Università
Ca'Foscari
Venezia

Dipartimento
di Scienze Ambientali
Informatica e Statistica

# DIGESTATE QUALITY, STANDARD AND NUTRIENT RECOVERY POTENTIAL

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LECTURE 16

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# WHAT IS DIGESTATE??

*"digestate is the semisolid or liquid product of anaerobic digestion of biodegradable materials. It can be presented as whole digestate or separated in a liquor phase and a fibrous semisolid phase." (JRC, 2012)*

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QUALITY OF DIGESTATE DEPENDS ON:

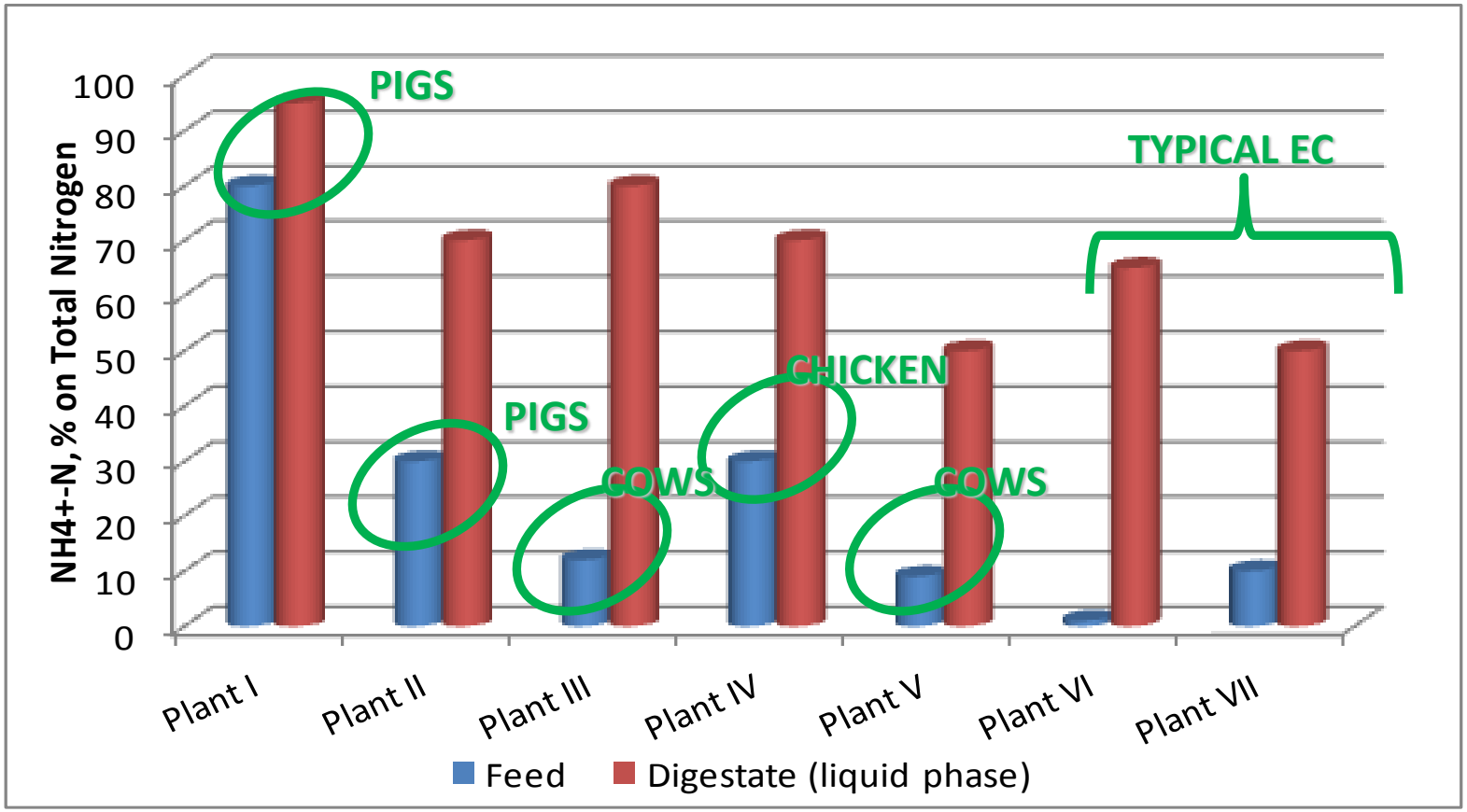
- Feedstock composition
- Microbiological performance
- Design of digester
- Operational configuration
- Post treatment

# DIGESTATE COMPOSITION

| Parameters<br>Substrates | Total solids (TS)<br>g/kg | Total volatile solids (TVS)<br>g/kg | TVS/TS<br>% | COD<br>g/kg dm | N<br>mg/kg dm | P<br>mg/kg dm |
|---|---|---|---|---|---|---|
| Dairy manure (solid) | 260-350 | 250-315 | 78-84 | 880-930 | 34-49 | 6.0-7.8 |
| Dairy manure (liquid) | 89-97 | 69-76 | 76-89 | 910-1020 | 31-41 | 7.6-8.1 |
| Piggery | 60-90 | 47-76 | 66-83 | 860-965 | 18-42 | 4.2-8.5 |
| Poultry (litter) | 467-688 | 397-530 | 72-87 | 751-1000 | 27-47 | 11.8-20.1 |
| Duck (liquid) | 124-190 | 105-155 | 81-88 | 802-871 | 27-39 | 10.7-11.6 |
| Rabbit manure | 192-255 | 154-213 | 80-84 | 803-970 | 19-21 | 8.0-10.7 |
| Maize silage | 272-453 | 262-440 | 89-96 | 545-1170 | 11-17 | 2.2-3.1 |
| Triticale silage | 190-315 | 167-282 | 87-95 | 990-1160 | 13-19 | 1.1-4.8 |
| Fruit marc | 220-255 | 210-230 | 96-98 | 1120-1250 | 25-35 | 1.2-3-2 |
| Potatoes | 157-192 | 167-180 | 92-94 | 980-1050 | 20-26 | 2.2-3-9 |
| Onions | 103-130 | 96-104 | 91-94 | 880-996 | 20-34 | 3.0-3.3 |
| Vegetables (e.g., lettuce) | 40-80 | 31-70 | 80-91 | 765-1050 | 21-36 | 6.4-7.7 |

# DIGESTATE COMPOSITION

ammonification




Typical nitrogen distribution in influent and effluent of Italian anaerobic digesters treating livestock effluents, energy crops and agro-waste

# *DIGESTATE COMPOSITION*

Feedstock composition influence on digestate characteristics

| substrate | impact |
|---|---|
| Energy crops | - High solid content<br>- High %TVS,TS |
| Organic wastes | - Low solid content<br>- Low %TVS,TS |
| High amount of manure | - Very low solid content<br>- High nitrogen concentration<br>- High ammonia % on TN |
| High amount of slaughterhouse waste | - High nitrogen concentration<br>- High ammonia % on TN |

*(Fuchs W et al,2010)*

# DIGESTATE COMPOSITION

***General composition***

-Water (90-95%)
-Residual organic content
-Woody part and fibers which are not converted by microorganism
-Sand and other impurities
-Nutrients (Nitrogen, Phosphorous, Potassium)
-Heavy metals (mercury, cadmium, copper …especially in OFMSW and sewage sludge)

A potential motivation to implement digestate treatment is the production of marketable organic fertilisers.

