Nutrient recovery from digestate: Techniques & end-products

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Content

I. Digestate characteristics
II. Flemish situation
III. Why recover nutrients?
IV. Nutrient recovery techniques
V. End-products
VI. Need for further research
VII. Related projects
VIII. Conclusions

I. Digestate characteristics

- Non-digested resilient fraction, water, micro-nutrients, macro-nutrients
- Composition depends strongly on ingoing streams






Parameter		Average value
Dry matter	Decreases due to organic matter decrease. More cattle/pig slurry → lower DM-content	9%
Total N	Constant during digestion. More pig slurry → more N	5 kg N/ton (+m) 3 kg N/ton (-m)
Mineral N	Increase due to organic N → NH_4^+ More organic waste → lower share of NH_4^+	44 – 47% ! 82% (100% pig slurry)
pH	Increase due to decomposition volatile fatty acids. Less dependency on input streams.	8.3
Phosphate content	Constant during digestion. More pig slurry → more P	4 kg P_2O_5/ton (+m) 3 kg P_2O_5/ton (-m)
Heavy metals & impurities	Constant. Can be problematic for Zn and Cu in pig slurry. Inactivation of weed seeds & pathogens depends on T & residence time	-

II. Flemish situation

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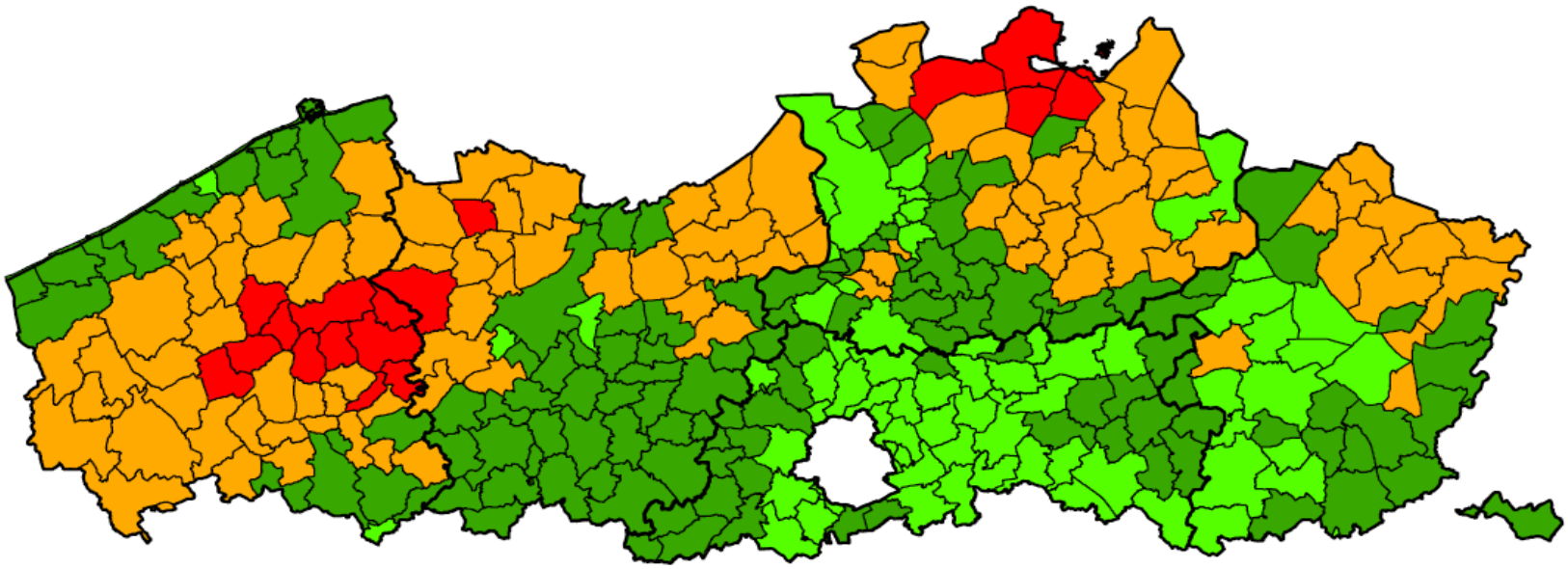
- Organic and inorganic fertilisers → water pollution
  - European Nitrate Directive (1991)
  - Limit nutrient dosage on fields
  - Strong limit on animal manure (170 kg N/ha)
  - Digestate equals animal manure
  - Raw digestate disposal is difficult, esp. in nutrient rich regions (West-Flanders, Antwerp)
- Most co-digestion plants invest in digestate processing techniques

