

# Summary of the ESPP Workshop (19th January 2023) on Nitrogen Recovery



www.phosphorusplatform.eu/NRecovery

Nearly 150 participants joined the ESPP **Workshop on Nitrogen Recovery** on **19<sup>th</sup> January 2023** (around half in Brussels and half online). This Workshop included presentations of nitrogen recovery technologies, presentations and panel on the political and regulatory context as well as industry perspectives, and discussions of how to develop further action.

These are summarised in this SCOPE Newsletter. ESPP's November 2022 General Assembly voted the modification of our <u>statutes</u> to widen the remit to cover "recycling of other nutrients". ESPP's first action was the organisation of a first Workshop on Nitrogen Recovery on the 19<sup>th</sup> January 2023. This Workshop addressed **"technical recycling" of nitrogen from waste streams**, that is recovery as a mineral chemical, for use as a fertiliser or in the chemicals industry. That is, organic N-recycling routes were not covered (e.g., recycling of nitrogen to soil in digestate or compost, or by production of algae or other organisms).

Slides, full list of participants (Brussels and online), session recordings and transcribed 'chat' have been circulated to all Workshop registrants.

Following this workshop, ESPP is establishing a Nitrogen Recovery Working Group aiming to:

- Identify actions to support development and implementation of N-Recovery
- Define consensus proposals to submit to policy makers
- Set up and secure funding for an appropriate 'structure' to take this forward (including funding human resources necessary for group moderation). This could be a separately funded activity within ESPP or a new structure outside ESPP.

Companies and stakeholders interested to participate in this Nitrogen Recovery Working Group should contact nitrogenrecovery@phosphorusplatform.eu

# White Ammonia Research Meeting Save the date – 7<sup>th</sup> June 2023 – Brussels and hybrid

Following this workshop, ESPP is organising a first **White Ammonia and N-recovery Research Meeting (WARM)** in **Brussels and hybrid**, **Wed**. **7**<sup>th</sup> **June 2023** (plus nitrogen recovery site visit 6<sup>th</sup> June). This will showcase research and innovation into nitrogen recovery and make links from EU R&D policy to industry implementation.

This is within <u>EU Green Week</u>, Brussels, and back-to-back to the 6<sup>th</sup> <u>NH3 Event</u> (& 6<sup>th</sup> Power to Ammonia conference), Europe's biggest ammonia event, Rotterdam 8-9 June 2023 (one hour train from Brussels).

Details coming soon on <a href="http://www.phosphorusplatform.eu/events">http://www.phosphorusplatform.eu/events</a>



# **Call for nominations**

# **SCOPE** selection of N-Recovery science

ESPP is preparing a **SCOPE Newsletter special** presenting the "best of" of recent scientific papers or reports on Nitrogen Recovery and Recycling. This will summarise a selection of around 25 scientific publications for the last few years, similar to SCOPE special editions on climate change – eutrophication links ( $\underline{n^{\circ}137}$ ) or phosphorus sustainability ( $\underline{n^{\circ}128}$ ).

Please send copies of or links to papers you suggest should be included, your own or other authors', to <u>nitrogenrecovery@phosphorusplatform.eu</u>.

Selection will target papers representing significant knowledge progress in N-recovery, both technical recovery (N recycling to industry or fertilisers) and biological or other N recycling routes, in particular: operating experience at full/pilot scale or innovative technologies leading to N-recovery in a form likely to be a marketable product.

This SCOPE Newsletter special will provide a starting point for the first White Ammonia Research Meeting, Brussels, 7<sup>th</sup> June 2023 <u>www.phosphorusplatform.eu/NRecovery</u>

	COL
White Ammonia Research Meeting	1
SCOPE selection of N-Recovery science	2
Editorial	3
Glossary, numbers, references	3
What next for an N-Recovery Group?	
Next steps	5
Policy context	5
N-recovery operator mapping	
Olivier Bastin, ESPP	
Dilution and logistics	
The price of nitrogen	
Mark Sutton, CEH and INMS	í.
Towards the objective "Halve Nitrogen Waste"	.6
The Colours of Ammonia	.7
Request for input to UNEP data base	7
Fabien Santini, European Commission, DG Agriculture7	
Food security	.7
Trudy Higgins, European Commission DG Environment7	,
Further reducing wastewater nutrient losses	.8
Evaluation of the EU Sewage Sludge Directive	.8
ESPP comments on the Green Deal Industrial Plan	8
Panel on industry perspectives	8
Cecilia Dardes, Fertilizers Europe	}
Industry will support N-recycling	
Oliver Loebel, Eureau	}
Johanna Bernsel, European Commission, DG GROW9	)
Recovered ammonia salts under the FPR	.9

# Contents

<b>cases. 1</b> 10 10 11 11
<b>10</b> 10 11 11
11 11
11
12
12
12
13
13
13
14
14
15
15
15
15
16
16
17
17
17
17



# **Editorial**



This first workshop on N-recovery was a great opportunity meet and discuss this new challenge with a range of stakeholders, including the European Commission, national governments, nitrogen producers and users, researchers and technology providers.

For ESPP this workshop is the first step to determine how we can, together, contribute to increase nitrogen recycling and reduce European dependency on nitrogen fertiliser imports and on natural gas.

Mark Sutton presented the colours today used to talk about different ammonia production routes: Grey ammonia, Blue ammonia, Green ammonia. The colours indicate how environmentally conscious is the production of the hydrogen atom (the base element to form ammonia). But these three colours are all "new" reactive nitrogen, made by combining hydrogen with N<sub>2</sub> in air using the Haber Bosch process.

But what do we call reactive nitrogen recovered from existing residues and brought back into the system as a circular nitrogen source? Mark Sutton brought forward the name "White" ammonia.

Using the term **"White Nitrogen"** to mean recycled reactive nitrogen (whatever its form: ammonia, nitrates, organic nitrogen products ...) facilitates discussion and can maybe provide the focus for a shared vision.

The workshop confirmed that there are a major challenges to recovering nitrogen as a mineral chemical. Today's processes all result in aqueous solutions, often with low concentrations. This makes transport and logistics prohibitive.

To follow up this workshop, it was agreed to set up a working group of industry and stakeholders, to define and promote actions to facilitate the development of a white nitrogen market, from recovery through to use. Part of this will be to tackle regulatory challenges which hinder the use of certain feedstocks making white nitrogen.

Robert Van Spingelen, ESPP President

# **Glossary**, numbers, references

# Understanding ammonia solution concentrations

Units of measurement: % = g/100 ml. molar (M) = mol/l.

- ammonium sulphate contains 21 %N
- **ammonium nitrate** contains **35 %N** (but if generated by recovering stripped ammonia using nitric acid, then only half of this N is recycled, the other half comes from the intrant nitric acid)
- ammonia (as in ammonia water) contains 79 %N

Above is based on atomic weights. This means, for example, that a 10% ammonium sulphate aqueous solution contains 2.1% N.

For reference, a "liquid inorganic macronutrient (nitrogen) fertiliser" must contain **minimum 5% N under the EU** Fertilising Products Regulation (PFC 1(C)(I)(b)).