But at the moment the products deriving from digestate achieve a low market value and they contribute only slightly to compensate the costs incurred with the treatment efforts.

However, with rising costs for nitrogen fertiliser production and the predicted depletion of the phosphorus reserves, this aspect will be of higher economic relevance in the future

# WASTE OR FERTILIZER?????

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## Regulatory framework of waste management in Europe

1975/442/EC: reduction of waste production and restriction of waste landfilling

1991/676/EC: Nitrate Directive

1999/31/EC: limits in biodegradable municipal wastes quantities to be landfilled

2002/1774/EC: Regulation animal by-product directive

2006/12/EC: recycling of organic substances (biological transformation processes)

2006/208/EC: amending annex VI and VIII of 2002/1774/EC, as regards processing standard for biogas and composting plant and requirements for manure

2006/209/EC: Regulation, partial revision of 2002/1774/EC as regards the extension of the validity of transitional measure for composting and biogas plants

2008/98/EC: Revision of Waste Framework Directive (waste hierarchy, end-of-waste)

August 2012: JRC's Third working document (IPTS, Institute for Prospective Technological Studies) end-of waste criteria on biodegradable waste subject to biological treatment

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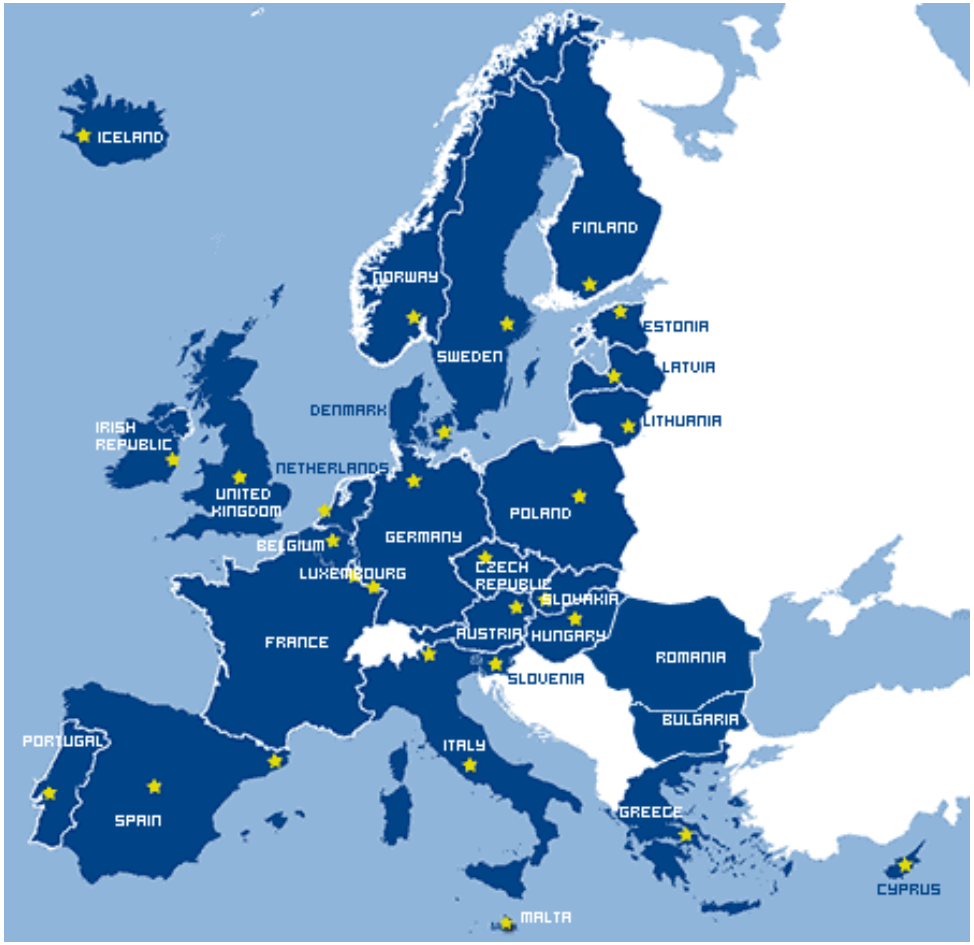
## Regulatory framework of waste management in Europe




# WASTE FRAMEWORK DIRECTIVE

**Bio-waste (Article 22)**

The Commission shall carry out an assessment on the management of bio-waste with a view to submitting a proposal if appropriate to examine the opportunity of setting minimum requirements for bio-waste management and quality criteria for compost and digestate from bio-waste, in order to guarantee a

**HIGH LEVEL OF PROTECTION FOR HUMAN HEALTH AND THE ENVIRONMENT.**

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WASTE FRAMEWORK DIRECTIVE

**EoW (Article 6)**

*'certain specified waste shall cease to be waste when it has undergone a recovery, including recycling, operation and complies with specific criteria to be developed in accordance with the following conditions:*

*a)The substance or object is commonly used for a specific purpose;*

*b) A market or demand exists for such a substance or object;*

*c) The substance or object fulfills the technical requirements for the specific purpose referred to in (a) and meets the existing legislation and standards applicable to products;*

*d) The use of the substance or object will not lead to overall adverse environmental or human health impacts.'*

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# WASTE FRAMEWORK DIRECTIVE

***EoW principle*** →

Waste ceased to be waste when a useful and safe product is placed on the market

***The framework condition*** →

- Commonly used
- A market or demand exist
- Meets technical requirements, standards and legislation
- No overall adverse environmental or human health impacts

***Specific criteria for each stream*** →

Quality product:
- Imput material
- Quality control procedure
- Provision of information
- Processes and technics

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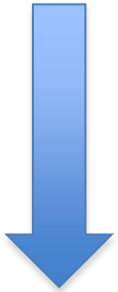
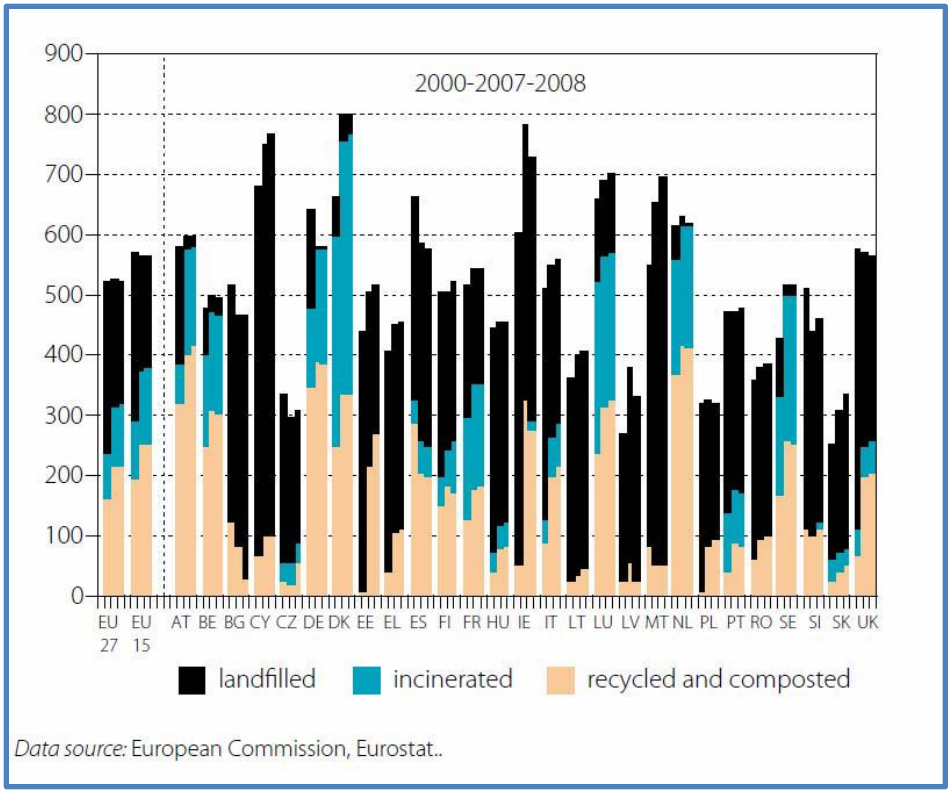
## WASTE FRAMEWORK DIRECTIVE