II. Flemish situation

Mestproductiedruk (kg N/ha) in Vlaanderen, 2010

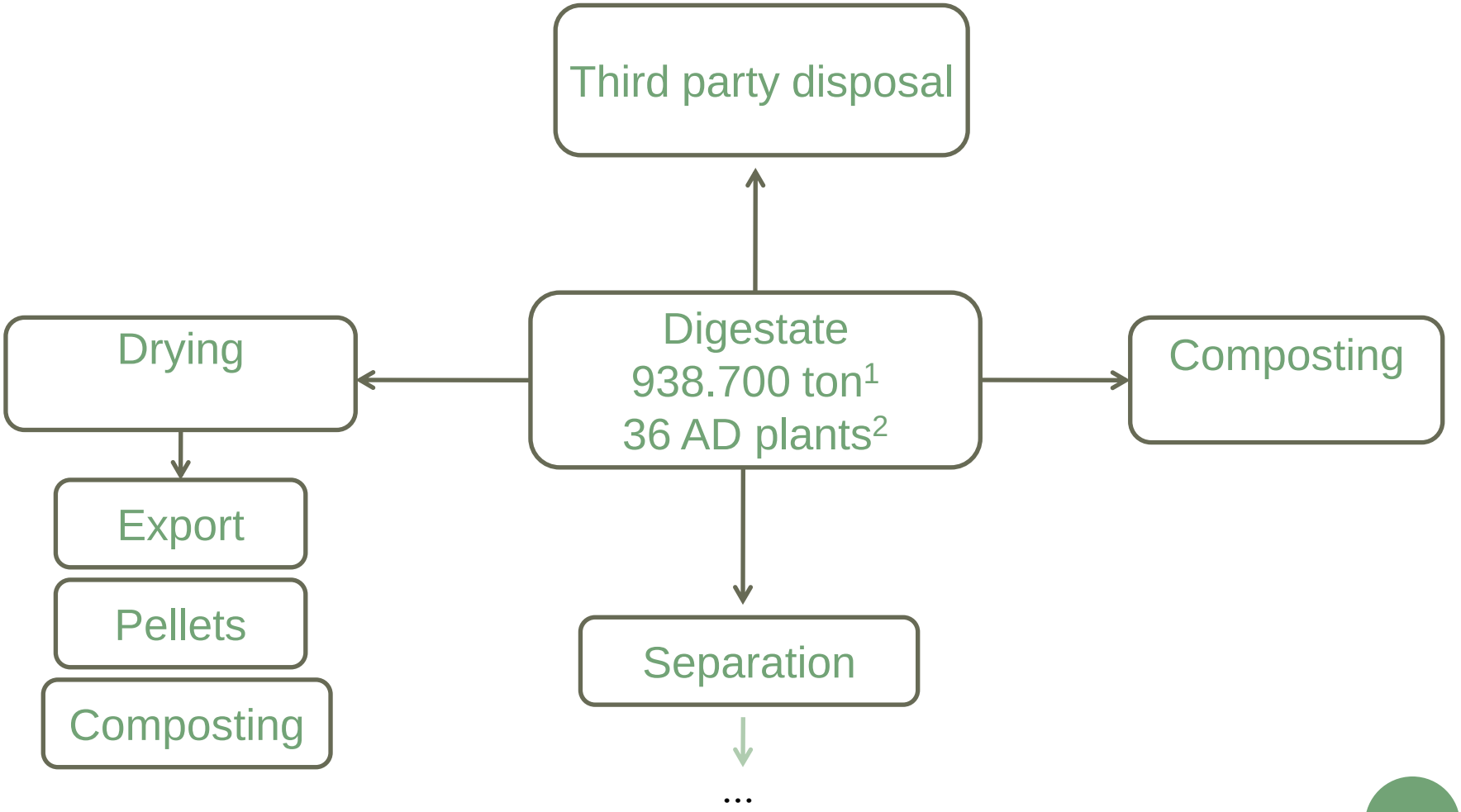
(bron: Mestbank)



Omschrijving mestproductiedruk

- <85 kg N/ha
- 85-170 kg N/ha
- 170-340 kg N/ha
- >340 kg N/ha

II. Flemish situation: digestate processing



[1] Vlaco activity report 2011
[2] VCM survey 2011, Progress report Biogas-e 2011