**Saturated solutions**: ammonium sulphate c. 43% (@ 25°C) (source), ammonium nitrate c. 68% (@ 25°C) (source)

### **Other conversions:**

1 g/l NH<sub>4</sub> = 0.78 mg/l N = 0.056M N (or NH<sub>4</sub>) = 0.08% N 1% N = 0.7M N (or NH<sub>4</sub>) = 10 g/l N = 12.8 g/l NH<sub>4</sub> 1M N = 1.4% N 1M (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> = 2.8% N

# Definitions (as used in this SCOPE Newsletter)

**"Stripping"**: removing a dissolved component (ammonia, carbon dioxide) from a liquid (waste) stream (e.g. digestate or manure) by a gas stream (air or steam) to a gaseous form (this may partly be water droplets, in which the ammonia or  $CO_2$  remains dissolved).

Stripping is generally achieved by a combination of one or more of the following to improve mass transfer efficiency:

- changes of temperature
- changes in pressure

- improving the contact between both phases (bubbling trough the liquid, packed column, etc.)

- raising the pH.

"Scrubbing": removing gases (ammonia, carbon dioxide,  $NO_x$ ) from a gas stream by passing through water, acid, ... If ammonia is "stripped" from e.g. manure to a gaseous stream, then this gaseous stream is "scrubbed" by passing it through sulphuric acid and the ammonia will be recovered as an (often dilute) ammonium sulphate solution.

# Other sources of information

For information on a number of nitrogen recovery processes see the ESPP-DPP-NNP Technology Catalogue www.phosphorusplatform.eu/techcatalogue



Niclogen re	covery main routes	
Substrate : liquid, slurry, solid or gas phase		
ORGANIC	INORGANIC	
Microbial concentration	Industrial byproduct recycling	
Microalgae	e.g. ammonium sulphate from	
Single-cell proteins	caprolactum production used in fertiliser	
Bacteria, fungi, etc.	industry	
Technologies may be combined in	Combinations occur within	
treatment trains for N recovery	one route or mix different routes	
Reuse in organic form	Technical recovery for organic fertiliser o	
	other chemicals	
Spreading on land (e.g. manure, sewage	Stripping & scrubbing (or condensation),	
sludge, liquid concentrate)	including membrane contactors &	
Can be done after some processing or	vacuum stripping (+ other developed)	
stabilisation, e.g. :	Precipitation - dissolution (struvite)	
- Manure acidification	Biological nitrification	
- N enrichment (ex. plasma)	Ion exchange with resins, zeolites,	
- Composting	geopolymers, etc. and adsorption (NOx)	
- Anaerobic digestion	Bipolar membrane electrodialysis	
- Solid - liquid separation (including	Concentration (ex.RO, nanofiltration,	
membrane filtration), thickening,	reverse osmosis, crystallisation)	
dewatering & drying	Others : polymer electrode membrane	
- Pathogen reduction (ex. : heating)	cell, electrochemistry, etc.	

Main routes of nitrogen recovery

# What next for an N-Recovery Group?

The final session of the Workshop, 19<sup>th</sup> January 2023, discussed **what actions are needed to take forward nitrogen recovery and recycling**, and what form of organisation or cooperation could contribute to this.

This will be taken forward by ESPP. However, ESPP emphasised that to date there is no funding for further action on nitrogen recovery, and funding must be either brought by companies and organisations engaging in further action or found through external funding sources.

For coming months, ESPP will continue to provide coordination and communications support to develop a Working Group on Nitrogen Recovery (or other form of cooperation to be defined), with the aim of this becoming then self-funding.

The following workshop conclusions for action were identified:

# **Define goals, propose policies**

- identify shared goals and vision
- promote the concept of "White Ammonia"
- clarify different approaches:
  technical N recovery (as a mineral chemical)
  - upgrading N in manure on-farm (e.g. <u>N2 Applied</u>)

- biological and organic routes for N reuse, either locally or in refined organic/organo-mineral fertilisers

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- develop consensus proposals for policy makers
  - engage different industries, stakeholders
  - develop a proposal on "market pull" policies (see below)



• input to EU R&D policy (Horizon, Life, ...) to develop funding of demonstration plants, with on-site, long-duration operational trials

# **Dialogue on technical and market questions**

- How to move from longstanding N-removal technologies (ammonia stripping, NO<sub>x</sub> scrubbing) to recovery and recycling?
- Provide proof of long-term process reliability, operator useability
- Bring together the supply chain to discuss how to adapt products to market and logistic requirements
- Identify regulatory obstacles and propose ways forward
- Involve farmers, food companies and local authorities

# **Collate and provide information**

- Different processes: state of development and operating experience, reference cases and scale, output products, suppliers, etc.
- Different output nitrogen forms, different output N chemicals

- Concentrations of output products (when as solutions)
- Agronomic field trials
- Quality and contaminants
- Sanitary safety (where Animal By-Products are inputs, including manure)
- LCA data, including monetarising social costs (ex. ETS) and impact on companies' CRS (Corporate Social Responsibility)

# Find resources for organising cooperation

- Funding from engaged companies and organisations?
- Human resources?
- Possible external funding?

# Next steps

ESPP will now set up a Start-Up Pilot Committee to take things forward. **Persons interested to engage are invited to contact** <u>nitrogenrecovery@phosphorusplatform.eu</u> This working committee will function by online and/or physical meetings and email

# **Policy context**

# N-recovery operator mapping

# **Olivier Bastin, ESPP**



Presented the operator mapping and literature search on N recycling and recovery carried out by Akinson Tumbure and himself for ESPP (see summary in ESPP eNews N°72 and full documents online

www.phosphorusplatform.eu/NRecovery).

Over 100 recent publications were analysed (full reference list online) and

**150 technology providers/operators were identified (90 in Europe),** covering some 25 different groups of technology. Organic N-recycling routes were not covered: e.g., recycling of nitrogen to soil in compost, or by production of algae or other organisms.

This mapping showed that recovery targets mainly N-rich liquid streams such as manure, digestates, leachates and that the output is generally a mineral fertiliser component (or ammonia water for flue gas treatment).

"Stripping" and/or scrubbing is the main industrial technology, with decades of implementation for removal of ammonia or  $NO_x$  from offgases, or from liquid via a gas phase. Other technologies are now developing and some are operational at industrial scale, including membrane

concentration, ion exchange and a few other innovative technologies.

# **Dilution and logistics**

The two key challenges which are apparent are the "dilute" nature of recovered products and the geographic dispersion of recovery sites.

Most processes recover **ammonia compounds in aqueous solution**. Often this solution is too dilute for transport over any distance to be feasible, so preventing industrial recycling either to chemicals or fertilisers. Even where ammonia compounds are in "concentrated" solutions, this can only reach a maximum of maybe up to 8 %N/wet weight (ww) for ammonia sulphate solution or maybe up to 15 %N/ww for ammonium nitrate solutions (of which half the N only is recovered, the other half from input nitric acid). This compares to 46% N by weight in a solid urea fertiliser, and to the minimum 5% N in a "liquid inorganic macronutrient (nitrogen) fertiliser" under the EU Fertilising Products Regulation (PFC 1(C)(I)(b)).

Also, most of the substrates for N-recovery (manure slurries, digestate) are also liquid, and so not feasibly transportable over significant distances. This means that **N-recovery operations need to be local, and so generally small scale**. This can render problematic access to secondary energy for concentrating or drying recovered solutions.