To fulfill recycling and reuse objectives for 2020
It is necessary to promote biological treatments



Composting and Anaerobic Digestion



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**Conditions for end-of-waste criteria** as defined in Article 6 of the WFD mean in the case of compost and digestate and how end-of-waste criteria need to be formulated so that compost or digestate only qualify when all four conditions are met.

## The substance has undergone a recovery operation

- Compost and digestate visibly are materials that are the result of a recovery operation.
- The recovery in this case constitutes a material recovery, as the organic matter of the input biodegradable waste is recovered and transformed into a material with more desirable properties with regard to nutrient value, soil amendment potential, sanitation, etc.

*(IPTS 2011)*

# EU DIRECTIVE ON DIGESTATE USE

The substance or object is commonly used for specific purposes

- There are a number of specific purposes for which compost and digestate are commonly used.
- The main use for compost and digestate is as a soil improver or an organic fertiliser in agriculture.
- Depending on the purpose and the specific situation, the use of compost and digestate is regulated at least in those Member States where such use is common.
- For use on soil, and particularly in agriculture, there are usually restrictions on the amounts of compost and digestate that may be used, often depending on the heavy metal and nutrient contents of the material.

# EU DIRECTIVE ON DIGESTATE USE

A market or demand exists for such a substance or object

- Theoretically, there is a strong need for compost in the EU, especially as a soil improver to work against the loss of organic matter from soil (erosion).
- The demand for digestate mainly originates from its merits as an organic fertiliser.
- In practice today, the market for compost and digestate is well established only in the part of the EU where compost/digestate production and use is concentrated, and is not coincident with the regions of most erosion or nutrient depletion.
- To prevent the ultimate disposal of compost and digestate, the end-of-waste criteria must be demanding in terms of usefulness, ensuring a high value when used for a specific purpose.
- The stricter the quality requirements in the end-of-waste criteria, the higher the price will be for compost and digestate that meet them.

# EU DIRECTIVE ON DIGESTATE USE

The substance or object fulfills the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products

The existing legislation and standards for using compost or digestate for the different purposes vary between countries.

It is reasonable that the specific conditions and rules for the application of compost and digestate to soils (such as how much compost and of what quality may be used on certain types of soil) are regulated at the level of Member States.

Diversity in soil properties, climates, land use practices, etc., throughout the EU is very high and there is a need for regulations to be adapted to the specific conditions

there is a need for harmonized technical standardization of compost and digestate quality parameters, sampling and testing across the EU, to avoid an artificial fragmentation of compost or digestate markets that is not justified by the real use requirements.

# EU DIRECTIVE ON DIGESTATE USE

The use of the substance or object will not lead to overall adverse environmental or human health impacts

Compost or digestate use should not exert any stress on soil that may compromise the multifunctional soil functions. Therefore, the transfer to soil of hazardous substances through compost/digestate application needs to be limited.

Compost/digestate should not pose any health risks because of macroscopic impurities.

Private quality assurance schemes play an important role in risk management in a number of countries, and sometimes are made quasi-compulsory (statutory) by reference in the relevant legal (waste or other law) instruments.

**Direct quality criteria on compost/digestate could likely include the following parameters:**

(1) Quantitative minimum limits of elements providing a soil improvement/fertilising function, such as organic matter content, or nutrient (N, P, K, Mg) content.

(2) Quantitative maximum limits on elements potentially toxic to human health or ecotoxic, such as heavy metals, or persistent organic pollutants.

(3) Quantitative maximum limits on macroscopic foreign materials (e.g. glass, plastics, metals)

(4) Limited content of pathogens (if appropriate through quantitative maximum limits)

(5) Limited presence of viable weeds (if appropriate through quantitative maximum limits)

(6) Minimum stability (if appropriate through quantitative maximum limits).

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# Annex 2

Overview of proposed allowed and non-allowed input materials for EU-wide end-of-waste criteria:

**General scope: compost and digestate materials obtained through a waste treatment process using materials from the separate collection of biowaste as well as biodegradable residues from agriculture, aquaculture, forestry, fishery and horticulture.**

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE
Institute for Prospective Technological Studies (Seville)
**Sustainable Production and Consumption Unit**

Seville, 11 February 2013

**Third Workshop on End-of-Waste (EoW) criteria for Biodegradable waste subject to biological treatment (compost and digestate)**

**Seville, Tuesday 26 February 2013**

**BACKGROUND PAPER (BP)**

***UK PERMIT TO SPREAD DIGESTATE:***

- NON WASTE FEEDSTOCKS: if you produce digestate from manures, slurries or energy crops (non-waste), no permits are needed to use digestate

- WASTE FEEDSTOCKS: need government permit and provide evidence of agricultural benefit

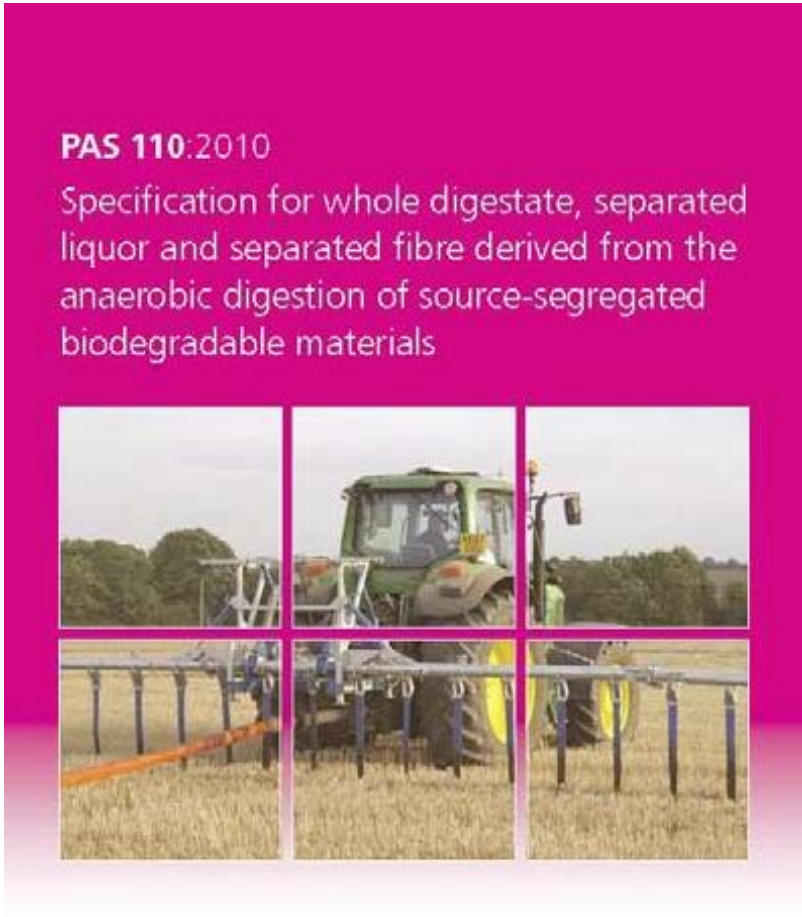
- OR Digestate Standard PAS 110 and AD Quality Protocol