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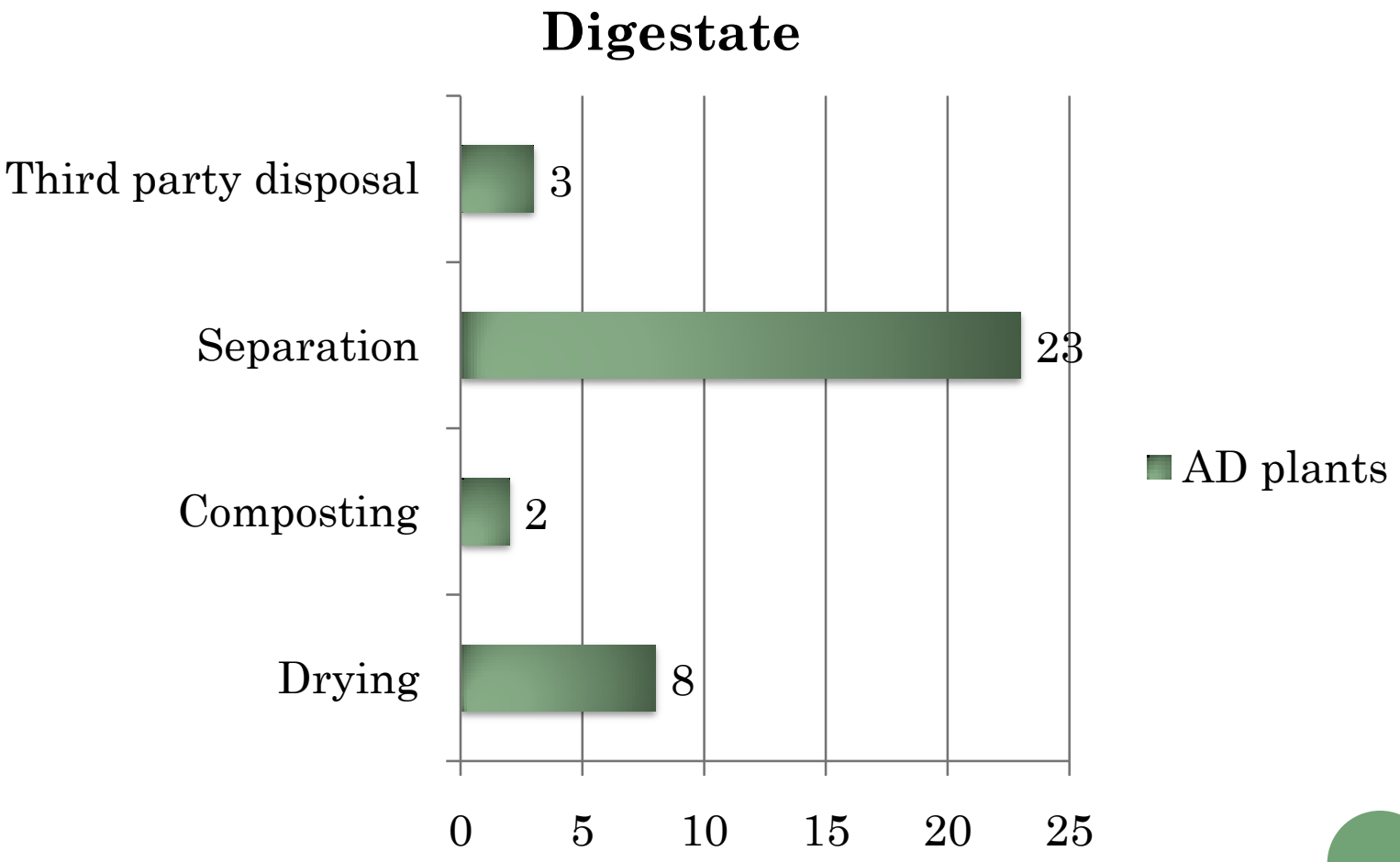
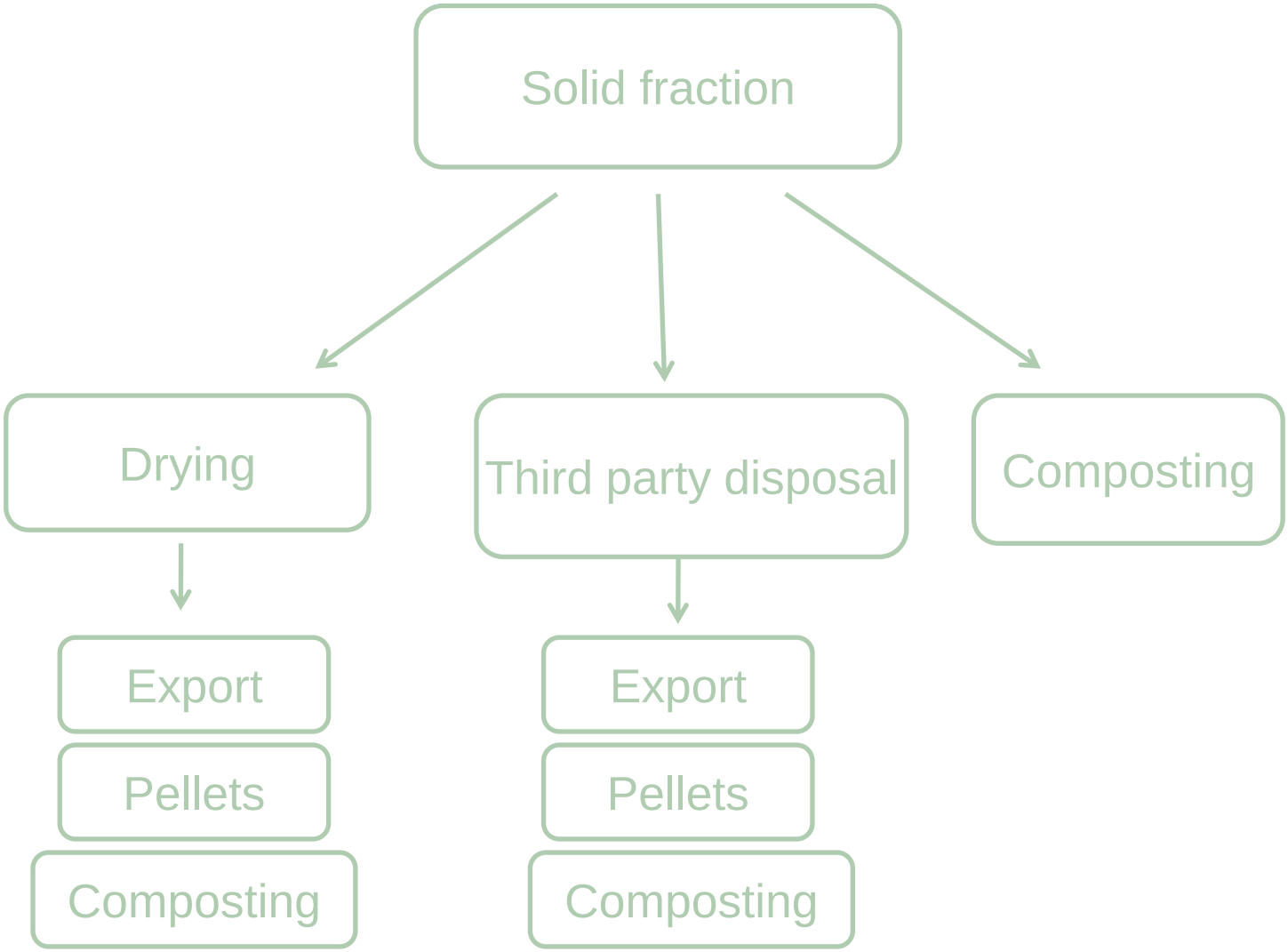