Overall tried-and-tested technologies and a number of operators exist for N-recovery from ammonia stripping from N-rich liquid wastes, but there are concentration and logistics challenges, and a need to demonstrate operational reliability of these N-recovery systems on-site (farm or sewage





works, daily operation by the farmer or sewage works operators).

On the other hand, few actors and industrial-scale technologies were identified for other substates such as lower concentration liquid streams, solid waste, off-gas  $NO_x$  stripping, etc.

It is also noted the potential for **local recycling processes**, **such as N2 Applied** (see below) **or CCm** (see SOFIE2 in ESPP <u>Scope Newsletter n°146</u>), where nitrogen is fixed into organic wastes to produce an organo-mineral product for local use or marketable.

# The price of nitrogen

# Mark Sutton, CEH and INMS



*UKCEH* = *UK Centre for Ecology and Hydrology* 

*INMS* = <u>International Nitrogen Management</u> <u>System</u>

Underlined that the United Nations and the EU have endorsed ambitious objectives to reduce nitrogen losses. Currently 80% of reactive nitrogen

resources are wasted globally.

One thousand years ago, 6 - 8 kg of reactive nitrogen cost about as much as a human life (price of a slave). Today the price is around 100 000 times lower\*. Today's price is unsustainable and does not account externalities (e.g. eutrophication, pollution, climate impacts).

\* Based on historical price comparison to gold and silver. See graph below. Note: the vertical scale is log%. Based on <u>Sutton et al. 2020</u>.

Over the past forty years, policy on nitrogen has moved from an **initially fragmented policy approach across different N forms** (e.g. in Europe, the Nitrates Directive, ammonia in the Emissions Ceilings Directive, ...), towards a positive approach aiming to improve nitrogen use efficiency (see Our Nutrient World 2013, in <u>ESPP SCOPE Newsletter n°96</u>). Today, **policy emphasis is increasingly on reducing wasted nitrogen resources**. This holistically considers losses of all forms of N, enables shared goals with economic benefits to farmers and to society, and includes nitrogen recycling.

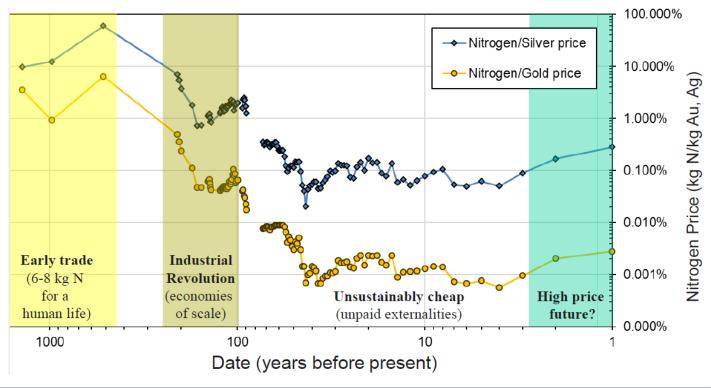
# Towards the objective "Halve Nitrogen Waste"

This is communicated in the "Halve Nitrogen Waste by 2030" objective, already endorsed by:

- The EU in the Green Deal "Farm to Fork" and "Biodiversity" Strategies: target to reduce nutrient losses by at least 50% (see <u>ESPP SCOPE Newsletter n°139</u>)
- United Nations Environment Assembly Resolution <u>UNEP/EA.5/Res.2</u> (2 March 2022) calls to "accelerate actions to significantly reduce nitrogen waste globally by 2030 & beyond" (<u>ESPP eNews n°67</u>)
- UN Convention on Biological Diversity COP15 (December 2022, <u>Target 7</u>): "reducing excess nutrients lost to the environment by at least half including through more efficient nutrient cycling and use"

This objective makes economic sense. The value of reactive nitrogen waste in the world agri-food system is c. 420 billion  $\notin$  (at 2022 N prices), that is around  $\frac{3}{4}$  of total world farming subsidies (derived from <u>Sutton et al. 2020</u>).

United Nations Environment is developing tools to support policies towards the "Halve Nitrogen Waste". The **Guidance** 







**Document on Integrated Sustainable Nitrogen Management**, adopted by the Geneva Air Convention, 18<sup>th</sup> December 2020 (United Nations Economic Commission for Europe (UNECE) <u>ECE/EB.AIR/149</u>) presents 24 principles and 76 measures.

This document validates a definition of Nitrogen Waste:

"A distinction is made between unreactive atmospheric dinitrogen ( $N_2$ ) and reactive nitrogen forms ( $N_r$ ), which represent valuable resources. Around 80% of anthropogenic  $N_r$  production is wasted as air and water pollution and through denitrification back to  $N_2$ ".

# The Colours of Ammonia

This needs to go beyond the current discussion of green and blue ammonia (see e.g. UK Royal Society green ammonia briefing, Feb. 2020) and to define:

- **Brown (or Grey) ammonia**: ammonia made using a fossil fuel as feedstock (as is generally the case at present with the Haber-Bosch process, using natural gas)
- **Blue ammonia:** low carbon ammonia, that is brown ammonia but with carbon capture and storage technology applied to the manufacturing processes
- Green ammonia: zero carbon ammonia, made using renewable electricity, water and air
- White ammonia: Recovery of ammonia from existing nutrient residues (Nitrogen Recycling).

# **Request for input to UNEP data base**



Will Brownlie, UKCEH, indicated that in the context of the United Nations Environment Guidance Document on Integrated Sustainable Nitrogen Management, UKCEH is compiling a data base of nutrient recovery and recycling technologies. Input on technologies and case studies can be sent to

wilown@ceh.ac.uk

# Fabien Santini, European Commission, DG Agriculture



Outlined the consequences on food security of the increases in natural gas prices aggravated by Russia's war of aggression in Ukraine. The European Commission supports farmers in this crisis, and adopted a crisis framework for state aid by which member states (MS) can support both the EU

fertiliser industry and farmer. Nitrogen recovery and recycling has an important place in this policy.

The recent peaks in gas prices have been matched by considerable reductions in ammonia production in Europe, increases in imports of nitrogen fertilisers, and a two to five fold increase in fertiliser prices for farmers. Fertilisers can be up to 15% of arable crops farmers costs in normal times.

# **Food security**

The consequence seems to be, to date, -10% estimated reduction in farmers' N fertiliser purchase, and so use. What impact this will have on food production is not yet clear and depends on a lot of factors, including climate.

The European Commission has responded with actions in the energy sector mobilisation of the 500 M $\in$  agricultural reserve (plus 700 M $\in$  of MS matching funding), suspension of import tariffs on urea and ammonia, and with the Commission Communication on the availability and affordability of fertilisers (November 2022, see <u>ESPP eNews n°72</u>).

The European Commission will announce a "Green Deal Industrial Plan" (<u>published</u> 3<sup>rd</sup> February 2023, see below). This includes a Net-Zero Industry Act and the Critical Raw Materials Act (public consultation organised in November 2022, see <u>ESPP eNews n°70</u>) and a proposed Temporary Crisis and Transition Framework for Member States' subsidies to industry.