# *STANDARD DEFINITIONS IN EUROPEAN COUNTRIES: UK*

In UK, from early 2010, digestates can be approved under BSI PAS110, which is a specification sponsored by WRAP (Waste and Resources Action Programme) in conjunction with REA (Renewable Energy Association).

-With PAS110 approval, the digestate does not have to be registered as a "waste", which has regulatory controls.

-Digestate is registered through the biofertiliser certification scheme, administered by Renewable Energy Assurance Ltd.



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Structure of PAS110

- Terms and Definitions
- Quality Management System (QMS)
- Hazard Analysis and Critical Control Point (HACCP) System
- Input Materials allowed
- Process Management
- Monitoring, Sampling and Validation
- Dispatch and Labelling

**Allowable Input Materials to Anaerobic Digestion (AD)**

- Biowaste, source-segregated waste of animal or plant origin which can be decomposed by micro-organisms, other larger soil-borne organisms or enzymes

- Source-segregated biodegradable materials eg catering Wastes

- Contaminated wastes not allowed

- Sewage sludge is not allowed

# STANDARD DEFINITIONS IN EUROPEAN COUNTRIES: UK

Test parameters, upper limit values and declaration parameters for validation for PAS 110 are listed below.

http://www.wrap.org.uk/farming_growing_and_landscaping/producing_quality_compost_and_digestate/bsi_pas_110_.html

| Parameter | Method of test | Upper limit and unit |
|---|---|---|
| **Pathogens (human and animal indicator species) in WD / SL / SF** | | |
| ABP digestate: human and animal pathogen indicator species | As per appropriate ABP regulation or any other method approved by the competent authority / Animal Health vet / Veterinary Service vet | As specified by the competent authority / Animal Health vet / Veterinary Service vet in the 'approval in principal' or 'full approval' |
| Non-ABP digestate: *E. coli* | SCA MSS Part 3A or BS ISO 16649-2 | 1000 CFU / g fresh matter |
| Non-ABP digestate: *Salmonella* spp | Method as specified by appropriate ABP regulation, according to nation in which digested material is produced, or SCA MSS Part 4A | Absent in 25 g fresh matter |
| **Potentially Toxic Elements in WD / SL / SF.** If necessary, WD and SL may utilize the exemption provisions in clauses 13.2, 14.1.6 and 14.1.7 with the declarations required under the * provision below in this table | | |
| Cadmium (Cd) | BS EN 13650 (soluble in aqua regia) | 1.5 mg / kg dry matter |
| Chromium (Cr) | BS EN 13650 (soluble in aqua regia) | 100 mg / kg dry matter |
| Copper (Cu) | BS EN 13650 (soluble in aqua regia) | 200 mg / kg dry matter |
| Lead (Pb) | BS EN 13650 (soluble in aqua regia) | 200 mg / kg dry matter |
| Mercury (Hg) | BS ISO 16772 | 1.0 mg / kg dry matter |
| Nickel (Ni) | BS EN 13650 (soluble in aqua regia) | 50 mg / kg dry matter |
| Zinc (Zn) | BS EN 13650 (soluble in aqua regia) | 400 mg / kg dry matter |
| **Stability of WD / SL / SF** | | |
| Volatile Fatty Acids | Gas chromatography (example provided in OFW004-005) | Screening value: 0.43 g COD / g VS |
| Residual Biogas Potential | OFW004-005 (WRAP) | 0.25 l / g VS |
| **Physical contaminants in WD / SL / SF** | | |
| Total glass, metal, plastic and any 'other' non-stone, man-made fragments > 2 mm | REA-DM-PC&S | 0.5 % m/m dry matter, of which none are 'sharps' (see 3.72) |
| Stones > 5 mm | REA-DM-PC&S | 8 % m/m dry matter |

*NOTE Separated liquor is exempt from physical contaminants tests only if the separation technology used by the producer results in all particles < 2 mm in the separated liquor fraction.*


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Minimum anaerobic digestion requirements specified in animal by-products (Animal By-product Regulation)

| System | National ABP Regulations, option for catering waste only | National ABP Regulations, option for catering waste only | EU ABP regulation 1774/2002 [5a] (See Note 4) |
|---|---|---|---|
| **Treatment technology** | Closed reactor | Closed reactor | Closed reactor |
| **Maximum particle size** | 50 mm | 60 mm | 12 mm |
| **Minimum temperature** | 57 °C | 70 °C | 70 °C |
| **Minimum time spent at the minimum temperature** | 5 hours | 1 hour | 1 hour |
| **Additional requirements** | Followed by storage for an average of 18 days if digestate is made from catering wastes that include meat | | No post treatment minimum storage period specified |

Pasteurisation is required if material moved between farms, isn't required if the feedstock material is produced and used on the same farm

# STANDARD DEFINITIONS IN EUROPEAN COUNTRIES: SWEDEN

In Sweden, there is a voluntary certification system in place for anaerobic digestate, the SPCR 120.

This SPCR is a quality assurance system for both the process and the quality of the end product, digestate.

The requirements for the final digestate product according to this QAS are listed in the next slide .

However, as in the case of compost guided by SPCR 152 QAS, digestate complying with the SPCR 120 quality label continues to have a waste status.

Substrates for certificated digestate should be clean, source separated and easily biodegradable. Sewage sludge is not included in the input materials list, but manure is allowed.

# STANDARD DEFINITIONS IN EUROPEAN COUNTRIES: SWEDEN

Sweden SPCR 120 QAS for digestate: requirements for final product

http://www.avfallsverige.se/fileadmin/uploads/Rapporter/Biologisk/B2009b.pdf

**Metals**

Guideline values for metal content in digestate are set out in Table 1.

*Table 1. Guideline values for metal content in compost.*

| METAL | MAXIMUM CONTENT, mg/kg TS[1)] |
|---|---|
| Lead | 100 |
| Cadmium | 1 |
| Copper | 600[2)] |
| Chromium | 100 |
| Mercury | 1 |
| Nickel | 50 |
| Zinc | 800[2)] |

1) All values, aside from those of copper and zinc, are conforming to the guideline values for soil improvers according to the "EU flower".