II. Flemish situation: SF Digestate



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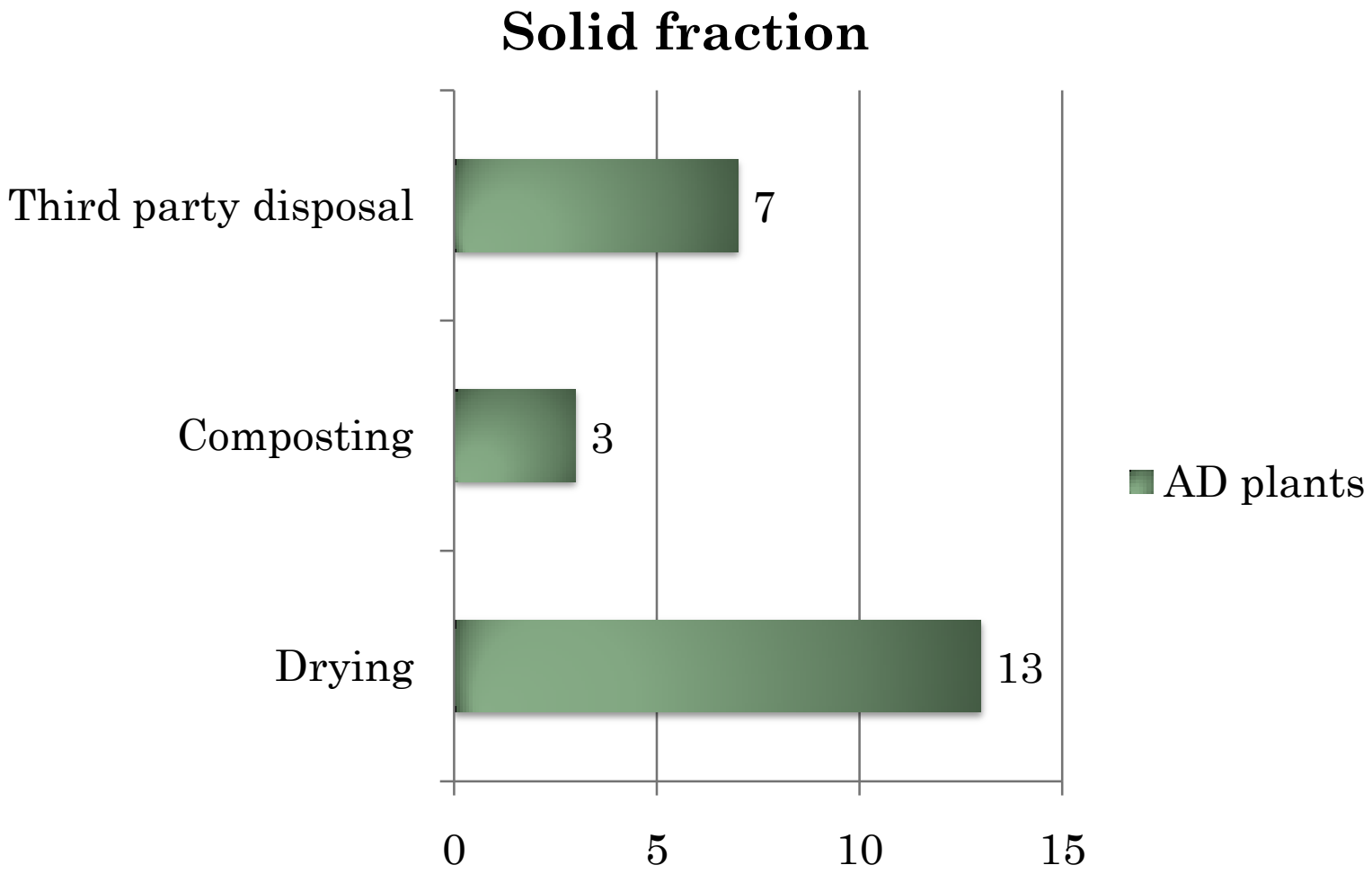