Longer-term policies which can support actions towards Nitrogen Recycling include the EU Integrated Nutrient Management Action Plan (expected 2023, and which should address the Nitrates Directive "processed manure" question), RePowerEU (biomethane and digestates), actions on nutrients in Member States' CAP "Strategic Plans", R&D funding (Horizon Europe, LIFE, DG AGRI, InterReg) on-going work on protein (first half 2024).

# Trudy Higgins, European Commission DG Environment



Summarised the current proposed revision of the Urban Waste Water Treatment Directive (UWWTD) 91/271/EEC. This includes tighter and more extensive discharge limits for nitrogen and phosphorus, and a mandate to the Commission to set possible "minimum reuse and

recycling rates for phosphorus and nitrogen from sludge" (art. 20) (see ESPP eNews n°71).

The evaluation of the UWWTD concluded that it has been effective with tangible impacts, simple, targeted and with economic benefits of improved water quality exceeding implementation costs. The Commission has pursued a carrot and stick policy, with infringement procedures taken to the European Court of Justice and significant funding through regional development funds.





# Further reducing wastewater nutrient losses

The proposed revision of the UWWTD, of which discussion is now started in the European Parliament and Council (Member States), addresses in particular certain remaining pollution challenges (stormwater, smaller settlements, emerging pollutants), energy use and greenhouse emissions monitoring, sewage sludge management, regulatory coherence and governance, and eutrophication. **Eutrophication is identified as a problem which is not resolved, despite significant improvements resulting from important investments** so that further action is needed. Tighter nitrogen and phosphorus discharge limits are proposed and nutrient discharges would be required for some waste water treatment plants where this is not currently the case. There is also a proposed widening of the application of "Sensitive Areas".

# **Evaluation of the EU Sewage Sludge Directive**

The EU Sewage Sludge Directive (SSD) 86/276/EC is currently under assessment. The finalised Evaluation should be published in coming weeks. Preliminary studies are already published:

- <u>Wood December 2021</u> Support to the evaluation of the Sewage Sludge Directive Exploratory Study (248 pages)
- <u>Wood March 2022</u> Support to the evaluation of the Sewage Sludge Directive. Final study report (243 pages)
- JRC (<u>Huygens et al.</u>) 2022 Screening risk assessment of organic pollutants and environmental impacts from sewage sludge management. See <u>ESPP eNews071</u>.

A feasibility study and technical assessment for a possible revision is ongoing (JRC).

These policies on wastewater treatment and sewage sludge management are linked to EU policies including the upcoming Integrated Nutrient Management Action Plan (INMAP, expected before summer 2023) and Soil Health law, Circular Economy, EU Fertilising Products Regulation, and in particular the **Green Deal target to reduce nutrient losses by at least 50% by 2030** whilst ensuring no deterioration in soil fertility.

# ESPP comments on the Green Deal Industrial Plan

ESPP notes that the general outline documents published by the European Commission on <u>3<sup>rd</sup> February</u> (IP 23\_510) do not mention fertilisers and are centred on carbon emissions reductions and renewable energies. For Critical Raw Materials (CRMs), emphasis is placed on elements needed for electronics and batteries. It remains to be seen whether the fertilisers sector and food security, and the CRM "Phosphate Rock" (for which the main use is food production) will be included. ESPP also notes that this initiative might be expected to centre on industries identified for green investment in the EU "Taxonomy". In the final Commission proposal for the "Taxonomy", phosphorus recovery from waste water is included, but not P-recovery from other wastes, and not Nrecovery (see ESPP eNews n°66).

# Panel on industry perspectives

# Cecilia Dardes, Fertilizers Europe



Presented the mineral fertiliser industry perspective on nitrogen recycling. Fertilizers Europe has developed a livestock-derived organic nutrients availability database and is planning to further develop it and extend it to other waste streams, including estimates of what proportion is currently effectively reused

(returned to crops, in a plant-available form, when and where needed by crops).

Fertilizers Europe estimates that **only 60-80% of nitrogen in secondary resources is currently recycled**, leaving a potential that should be exploited, for example by acidification of manure and by reducing losses in the food processing chain (e.g. animal by-products).

**Europe's fertiliser industry currently faces a crisis**, with a third of EU N-fertiliser production currently down, but a +40% increase in urea fertiliser imports. This makes Europe dependent on imports for fertilisers, so compromising our food security and resulting in higher prices for farmers.

# Industry will support N-recycling

The mineral fertiliser industry wishes to play an important role in developing nitrogen recycling, providing logistic, industrial, agronomic and market structures and expertise.

Mineral and organic fertilisers are complementary, and both are needed to achieve balanced nutrient to supply according to plant needs and to **ensure Europe's food security**.

# **Oliver Loebel, Eureau**



European Federation of National Associations of Water Services

The water industry's objective is to make wastewater treatment plants into resource factories. The proposed revision of the Urban Waste Water Treatment Directive (see above) will accelerate this with tighter requirements for P and N removal and

obligations to become energy neutral and reduce greenhouse gas emissions.



VIENNA 20-22 June 2022 ESPC4 European Sustainable Phosphorus Conference

Current technologies for nutrient recovery often imply high costs and energy and/or chemicals consumption, or pose challenges to achieve end-user quality requirements. No market for the recovered nutrient means no business case for the water industry.

The water industry is looking for solutions embracing the holistic approach to energy and resource recovery from wastewater, with tried-and-tested technologies, and which are not only applicable in large but also small and medium waste water treatment plants (< 50 000 p.e.). These technologies must support the sector in becoming energy and climate-neutral.

The European water industry needs industrial partners to share risk, investment and costs, and to identify applications where the value of recovered nutrients is demonstrated.



Wastewater treatment plant

# Johanna Bernsel, European Commission, DG GROW



Underlined that the objective of the EU Fertilising Products Regulation 2019/1009 (FPR) is to enable placing on the EU market of recycled nutrients and use of secondary raw materials, with appropriate safety requirements.

In particular, all materials used in a fertilising product must respect the criteria of one of the "CMCs" (Component

Material Categories). It is the final material, as used in the fertilising product, which must be a CMC. Thus, if a digestate (CMC5) is chemically processed (using chemicals which are CMC1), then the resulting material may no longer be eligible to be used in an EU fertilising product (unless this specific processing is foreseen in CMC5). It is therefore necessary to verify carefully the relevant CMC criteria (in the consolidated FPR text) for any materials derived from waste.

Further indications can be found in the "Frequently Asked Questions" document regularly updated by the Commission <u>here</u>.

# **Recovered ammonia salts under the FPR**

Under the FPR (EU Fertilising Products Regulation), recovered nitrogen materials may be covered by CMC11 "By-products" (see delegated act <u>here</u>), or by CMC15 "Recovered high purity materials" (see FPR consolidated text), subject to the criteria of these CMCs.

# ESPP comment:

SCOPE NEWSLETTER

Simplified and subject to limitations in the CMC15 criteria:

- CMC15 will generally cover ammonium salts recovered via stripping (that is, via offgas) from manures, digestates, sewage sludge or any other liquid.
- Ammonium salts recovered from **solid or liquid phase** (not via gas stripping) may be covered under CMC15 or CMC11 (by-products) but only if recovered from an industrial production process (that is, not from waste or wastewater treatment).