2) The values applied to copper and zinc are the same as for waste water sludge allowed for dispersion on fields, see SNFS 1998:4.

**Disease control**

The product must meet the requirements for disease control specified in Appendix 3.

**Visible impurities**

'Visible impurities' means foreign substances such as plastic, glass, metals and composites. The total content of visible impurities >2 mm must not exceed 0.5 % of the dry substance weight.

If the input material is of a kind that has a low probability for visible impurities, the certifying authority can give approval of dispensation from this requirement.

**Requirements for solid digestate**

- **Viable weed seeds and plant parts** – requirements for approval are that the product contains less than 2 viable weed seeds or plant parts per liter.
- **Organic substance** – The product must contain at least 20 % of organic substance, measured as loss on ignition in percent of the dry substance weight.

# STANDARD DEFINITIONS IN EUROPEAN COUNTRIES: GERMANY

In Germany, the Bundesgütesgemeinschaft Kompost (BGK) is the carrier of the quality label for compost, digestate products and composted sewage sludge.

BGK is recognised by RAL, the German Institute for Quality Assurance and Certification, as being the organisation to handle monitoring and controlling of all quality labels in Germany.

According to the input materials used, there are two product groups for digestate and two corresponding labels: RAL GZ 245 for digestion products derived from biowaste and RAL GZ 246 for digestion products from renewable energy crops.

The allowabale input materials are marked on a positive list and should be source separated. Sewage sludge is not included in the input materials list, but manure is allowed.

The RAL GZ 245 is a voluntary scheme, yet the efforts of participants are rewarded by the authorities by exempting member plants from some control requirements which are subject to the waste legislation. By means of that procedure quality assured digestate have a "quasi" product status in Germany.

# STANDARD DEFINITIONS IN EUROPEAN COUNTRIES: GERMANY

Quality criteria for digestate products from biowaste according to German RAL GZ 245 quality assurance scheme

http://www.kompost.de/uploads/media/Quality_Requirements_of_digestion_residuals_in_Germany_text_02.pdf)

| Quality criteria | Quality requirements |
|---|---|
| Hygienic aspects | - Proof for successful treatment for sanitization (heating of the input material to 70 °C for at least 1 hour or input-output control)<br>- Proof of compliance with the hygienic requirements by temperature profiles (monitoring the process temperature)<br>- Maximum of 2 germinable weeds and sprouting plant parts per liter<br>- Salmonella not traceable |
| Impurities | - Maximum 0,5 M.-% dm selection and weighing of impurities (glass, plastics and metals > 2 mm<br>- With an impurity content > 0,1 M.-% dm: maximum area sum of the selected impurities shall not exceed 25 cm²/l fm |
| Degree of fermentation | - Organic acids (total) ≤ 4.000 mg/l |
| Odour | - Free from annoying odours |
| Organic Matter | - Minimum 30 M.-% dm, determined by loss on ignition |
| Heavy metal content (Pb, Cd, Cr, Cu, Ni, Hg, Zn) | - Limit values correspond to the waste and fertiliser legislation<br>- For micro-nutrients Cu and Zn plausible value should not be exceed. |
| Parameter for declaration | - Product type (digestate product liquid or solid)<br>- Name of producer<br>- Bulk density (volume weight)<br>- Dry matter content<br>- pH-value<br>- Salt content<br>- Plant nutrients (total) (N, $P_2O_5$, $K_2O$, MgO, S)<br>- Nitrogen soluble ($NH_4$-N; $NO_3$-N)<br>- Micro-nutrients (according to fertiliser legislation)<br>- Organic matter<br>- Alkaline effective matter (CaO)<br>- Benefit value index<br>- Weight or volume<br>- References for good practical use |

# STANDARD DEFINITIONS IN EUROPEAN COUNTRIES: FRANCE

Digestate can be spread on agricultural land after declaration, registration or authorization depending on the type of input treated in the anaerobic digester and the quantity of digestate produced.

NF U 44 051: Digestate can be considered as organic soil improver only after characterized composting

NF U 42 001 : Digestate is at the moment not taken in consideration in the list of organic fertilizers.

In France, quality and innocuousness of digestate would have to be proven in order to develop a specific standard or to modify existing standards and thus be considered as a product.

# STANDARD DEFINITIONS IN EUROPEAN COUNTRIES: ITALY

***Law 748/84 on fertilizer*** → ***D.Lgs 217/2006***

***2008/98/EC***

***D.LGS 75/2010***

***Regional regulation***

***D.Lgs 152/2006***

***D.Lgs. 205/2010 (EoW criteria)***

***D.M. 7/04/2006 MiPAF***

# STANDARD DEFINITIONS IN EUROPEAN COUNTRIES: ITALY

| | Piemonte | Lombardia | Emilia Romagna | Veneto |
|---|---|---|---|---|
| Locla regulation | DGR 23/2/2009 n 64-10875 | Piano d'Azione Nazionale | DGR 28/7/2008 n 1255 | DGR 7/8/2007 n 2439 |
| Digestate That can be spread | - Zootecnical effluent only<br>- Agrowaste/Energy crops+zootecnical effluent (at least 50%) | - Zootecnical effluent only<br>- Non zootecnical, Agrowaste/energy cops<br>- Mixed(?) | - Zootecnical effluent only<br>- Energy crops only<br>- Zootecnical mixed (effluent+agrowaste+energy crops)<br>- Zootecnical mixed (effluent+animal by-products+energy crops) | - Zootecnical effluent only<br>- Agrowaste/Energy crops+ zootecnical effluent |

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209/2006/CE

art. 112 del D.Lgs. 152/2006

D.M. 07/04/2006 "General criteria and technical standards to govern the regional agronomic use of manure"

D.M. 06/07/2012 "renewable energies"

In general:

-sewage sludge not allowed
-max 30% of energy crop
- incentives for nitrogen removal and recovery
-Kitchen and restaurant waste allowed for incentives but digestate is still a waste and must be composted

Table 7: Comparison of digestate standards in DE, UK, SE and Switzerland (Source: European Biogas Association)

| *Characteristic* | *Germany (RAL-GZ 245)* | *UK (PAS 110:2010)* | *Sweden (SPCR 120)* | *Switzerland* |
|---|---|---|---|---|
| Hygienic aspects | | | | |
| Proof of successful treatment for sanitization | X | X | X | X |
| If demanded by ABP regulation: treatment with 70°C for 1 hour and particle size of 12 mm | X | X | X | X |
| minimum temperature during a hydraulic retention time of 24 h | 55 (50) °C | based on HACCP plan | | 53°C |
| input-output-control | As possible hygienic proof | X | | |
| germinable weeds and sprouting | Max. 2 / liter | | X | X |
| Salmonella | absent in 50 g fresh matter | absent in 25 g fresh matter | | X |
| Additional hygienic parameters for the treatment of animal-by products | | | | |
| 4 of 5 E.Coli samples 1000 CFU / g fresh matter | As possible hygienic proof | X | X | |
| Impurities | | | | |
| Maximum 0,5 % dm selection and weighing of impurities (glass, plastics and metals > 2 mm) | X | X | X | X |
| Laminary impurities | area sum of the selected impurities < 25 cm²/l fm | | X | > 0,1 % |