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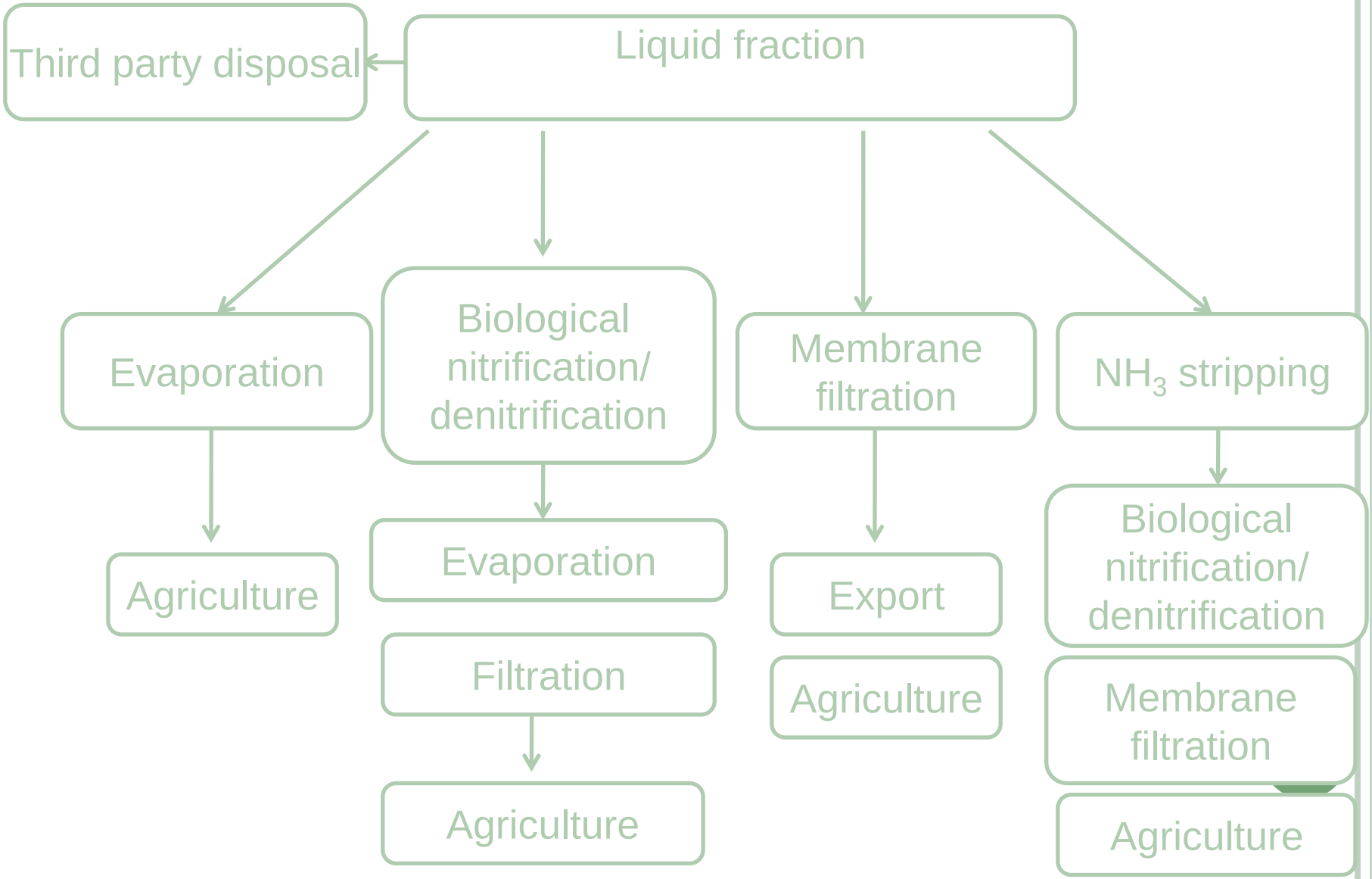