# Stimulate the market for recovered nutrients

**Olivier Loebel** emphasised the **need for market "pull" for recovered nutrients** and suggested that this could be achieved by requiring a minimum recycled nutrient content for the fertilisers market. **Cecilia Dardes** considered that this is likely to lead to **market distortions**, for example "artificial" processing of organic by-products which are at present efficiently used locally. It would be essential to ensure the same requirements both **for imported fertilisers but also for imported food and feed**, to not disadvantage European farmers. **Johanna Bernsel** suggested that the EU Fertilising Products Regulation aims to enable nutrient recycling and that **market pull could be created by EU policies** such as EcoDesign or the upcoming INMAP (Integrated Nutrient Management Action Plan), and supported by initiatives on Green Labelling.

# **Proposal for action on market pull tools**

A proposal was made that **ESPP try to develop a stakeholder consensus joint proposal on market pull tools** (market stimulation policies) for recycled nutrients, to put forward to policy makers, with water and waste industries, fertilisers sector, farmers' organisations.







# **Digestate and compost**



**Erik Meers, Gent University,** for EBA (European Biogas Association), indicated that around 250 Mt wet weight of digestate was produced in Europe in 2021 (expected to double by 2030). This contains an estimated 1 million tonnes of N, which can be recycled by use of digestate as an organic fertiliser, either directly or after processing, or by

recovery of the nitrogen as a mineral salt (ammonia stripping and recovery).

Source: EBA Statistical Report 2022

**Stefanie Siebert, European Compost Network**, representing the biowaste sector in Europe, indicated that today 21 million tonnes of compost are produced with an overall fertiliser value of 864 M€. Compost contains on average c. 1.4 %N/dm, compared to nearly 0.1-1 %N/ww



in the liquid fraction of digestates (in both cases, this will vary considerably depending on the input materials).

Compost in Europe (EU27 inc. CH, NO, UK) is around 170 ktN/y, 63 ktP/y and 100 ktK/y.

Around 6% of N in compost is available in the first year after application to soil

(16% after 3 years), compared to 65% (75%) for digestate. *Source: ECN <u>Data Report 2022</u> (free online).* 

### Nitrogen losses from composts

Nitrogen losses during composting were not discussed whereas up to <sup>3</sup>/<sub>4</sub> of total nitrogen can be lost to the atmosphere as ammonia during composting (Zeng 2012, Szántó 2009) Wageningen WUR) and up to 20% in leachate (Yang 2019). The possibilities of trapping and recovering these N-losses were not discussed.

# Nitrogen recovery technology showcases

# Ammonia stripping and scrubbing

# Circular Values BV

www.circularvalues.eu



#### **Sven Mommers**

(Could not be present, content added after the workshop)

**Company**: founded 2017, The Netherlands, 10 staff.

**Technology**: ammonia stripping by pH increase and heat, with recovery in acid to ammonium salt solution (scrubbing).

Mobile containerised installations, turn-key for on-farm operation (FarmCubes) and customised fixed industrial scale installations.



FarmCubes installation

Installations running to date: 15 with N-recovery, with input capacities of 8 000 to 60 000 t/y liquid manures or manure

digestates. Recovery of N to ammonium sulphate solution: 1000 tN/y.

**Recovered product**: current installations recover N as ammonium sulphate solution (7-8 %N/ww) or ammonium nitrate solution (12-15 %N/ww).

**Pilot project under construction** to convert ammonium sulphate solution to crystalline ammonium sulphate, using electrical power for cooling and crystallisation. Capacity 60 000 Mt ww per year input. Commissioning planned 2023.

# Colsen (AMFER®)

<u>www.colsen.nl/en/services/n-recovery</u> See also ESPP-DPP-NNP Technology Catalogue <u>www.phosphorusplatform.eu/techcatalogue</u>



# Jan Willem Bijnagte

**Company**: founded 1989 in The Netherlands, ca. 75 staff worldwide, with offices today also in Spain and South Africa. Offers services in water, manure and digestate treatment.

**Technology: AMFER**<sup>®</sup> ammonia stripping, by pH increase achieved by CO<sub>2</sub>

stripping (no alkali dosing), and recovery by acid scrubbing. Modular or containerised, capacity inflow 1-100 m<sup>3</sup>/h.

**Installations running to date**: 3 with N-recovery in poultry manure digestion (2) and co-digestion (1). Recovery of N to ammonium sulphate solution: 950 tN/y.

**Recovered product**: ammonium sulphate solution (7.5 %N/ww) or ammonium nitrate solution (15 %N/ww).



VIENNA 20 - 22 June 2022 ESPC4 European Sustainable Phosphorus Conference

## **Comments**:

- N-removal upstream can **improve anaerobic digestion**, so increasing methane production
- Low operating temperature (55-65°C, compatible with thermophilic digestion), so low temperature waste heat is possible (e.g., from CHP)
- Personal opinion as input for discussion: Salt solutions recovered from stripping are "mineral" products (near zero organic carbon), very different from membrane "concentrates". The EU RENURE proposals go in the wrong direction by proposing local Nitrates Directive exemptions under certain conditions for organic carbon rich manure derived materials, instead of fixing an EU wide exemption for all "mineral" products processed from manure.

# Detricon

#### www.detricon.eu



Wouter Naessens

**Company**: Belgian SME founded in 2014.

**Technology:** two-stage ammonia stripping, achieved mainly by  $CO_2$ stripping and limited heating, then recovery by acid scrubbing. Stripping at c.  $55^{\circ}C$  can achieve over 65% ammonia recovery without alkali dosing, nearly

90% recovery with alkali dosing. Containerised units (see below) with capacity 2 m<sup>3</sup>/h ww input.



**Installations running to date**: four with N-recovery from digestates of pig manure, chicken manure, sewage sludge, municipal organic waste, in Hooglede (BE, BioSterco), Antwerpen (BE, Aquafin), Barcelona (ES, Ecoparc2), Gistel (BE, Ivaco, currently in reformation). Recovery of N to ammonium sulphate or ammonium nitrate solution: 50 tN/y.

**Recovered product**: ammonium sulphate solution (8 %N/ww) or ammonium nitrate solution (15 %N/ww).

# **Comments**:

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- N-removal upstream of digester can **improve anaerobic** digestion, so increasing methane production
- Costs c. 550 €/tN for recovered ammonia salt solution, depending on energy costs (excl. sales).

# **RVT Process Equipment**

# www.rvtpe.com/global/en/products/turnkey-units

# Andreas Geißler

**Company**: Founded in 1976, nowadays approximately 200 employees serve clients all around the world from locations in Germany, USA and China. Besides supplying components for mass and heat transfer processes, areas of expertise are turn-key units for scrubbing and stripping applications as well as thermal oxidizing.

**Technology**: Over 30 years' experience building turn-key ammonia stripping-scrubbing units, using air and steam stripping, for agriculture, industry (power industry, mining, recycling) and wastewater treatment applications. With air stripping, in a first column, alkalised waste liquid is stripped of ammonia and in a second column the ammonia is recovered with acidic solution (mainly with sulphuric acid as ammonium sulphate). The air is circulated in a closed loop between the two columns equipped with packed beds. With steam stripping, the ammonia is stripped in one single column and recovered by condensation as ammonia water.