| | | | | |
|---|---|---|---|---|
| Degree of fermentation | | | | |
| Organic acids (total) ≤ 1.500 mg/l | X | | | |
| Volatile Fatty Acids | | X | | |
| Residual Biogas Potential | | X | | |
| Odour | | | | |
| Free from annoying odours | X | | | |
| Organic Matter | | | | |
| Minimum 20% (w/w) dm | | | X | |
| Minimum 30% (w/w) dm for solid digestate Minimum 40% (w/w) dm for liquid digestate | X | | | |
| potentially toxic elements | | | | |
| Threshold for heavy metals (Pb, Cd, Cr,Ni, Hg) For micro-nutrients Cu and Zn plausible value should not be exceed. | X | X | X | X |
| Parameter for declaration | | | | |
| Product type (digestate product liquid or solid) | X | X | X | X |
| Name and details of customer | | X | | |
| Name and details of producer | X | X | X | X |
| Weight or volume | | X | X | X |
| Date of dispatch | | X | | |
| density | X | | | |
| Dry matter content | X | X | X | X |
| Organic matter | X | X | X | X |
| pH-value | X | X | X | X |
| Salt content | X | | | X |
| Plant nutrients (total) (N, $P_2O_5$, $K_2O$, MgO, S) | X | X (MgO, S optional) | X | X |
| Nitrogen soluble ($NH_4$-N, $NO_3$-N) | X | X (only NH4-N) | X | X |
| Micro-nutrients (according to fertiliser ordinance) | X | | | |
| C/N ratio | X | | | X |
| Water soluble chloride (Cl-) | | X | | |
| Water soluble sodium (Na) | | X | | |
| Heavy metals if the thresholds have been exceeded | X | X | X | X |
| Alkaline effective matter (CaO) | X | | X | |
| References for good practical use | X | X | X | X |

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Now we know that:

**the quality of digestate is directly connected with feedstock quality, process performance and quality standard (laws on fertilizers)**

SO….

HOW CAN WE USE DIGESTATE??

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The simplest and most economic USE is direct spreading on fields

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*(SØRENSEN and MØLLER, 2008)*

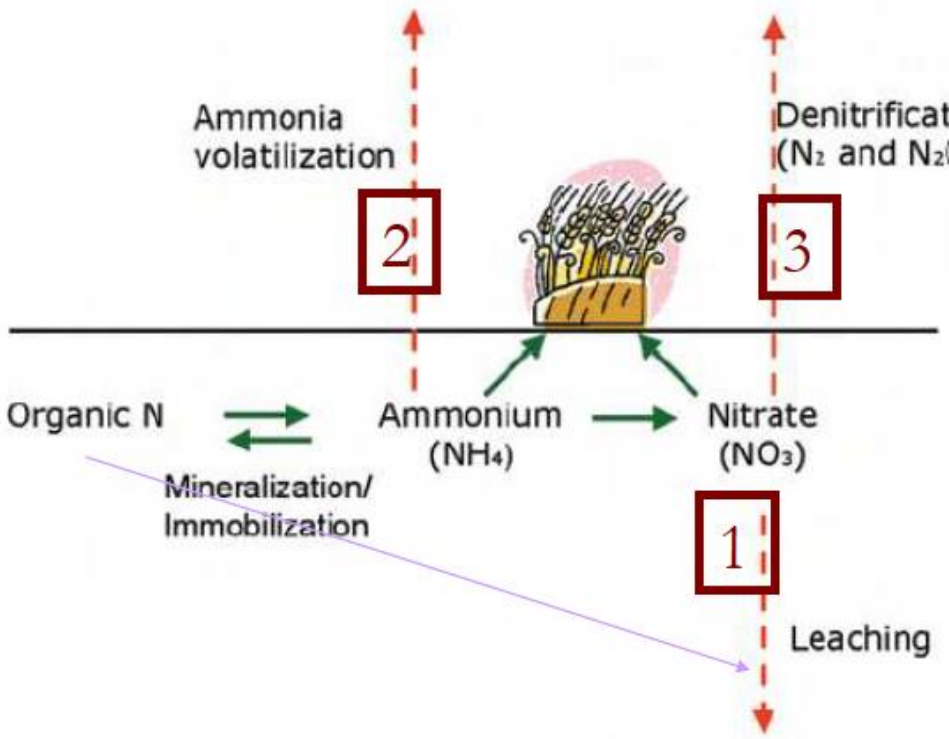


**Figure 1.** *The most important N transformations and losses after application of animal manure to soil.*

The use of digestate allows less ammonia emission (better infiltration in the soil) and less $N_2O$ emission due to a previous rbCOD removal.

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## DIRECT spreading on fields

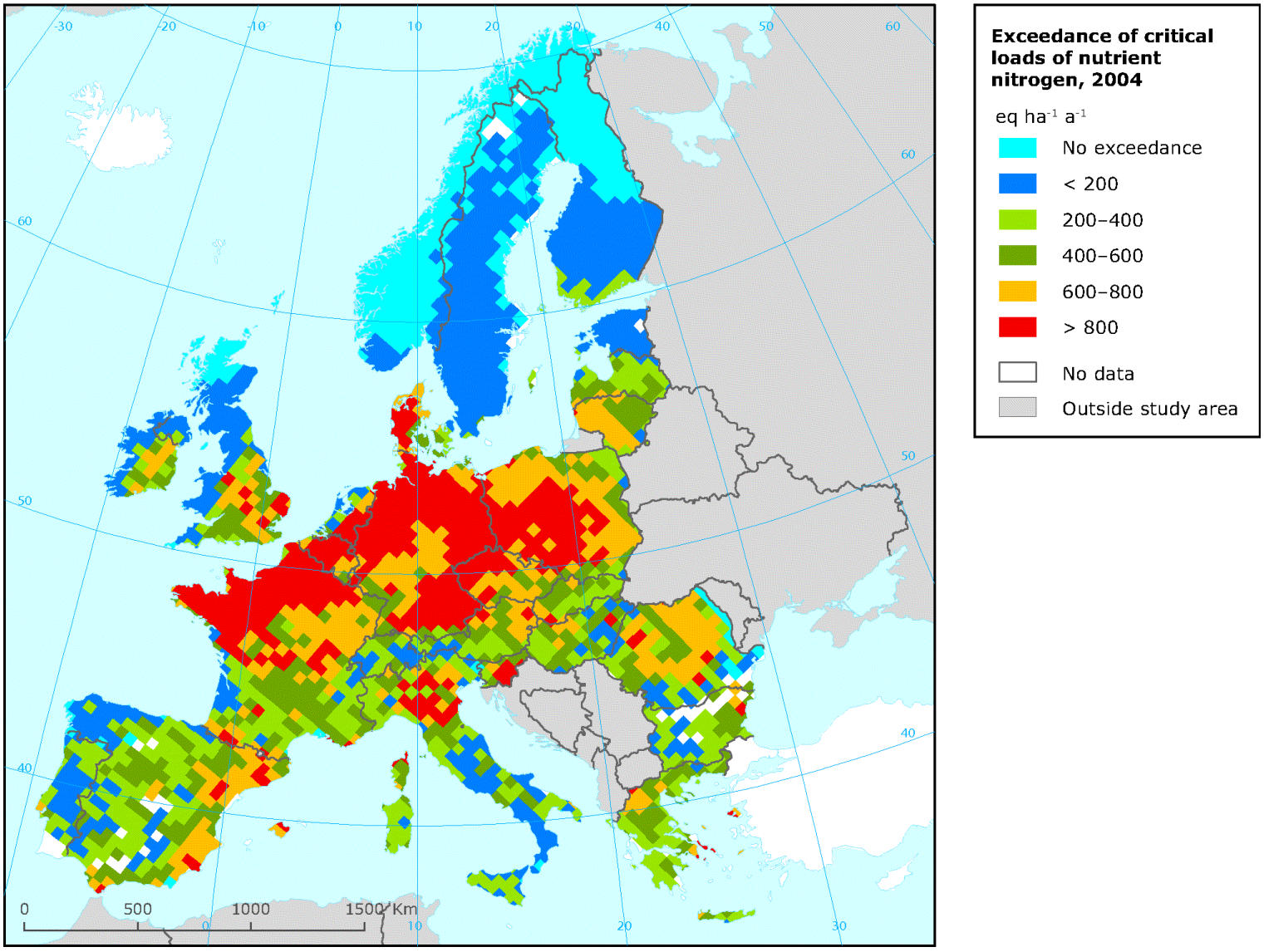
✓ it is the cheapest technique for digestate management