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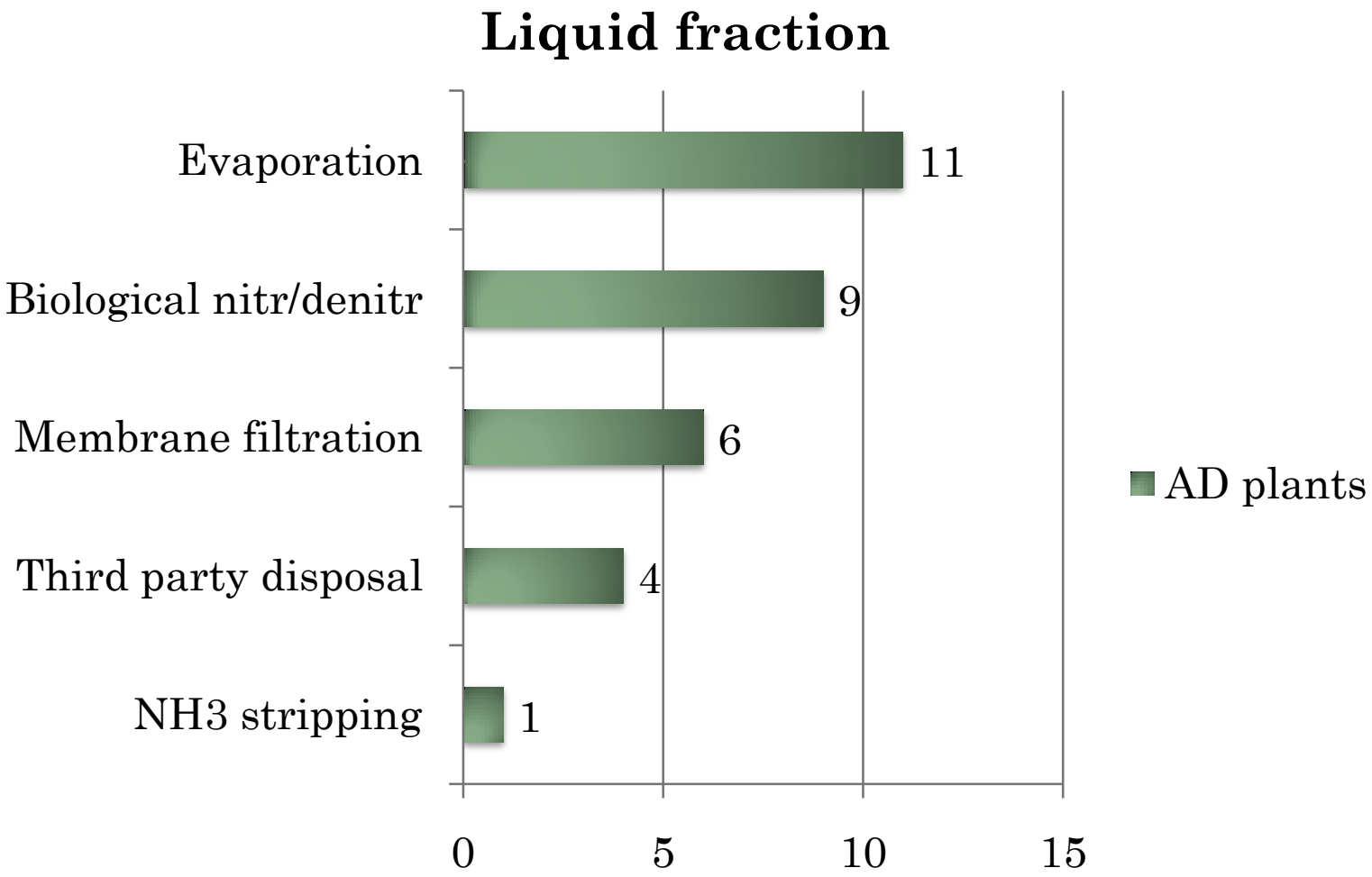
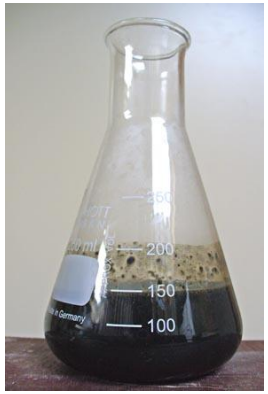


III. Why recover nutrients?

- Awareness of phosphorus depletion
- Awareness of increasing artificial fertiliser use
  - Energy consuming
  - Economical burden for farmer

- Question: how can digestate be valorised as a valuable source of nutrients?
- OR: how can digestate be turned into a 'green' substitute for artificial fertilisers?

