Ammonia Stripping: using either nitric acid or sulphuric acid to convert the gas into a salt • Struvite recovery using various methods • Recovery using calcium sulphate
Wastewaters and Sewage Sludge	Whilst nitrification and denitrification processes are commonly used practice to reduce reactive nitrogen concentrations in sewage, they do not allow for nutrient recovery, since nitrogen is emitted to air in the form of N_2, and a large surface area is required to place the tanks where this biological nitrogen removal process takes place. An alternative option is ammonia stripping, where ammonia gas can be recovered in the form of a salt.	Digestate with a fertiliser effect (NPK) or soil improver and biogas. Ammonia water or salt solution (NH_4SO_4; NH_4NO_3). Ammonia stripping can produce nitrogen fertiliser with a market value in the form of ammonium sulphate or ammonium nitrate depending on the acid used.	Collection of sewage into central treatment works and switching existing treatment works from nitrification/denitrification to ammonia stripping. Building confidence in farmers about the consistency, content and plant-availability of the nutrients present in the land applied sludge. Removal of heavy metals, pathogens, pharmaceuticals and complex organic compounds from wastes	• Ammonia Stripping, using either nitric acid or sulphuric acid to convert the gas into a salt.

Food processing wastes	Nutrients can be recovered from biodegradable waste through composting, anaerobic digestion and incineration (in certain cases). Domestic wastes are often collected for composting. The main process of nutrient recovery from slaughterhouse waste (i.e. meat and bone meal (MBM) is incineration in Combined Heat and Power (CHP) plants.	Digestate with a fertiliser effect (NPK) or soil improver and biogas. Domestic food wastes produce composts for direct use. About 80% of slaughterhouse waste is used to produce meat and bone meal (MBM) which is incinerated to produce a combination of bed ash and fly ash.	Cost efficiency of decomposition of organic material at high temperatures in the absence of oxygen.	• Composting • Incineration of organic wastes to produce ash.
NO_x capture	Up to $40 US Billion in nitrogen is lost to the atmosphere as NOx each year. A large source of release is combustion of fuels from stationary industrial sources. The basis of most NO_x recovery processes involves selectively adsorbing nitrogen from a gas mixture (i.e. fuel combustion exhausts) by drawing the gas mixture through a zone of an adsorbent which is selective for the adsorption of nitrogen.	Various depending on adsorbent used.	Much of the technology is still under development and is not main stream.	• Ozonated Wet Scrubbers: including “The LoTOx process” • NOx abatement System for Thermal Energy Storage, DeNOx Recovery system of the solar power plant. http://infuser.eu/nox/ • Xeolites, temperature swing technology • Recovery using crystalline struvite [Mg(K,NH4)(PO4)·6H2O]

References:

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