✓ Can be applied only to a certain extent (nitrogen loading for NVZ is limited to 170 kgN/ha per year)

✓ it is a spatially limited solution: it makes sense only if the transportation is < 30 km

✓ it does not prevent from ammonia dispersion in the environment

✓ it not allows for "transfer" of nutrients from an area (e.g., extra-loaded) to another one


Exceedance of critical loads of nutrient nitrogen, 2004
eq ha-1 a-1
No exceedance
< 200
200–400
400–600
600–800
> 800
No data
Outside study area
0
500
1000
1500 Km

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The way to reduce nitrogen "damage" is digestate TREATMENT!

TREATMENT OBJECTIVE:

- Enable disposal
- Reduce the dependence on land application
- Reduce the volume (transport and disposal cost)
- Ensure more sustainable use of digestate products
- Remove and recovery substances
- Produce a customized fertilizer increasing digestate value
- Create new markets for digestate products

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**TREATMENT COULD BE:**

***PARTIAL TREATMENT***

quantity reduction or separation into individual fractions which can be handled or stored more easily.

***COMPLETE TREATMENT***

to separate and concentrate the valuable ingredients while the remaining liquid fraction is purified permitting reuse or direct discharge into a water body

- combination of different technics
- It depend on the requirement for end product
- It depend on the composition of the raw material
- There is not a recognize standard
- The cost of post treatment could be high compared with final use proposal
- Recovery or removal approach

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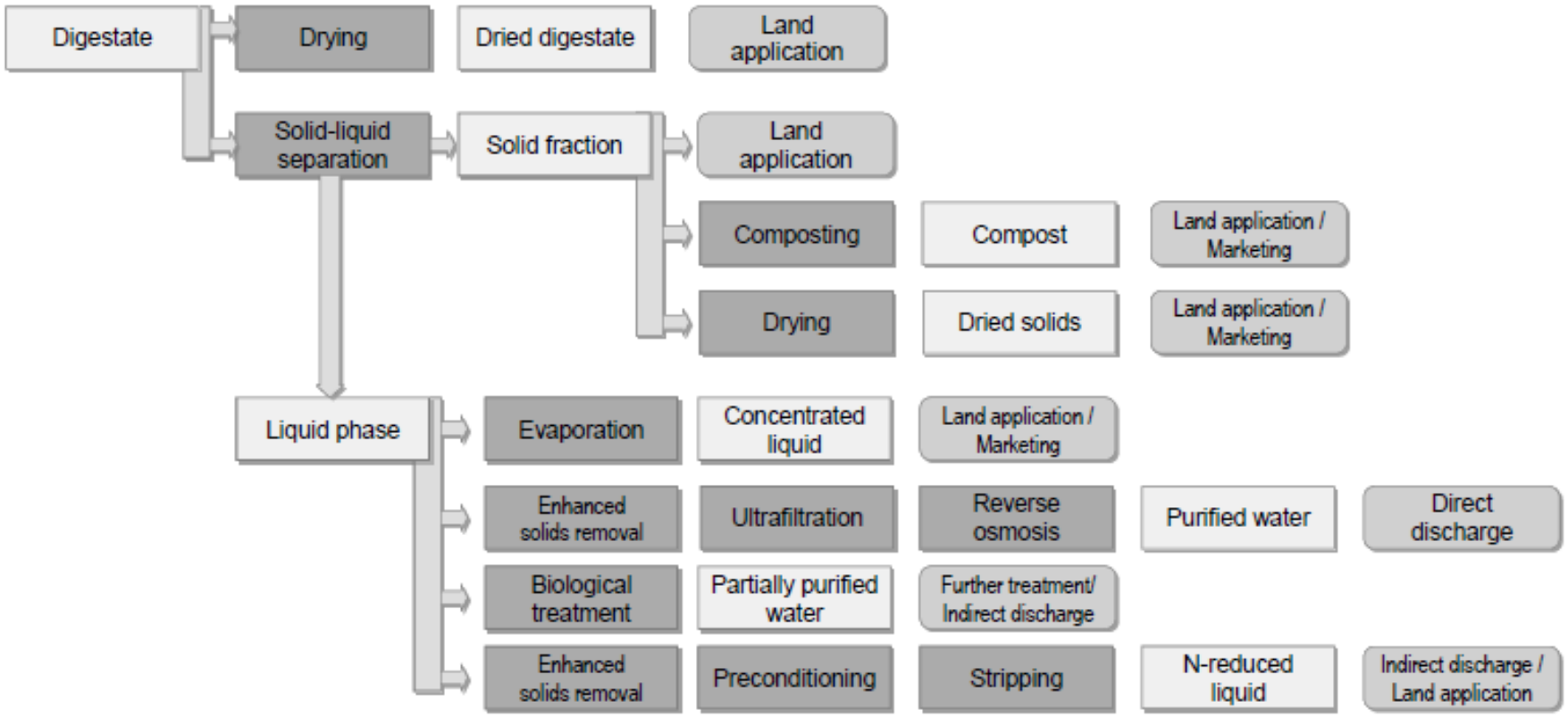
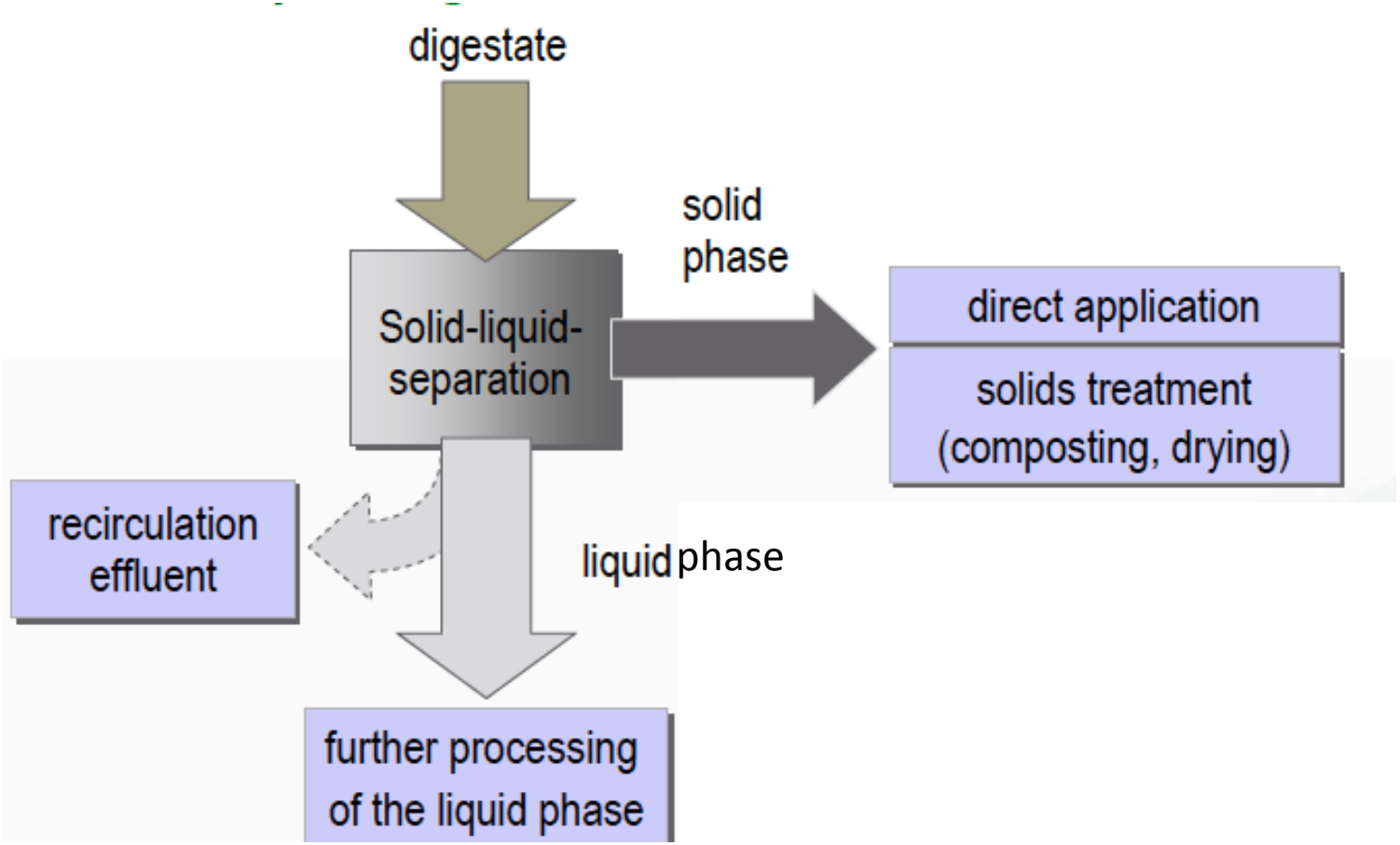