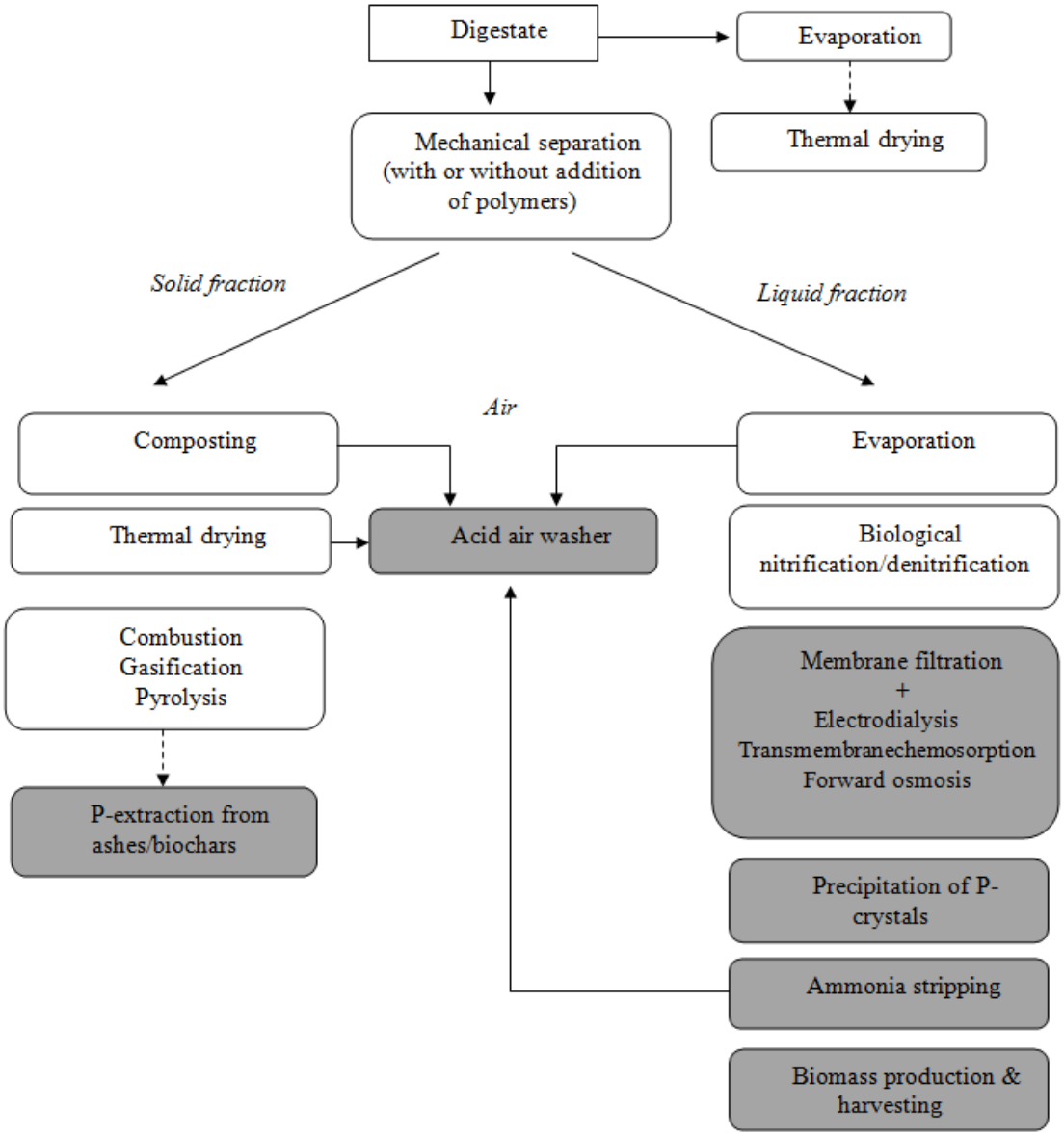


→ Extract nutrients!

IV. Nutrient recovery techniques

- Hard to define
- Interpretation:
  - End-product with a higher concentration of NPK than raw digestate
  - Techniques that separate NPK of organic matter
  - Goal: end-product that can substitute artificial fertiliser **or** as a feedstock in industrial processes

IV. Nutrient recovery techniques



IV. NRT (1): Acid air washer

- Drying, composting, evaporation, …
- Important: treat drying gases!
  - Dust, ammonia, odorous gases
  - Acid air washer that captivates NH_3
    - End-product: $(NH_4)_2SO_4$
    - Flanders: artificial fertiliser
    - Variable N-content
    - Low pH, high salt content
    - Sulphur content

Restrains use

- Status: full scale

IV.NRT(2):Extraction of organically bound P

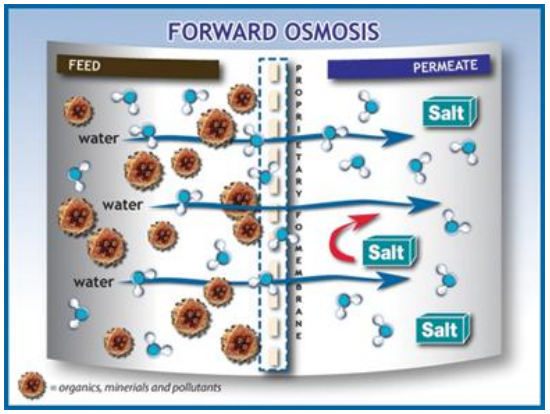
- Ashes: P-, K-, Al- & Si-components + heavy metals (Cu, Zn, Cd)
- Several processes
  - Thermochemical
    - Addition of $MgCl_2$ & heating up to 1000°C
    - Heavy metals in the gaseous phase
    - Production of e.g. $CaHPO_4$
  - Wet-chemical extraction techniques
    - Acid extraction
    - Fertilising value (Kuligowski et al., 2010)
- Status
  - Full scale for ashes of sludge WWT (SNB – Thermphos), poultry manure (NL)
  - Lab scale testing

IV. NRT(3): PRESSURISED MEMBRANE FILTRATION

- Types
  - Pressure: RO > UF > MF
  - Pore size: MF > UF > RO
  - Concentrate: suspended solids (MF), macromolecules (UF), ions (RO)
  - Other pre-treatment: DAF (+ flocculants)
- Bottleneck: blocking of membranes
  - Suspended solids, salts with reduced solubility, biofouling
  - Higher tangential flux, anti-scalants, cleaning agents (NaOH & H_2SO_4)
- Pilots mineral concentrates (NL)
  - Agronomic, economic & environmental effects of MC
  - Goal: recognition as an artificial fertiliser
    - EU 2003/2003 (EU-fertiliser)
    - Nitrate Directive
- Status: full-scale

IV. NRT(4): OTHER MEMBRANE TECHNIQUES

- Forward osmosis
  - Draw solution in stead of pressure
  - Status
    - Full-scale in other sectors, no testing (?) with digestate