**Recovered product**: ammonium sulphate solution 35-40% (c. 8 %N/ww) or ammonium water up to 20% (16 %N/ww).



RVT air stripping unit





**Installations running to date**: More than 50 installations worldwide, with inflow capacities of up to 80 m<sup>3</sup>/h of liquid. Mobile 1 m<sup>3</sup>/h test unit available.

#### **Comments**:

• N-recovery as ammonia water is mostly installed where steam/heat is available and there is on-site use of the product.

# Nijhuis Industries (Byosis)

www.nijhuisindustries.com/solutions/resource-recovery/byoflex www.byosis.com

See also ESPP-DPP-NNP Technology Catalogue <u>www.phosphorusplatform.eu/techcatalogue</u>

#### Gertjan Buffinga



**Company**: Nijhuis Industries is part of the Saur (12 000 staff worldwide, 1.9 billion  $\in$  revenues 2022). Within Nijhuis, Byosis was started 12 years ago to work on ammonia recovery processes, with today16 staff.

**Technology**: The **ByoFlex**® ammonia recovery is a standard or custom-built ammonia stripping, using mainly heat to

strip ammonia, and recovering N as ammonium sulphate solution. Up to 85% ammonia removal from substrate liquors is achieved without alkaline chemical dosing, and higher removal rates with alkali dosing.

**Installations running to date**: 25 ByoFlex installations are today in operation in Western Europe, with inflow capacities of up to 80 m<sup>3</sup>/h of liquid. The references to recover nitrogen are in different market like treatment of digestate from chicken manure, food waste + manure, manure + crop wastes. Also the first installations are in operation to recover nitrogen from centrate after municipal sewage sludge digestion.

**Recovered product**: ammonium sulphate solution (8.5 % N/ww).



*ByoFlex stripping of 80 m<sup>3</sup>/hr digestate* 

# **Comments**:

- Heat recovery ensures energy efficiency
- Suitable for separated and even non-separated substrate
- If the ammonia stripper is installed in a recycle over a digester, the ammonium level in a digester can be controlled by continuously removing part of the ammonium and using the stripped effluent to dilute the fresh incoming material. This enables the feeding of

nitrogen-rich materials, such as poultry manure or food waste to the digester without adding water

- Adapted to installation at sites with secondary heat available from biogas combustion
- Also available as modular and rental units
- See also below Nijhuis Byosis projects underway to produce nitrogen fertiliser products with higher N content/lower sulphur content.

# From stripping to fertiliser products

# PureGreen

www.growpuregreen.com

### **Michael Friedman**



**Company**: Established in 2016. Two sites in Raleigh, NC and Walnut Creek, CA (USA), 8 staff.

**Technology: ART** ammonia stripping and scrubbing technology generating up to 10-12% ammonia salt solution. This is used to feed a bio-reactor (patented **AIR** technology) where potassium is dosed and

bacteria oxidise the soluble ammonia to potassium nitrate solution.

**Installations running to date**: two ART installations are today operational, treating biogas digestates, fish arming effluents, livestock manures (cattle, swine). These produce a total of around 4.4 million litres (2023 est.) in fertiliser or industrial chemicals and will produce 15 million litres in 2024 (est.) based on active production installations and installations currently being commissioned.



PureGreen installation

**Recovered product**: refined, concentrated potassium nitrate liquid fertilisers (KNO<sub>3</sub> 3-0-9 (3 %N/ww) and 2-0-7(2 %N/ww)) or processed to food-grade nitric acid for industrial applications. The potassium nitrate fertiliser is <u>OMRI</u> Listed for Organic Farming in the USA.





# **Comments**:

- Microbial process is relatively energy efficient (requires aeration, low grade heat), uses secondary energy from biogas fueled electricity generation
- Ammonia stripping/scrubbing and microbial oxidation reactors can be customised to different scales.

# Nijhuis Industries (Byosis)

www.nijhuisindustries.com/solutions/resource-recovery/byoflex www.byosis.com

See also ESPP-DPP-NNP Technology Catalogue

www.phosphorusplatform.eu/techcatalogue



Gertjan Buffinga

Company: see above.

**Technologies**: Nijhuis Byosis has developed three processes for nitrogen recovery in concentrated forms, with lower sulphur content than ammonium sulphate:

- Genius → nitrogen-potassium-sulphate solution
- ByoNix → ammonium bicarbonate or ammonium water solution
- **ByoFlex** → ammonia stripping (see above) with (sulfuric) acid recovery (under development)

**Genius:** Two stage liquid-liquid membrane process, separates ammonia and potassium ions from liquid manure digestate, resulting in an ammonia – potassium sulphate solution, a solid organic fertiliser and cleaned discharge water.

**Installations running to date**: The first full-scale plant is operating since 2019 at a manure and cosubstrate processing/mineral plant (100 000 t/y ww digestate input). New projects are currently under construction.

**Recovered product**: nitrogen potassium solution (c. 0,8-1.5 % N/l, c. 1-1,5 % K/l), a solid organic fertiliser (1-3% P/dry weight) and clean surface water.

### **Comments**:

- modular concept with proven technologies from the waste and wastewater market
- NK concentrate, to be used as biobased fertilizer
- low chemical usage compared to other concepts
- complete solution for manure processing without residual streams
- In combination with digestion energy positive.

See also ESPP-DPP-NNP Technology Catalogue www.phosphorusplatform.eu/techcatalogue

**ByoNix:** ammonia stripping (ByoFlex see above) but using carbon dioxide (not sulphuric acid) for ammonia scrubbing, resulting in an ammonium carbonate solution (1-2% N) that can be upgraded to an ammonium carbonate solution of 15% N or ammonia water of >20% N. This can fix  $CO_2$  from anaerobic digestion.

**ByoFlex ED-BPM**: ammonia stripping (ByoFlex see above) followed by sulphuric acid recovery from the ammonium sulphate in a 3-membrane electrolysis cell. This enables

recycling of the sulphuric acid back to the scrubbing column, and generates ammonia water of app. 2% N. This ammonia water can be concentrated to a level of >20% of N. This process is currently at a pilot stage (test unit with input capacity of 250 l/h of ammonium sulphate solution produced from municipal waste water).



20 m<sup>3</sup>/hr membrane filtration (MF) and reverse osmosis (RO) installation at a manure processing/mineral plant to produce NK concentrate and clean water

# Membrane ammonia stripping

# **Membratec**

www.membratec.ch



### **Alexandre Bagnoud**

**Company**: Established 1997 specialising in ultrafiltration of drinking water with today over 100 ultrafiltration plants installed.

**Technology**: Heat and alkali are used to strip ammonia from waste liquors in a hollow fibre membrane contactor (80-95% N<sub>-total</sub> removal). Ammonia crosses

the membrane and is reacted with sulphuric acid to generate ammonium sulphate solution. Input stream must have <1 g/l TSS (total suspended solids).

**Installations running to date**: Two full scale installations at Yverdon (since 2019) and Altenrhein (since 2021, capacity increase underway) waste water treatment plants, with inflow capacities of 4-7 m<sup>3</sup>/h digested sewage sludge centrate.

**Recovered product**: 38% ammonium sulphate solution ( = 8% N). High purity of the product.

### **Comments**:

- Membrane stripping cell is around ten times more compact that conventional "stripping towers"
- By removing ammonia from sludge digestate centrate return stream, reduces N<sub>2</sub>O emissions and oxygenation requirements (for biological treatment) in the waste water treatment plant





• Oils and surfactants must not be present in inflow liquor or could damage membrane process.



Membratec stripping membrane

# VTT Finland (TYPKI)

www.typki.fi

# Hanna Kyllönen

**Company**: VTT Technical Research Centre of Finland Ltd.

**TYPKI** is a two-year nutrient recycling R&D project finishing January 2023.

Different technologies tested on different streams: Ammonium concentrated from a mine effluent by

nanofiltration after scalant removal (Kyllönen et al. 2022), transferred to ammonia by increasing pH (alkali dosing) to be absorbed by membrane contactor technology to sulphuric acid, and concentrated as ammonium sulphate by acid resistant nanofiltration membranes producing 30% ammonium sulphate solution (6.3% N). Sodium nitrate from flue gas scrubber water (NO<sub>x</sub> removal) concentrated via nanofiltration pre-treatment and reverse osmosis concentration up to 8% sodium nitrate (1.3 %N). Potassium nitrate recovery from explosives contaminated surface water using nanofiltration pre-treatment and reverse osmosis concentration.

**Installations running to date:** Ammonium sulphate solution from mine effluent recovery has been tested using pilot scale 2540 spiral wound elements (40 l/h input, 100 l of mine water treated, element's performance tested in one day). Demonstration at the mine is planned (~10 m<sup>3</sup>/day). Potassium nitrate and sodium nitrate recovery have been tested at lab scale.

**Comments**:

• Developing with University of Verona/Nicola Frison of a process to treat ammonia from biogas digestate by oxidation to nitrate using nitric acid with hydrogen peroxide as an absorption solution in membrane contactor.



VTT's nanofiltration and reverse osmosis pilot device

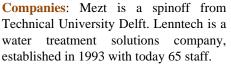
### Mezt, Lenntech

<u>www.mezt.eu</u> <u>www.lenntech.com</u>

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### Adriaan Lieftinck, Niels van Linden





**Technology:** bipolar membrane electrodialysis. Ammonia rich wastewater (e.g., animal manure) passing between the two membranes has positive ions (e.g., ammonia, potassium) driven out through one membrane and negative ions out through the other (carbonate, converted to  $CO_2$ ) due to a potential difference over the membranes.



Specific membranes can be used to separate different positive ions, enabling recovery of ammonium and potassium solutions, or ammonia gas can be extracted from the positive ion chamber using vacuum.

**Installations running to date**: extensive lab scale testing. Containerised pilot (inflow 300 l/h, batch process) has been operated using as input the liquid fraction of animal manure (e.g., raw and digested pig and cow manure and cow urine). **Comments** 

- Pre-treatment may be needed to avoid suspended solids entering the cell, as these can foul the membranes
- Process requires no chemical inputs, only electricity
- Low energy (electricity) consumption (no heating required)







MEZT prototype installation

# Ion exchange

# Agua DB

#### www.aguadb.com

See also ESPP-DPP-NNP Technology Catalogue <u>www.phosphorusplatform.eu/techcatalogue</u>



### Mike Waite

**Company**: Agua DB is a technology start up since August 2017, currently with technology at the pilot scale.

**Technology**: Agua DB's NTPlus is a new method of regenerating an anion ion exchange resin used to remove nitrates from drinking water supply. Sulphate and carbonate from the water also occupy the

ion-exchange resin sites. Potassium chloride (KCl) is used to regenerate the anion resin, rather than using salt (sodium chloride), so without generating brine waste liquor, and producing only nutrient solution with no waste (solution of potassium sulphate, nitrate and carbonate).

**Installations running to date**: One pilot being tested in the UK treating drinking water, 250 l/h input flow, operated to date for approx. 9 months.

**Recovered product**: 3% concentration solution (3% TDS) with around half potassium sulphate ( $K_2SO_4$ ), one quarter potassium nitrate ( $KNO_3$ ) and one quarter potassium carbonate ( $KHCO_3$ ), that is: c. 0.1% N/wet weight, c. 1.2% K/ww and c. 0.3% S/ww. This can be used for fertigation in local agriculture, partially replacing synthetic fertilisers and potash.

## **Comments**:

• Low carbon footprint potassium sulphate solution.

- Potassium sulphate is reported to give 10 15% higher crop yields than potassium chloride, by improving turgor.
- 65% of the functional sites on the resin are regenerated with first order reaction kinetics, enabling nearly 100% efficient regeneration.
- Objective is to adapt the technology to treat sewage works final discharge water, reducing N levels to <5 mg/l and soluble phosphorus to < 0.5 mgP/l.

# Cranfield University, UK

# www.cranfield.ac.uk



# **Ana Soares**

**Company:** Cranfield University is developing a number of innovative phosphorus and nitrogen recovery processes, in cooperation with UK water companies.

**Technology**: Treatment of wastewater (diluted) by zeolite-N ion exchange,

followed by sodium hydroxide regeneration producing up to 0.2% N solution. This is then concentrated using hollow fibre membrane contactor (membrane stripping) with sulphuric acid dosing, to up to c. 4% N ammonium sulphate solution.

#### Comments

- Solid ammonium sulphate crystals can be produced by air drying
- Can be combined with a second ion exchange column for phosphorus removal and recovery see ESPP-DPP-NNP Technology Catalogue www.phosphorusplatform.eu/techcatalogue.
- The critical aspect for economics is the recycling of sodium hydroxide used for regeneration (higher economic impact than value of recovered nutrients)
- Research is ongoing into using micro-organisms to biogenerate struvite from sludge dewatering liquors, also an ammonia recovery process.

# KAMK University of Applied Sciences, Finland

<u>https://www.kamk.fi/en/Cooperate-with-KAMK/Core-Ramp;D-</u> <u>Competences/Industrial-materials-applications</u>



# Tatiana Samarina

**WaterPro** project has reviewed possible routes for N-recovery: struvite precipitation, air stripping and scrubbing for recovery, membrane separation, ion exchange.

**Technology**: Following this evaluation, a three-step system (**NutriCON**) was

designed using (1) selective ammonium adsorption by inorganic polymers (produced by alkaline activation of aluminosilicate precursors) or natural zeolites, (2) desorption of collected ammonium from adsorbent, and (3) recovery of preconcentrated ammonium by transmembrane chemical absorption. A membrane contactor unit with sulfuric or

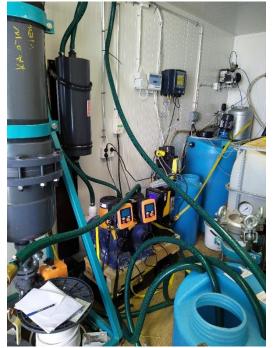




phosphoric acid dosing was used to generate ammonium sulphate or ammonium phosphate solution in continuous mode.

**Installations running to date**: After lab scale testing (see <u>Samarina et al. 2022</u>) a containerised pilot plant (inflow c. 400 l/h, continuous) was constructed and has been tested for 10 weeks at municipal sewage works (KajaaniVesi, Finland) during WaterPro project and for 4 weeks treating landfill leachate treatment plant (EkoKumppi, Finland) during SUSWAM project.