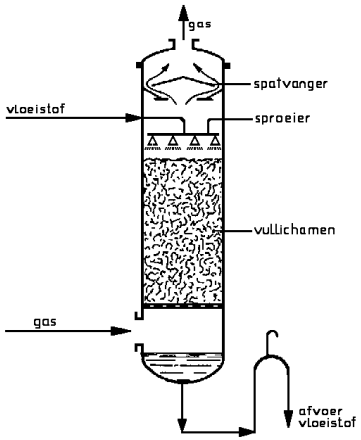
- Electrodialysis
  - Ion exchange membrane + electrical voltage
  - Transfer of NH_4^+, K^+ en HCO_3^-
  - Status
    - No full-scale on digestate, tests on lab-scale in literature
- Transmembrane chemosorption
  - Innovative pig slurry treatment in NL
  - Gaseous NH_3 diffuses through membrane & is captured in sulphuric acid
  - Status: pilot in NL

IV. NRT (5): P-PRECIPITATION

- Soluble P (ortho-phosphate) can be precipitated by:
  - Ca^{2+} → $Ca_3(PO_4)_2$
  - Mg^{2+} → $MgNH_4PO_4$ of $MgKPO_4$ (MAP of struvite)
  - K^+ → $K_2NH_4PO_4$ (potassium-struvite)
- Commercial processes in development:
  - Reactors
  - Large, pure crystals (seeding)
  - Full-scale in WWT
- Status: full-scale for calf manure + pilot testing on digestate
- Optional: dissolve organically bound P
  - Acid extraction
  - Creates a P-low solid fraction

IV. NRT(6): Ammonia stripping

- Aeration in packed column
  - pH: 10, T: 70°C
  - Bottlenecks: precipitation of salts & fouling of the packing material, periodical cleaning necessary
- Acid air washer
  - Stripgas + sulphuric acid → ammonia sulphate
  - Higher N-content than air washer drying gases/stables
- Lime softening step with $Ca(OH)_2$
  - Removes Ca^{2+}, Mg^{2+}, carbonates
  - Preferred pH-increase
- Status
  - Full-scale



IV. NRT (7): Biomass production & harvest

- Research on algae & duckweed
  - Removal of P&N by plant uptake
  - Bottleneck: suspended solids, humic acids,... → reduction of penetration of light
  - Max. additions in growing medium
  - Large surface
  - Valorising harvested biomass
    - Biobased chemicals
    - Biofuels
    - Fertilisation
    - Feed (GMP)
- Status
  - Lab tests + pilot on duckweed

V. END-PRODUCTS

TECHNIQUE	STARTING FROM	END-PRODUCT	CHARACTERISTICS
Acid air washer	Air charged with NH_3	$(NH_4)_2SO_4$ solution	$(NH_4)_2SO_4$ solution : 30-70 kg N/m³, pH 3-7
P-extraction	Ashes/biochar/SF digestate	Acid P-extract/$CaHPO_4$	Acid P-extract: Ptot: 0.192 g/kg
Reversed osmosis	UF/MF/DAF-permeate	RO-concentrate (NK-fertiliser)	Ntot: 7.3 g/kg Ktot: 2.9 g/kg Ptot: 0.42 g/kg
Forward osmosis	UF/MF/DAF-permeate	FO-concentrate (NK-fertiliser)	?
Electrodialysis	LF digestate	NK-fertiliser	?
TMCS	LF filtered on 10 µm	NK-fertiliser	$(NH_4)_2SO_4$ solution: 50 - 150 kg N/m³
P-precipitation	(LF) digestate	$MgNH_4PO_4$/$MgKPO_4$/$CaNH_4PO_4$	12.65/11.62/11.86% P
NH_3-stripping & acid air washer	LF digestate	$(NH_4)_2SO_4$ solution	350 kg N/m³ pH: 3-4
Biomass production	Diluted LF digestate	Biomass	Duckweed: 30% CP (dm)

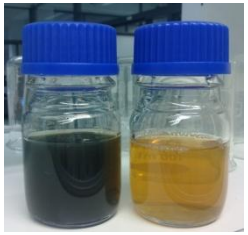
VI. Need for further research

- Technical bottlenecks
  - WWT-techniques translated to digestate → bottlenecks
- Marketing
  - Added value of the end-product vs investment to be made
  - End-users: farmers or industrial users?
- Legislative
  - Redefine “artificial fertiliser”
- Sustainability
  - Comparative analysis of environmental impact (LCA)
  - Consumption of heat, electricity & chemicals, risk for emissions
  - Reduction of the artificial fertiliser use

VII. Related projects

- ARBOR
  - Interreg IV.B
  - Accelerate development of renewable energy in NW-Europe
    - Inventory of nutrient recovery techniques + LCA + EA
    - Characterisation of end-products
    - Field trials
    - Market study

- MIP Nutricycle
  - Flemish project
  - Produce artificial fertiliser replacers
    - Pilots on ammonia stripping & preconditioned separation
    - Lab tests with struvite



VIII. Conclusion

- High nutrient pressure + P depletion
  - Digestate treatment is inevitable
  - As a valuable source of nutrients
- Techniques
  - Full-scale
    - Acid air washers, membrane filtration, ammonia stripping
  - Breakthrough full-scale
    - Struvite precipitation
  - Potentially long-term
    - Electrodialysis, forward osmosis, TMCS, biomass production
  - Questionmark
    - P-extraction from ashes/biochars
- Further developments will only take place if recovery is profitable
  - Price for recuperated nutrients = price for nutrients in artificial fertilisers

THANKS FOR THE ATTENTION

QUESTIONS?

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