**Recovered product**: the pilot generated 17% ammonium phosphate solution or 22% ammonium sulphate solution (both 4.5-5% N).



Adsorption columns and membrane contactor inside the NutriCON container

### **Krajete**

www.krajete.com



### Alexander Krajete

**Company:** Krajete GmbH was established in Austria in 2012 to develop and commercialise a biological carbon fixation process, using Archaea fed with hydrogen to convert  $CO_2$  to methane. The company now offers total emission capture. Today the company employs a staff of 7 people.

**Technology**: Adsorption using zeolites (or other adsorbents) to capture  $NO_x$  (and hydrocarbons/SO<sub>x</sub>) from industrial or combustion offgases, or for city air purification. The zeolites are then regenerated by heating, releasing  $NO_x$  and  $SO_x$ .

**Installations running to date**: One pilot-scale NO<sub>x</sub> removal installation for purifying city air (Heilbronn, Germany, in cooperation with Audi). 1500  $m^3/h$  of air are treated, with >

80% NO<sub>x</sub> removal during 1.5 years continuous operation. Another semi-commercial scale NO<sub>x</sub> removal unit for purifying city air (Enns, Austria, in cooperation with Audi). 12  $500 \text{ m}^3/\text{h}$  of air are treated. Large scale installation units to treat up to 100 000 m<sup>3</sup>/h of emission gas (up to 500 ppm NO<sub>x</sub>) are in planning phase.

**Recovered product**: they are planning to in the future to convert NO<sub>x</sub> to nitric acid.



Heilbronn NOx Removal Unit

# Cetaqua

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https://www.cetaqua.com/



### Álvaro Mayor Pillado

**The project:** The LIFE ENRICH project (Cetaqua, Spain) tested a N-recovery pilot at Murcia Este wwtp, in which ammonia is separated from effluent in a zeolite ion exchange bed, then the ion exchange eluate is treated using a liquid-liquid membrane contactor in order to recover nitrogen as ammonium salts.

**Technology:** Ion exchange with zeolites (ZE) and membrane contactor. This treatment train has been tested with the anaerobic digestion centrates from Murcia Este WWTP.

The ion exchanger reduced influent ammonia concentration from 600-800 mg N-NH<sub>4</sub>/l to <150 mg N-NH<sub>4</sub>/l (around 80% N-removal). The zeolite ion exchange bed was regenerated using sodium hydroxide which was then sent to the membrane contactor to recover the nitrogen and transform it into ammonium nitrate.

**Installation:** N-recovery was installed in 2019 in Murcia Este (WWTP 500 000 p.e.), with a 1  $m^3/h$  pilot ion exchange – membrane contactor unit operating on part of the sludge centrates, after anaerobic sludge digestion. This pilot was operated for a total of 1.5 years.

**Recovered product**: The membrane contactor removed around 90% of N-NH<sub>4</sub> from the eluate, and with nitric acid as input, an ammonia nitrate solution of 7-26 %N was produced.





# Next steps:

Further work on recovered ammonium salts and other recycled fertilisers from municipal sewage is underway in the WalNUT projet (EU Horizon 2020).

Life Enrich final report 28/02/2022 (81 pages) <u>www.life-</u> <u>enrich.eu/</u> and WalNUT <u>www.walnutproject.eu</u>



Membrane contactor pilot

# **Chemical N-recovery from liquid phase**

# *EasyMining (Aqua2N) – ESPP member*

www.easymining.se/projects/re-fertilize



### Anna Lundbom

**Company:** EasyMining is since 2014 part of Ragn-Sells, a leading company in waste management and environmental engineering in Northern Europe, with 2500 employees. EasyMining was established in 2007 to develop circular solutions for nutrients, and today has 40+ employees and offers solutions for

phosphorus (Ash2Phos), nitrogen (Aqua2N) and potassium (Ash2Salt) recovery. See also ESPP-DPP-NNP Technology Catalogue <u>www.phosphorusplatform.eu/techcatalogue</u>

**Technology**: nitrogen is separated from liquid waste streams to solid by precipitation of struvite (magnesium ammonium phosphate), by dosing magnesium and phosphate as needed. The struvite is then dissolved with sulphuric acid to regenerate magnesium and phosphate ions, which are recycled back to the process, and ammonia which is recovered as ammonium sulphate solution. The process can achieve up to 95% ammonia removal from liquid waste streams (down to 25-50 mg N-NH<sub>4</sub>/l).

**Installations running to date**: EU LIFE Re-Fertilizer project. <u>Demonstration unit operating</u> at Lynetten wwtp (near Copenhagen), Denmark. Capacity 4 m<sup>3</sup>/h input, testing sewage sludge digestate centrate and landfill leachate. Successfully operated during fall 2022. **Recovered product**: ammonium sulphate 10% solution (c. 2% N). Objective is to increase to 30% solution. Ammonium nitrate, phosphate or chloride could also be produced depending on the acid used to dissolve the struvite. **Comments**:

# • Following successful pot trials, the fertilising efficiency of the recovered ammonium sulphate was proven in pot trials by SLU (Swedish Agricultural University) and by the Sweden agriculture cooperative Lantmännen

- The recovered ammonia salt solutions are eligible for use as fertiliser components under the EU Fertilising Products Regulation (CMC12: the struvite is a CMC12 "Precipitated Phosphate" and the ammonia salts are "derivates")
- Significantly lower carbon footprint per kg of N than Haber Bosch (reference LCA done for the process during the LIFE RE-Fertilize project)
- Low levels of contaminants in recovered ammonia salt solutions (well within EU FPR limits)

• Process is now starting industrial commercialisation.



EU LIFE Re-Fertilizer project demonstration unit

# **On-farm N-recycling:** "improved manure"

# N2 Applied - ESPP member

www.n2applied.com

See also ESPP-DPP-NNP Technology Catalogue www.phosphorusplatform.eu/techcatalogue

#### **Kenny Brown**



**Company**: N2 Applied is a scale-up technology company providing an innovative environmental technology for on-farm slurry treatment. The treatment uses electricity to improve the fertiliser value while reducing environmental emissions. N2 Applied was founded in 2010 and currently has 45 staff over three countries.





**Technology**: an electric plasma process combines  $N_2$  and  $O_2$  from air to produce a NO<sub>x</sub> gas. The NO<sub>x</sub> gas is absorbed into organic slurries or digestate as nitrate. This lowers pH and generates stable N compounds. This considerably reduces atmospheric nitrogen and methane emissions from manures/digestates during storage and during field application, prevents odours, improves crop Nitrogen Use Efficiency (NUE) and increases crop yields (see <u>ESPP eNews</u>  $n^{\circ}58$ ).

**Installations running to date**: there are nine N2 Applied units operating today in 4 countries. (e.g. More Biogas, Småland, Sweden, manure and food waste digestate, see <u>ESPP eNews</u>  $n^{\circ}64$ ). Some units have now been operating successfully for more than two years.

#### Comments

 LCA analysis indicates that N2 Applied application and storage can reduce dairy farming carbon footprint by –27% (source).



N2 applied unit

# **ESPP members**

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