*From Fuchs and Drosg, ADSW&EC, 2011*

# DIGESTATE TREATMENTS

FIRST STEPS




*From Fuchs and Drosg, ADSW&EC, 2011*

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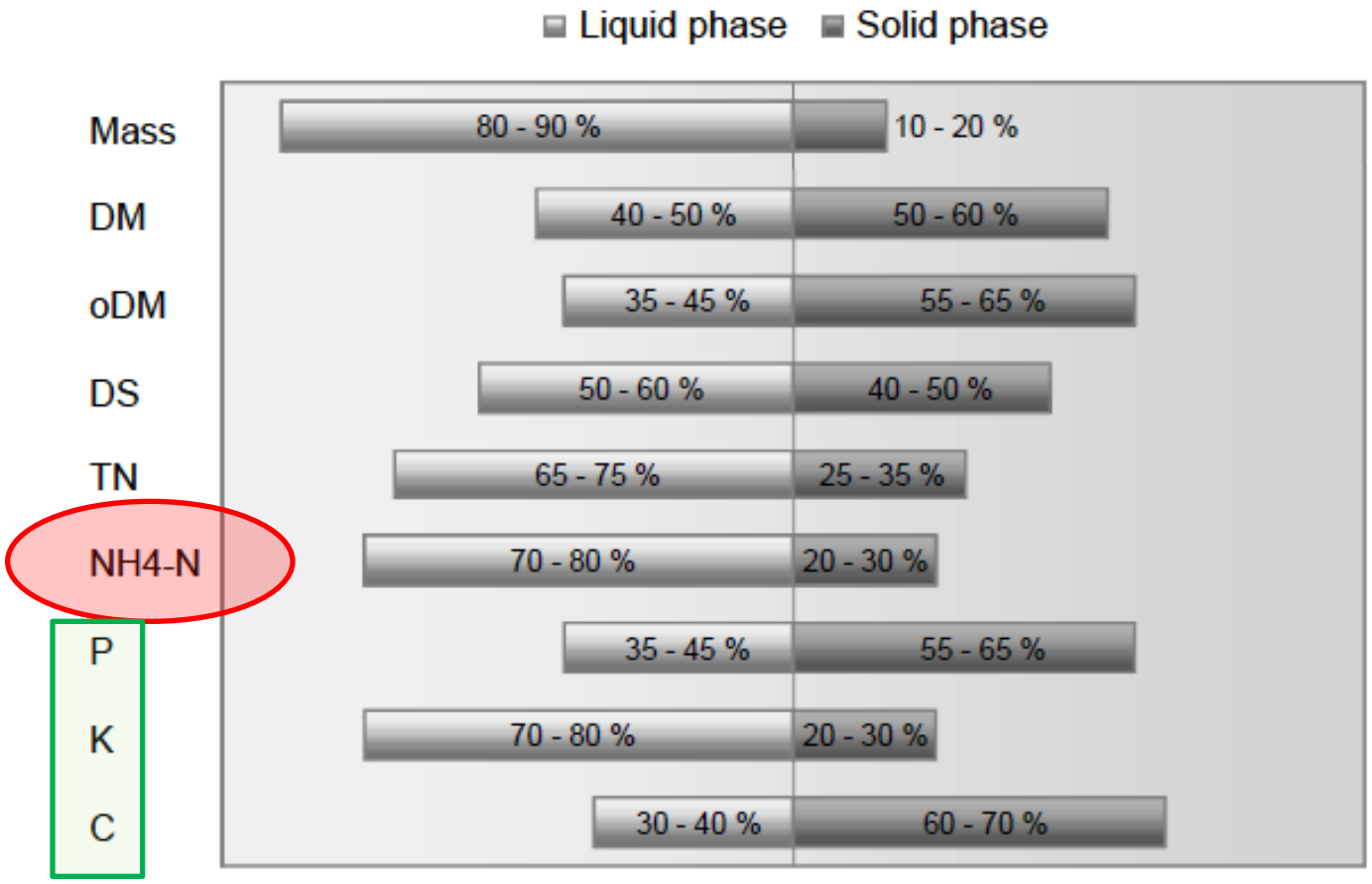
# Typical distribution between the solid and liquid phase

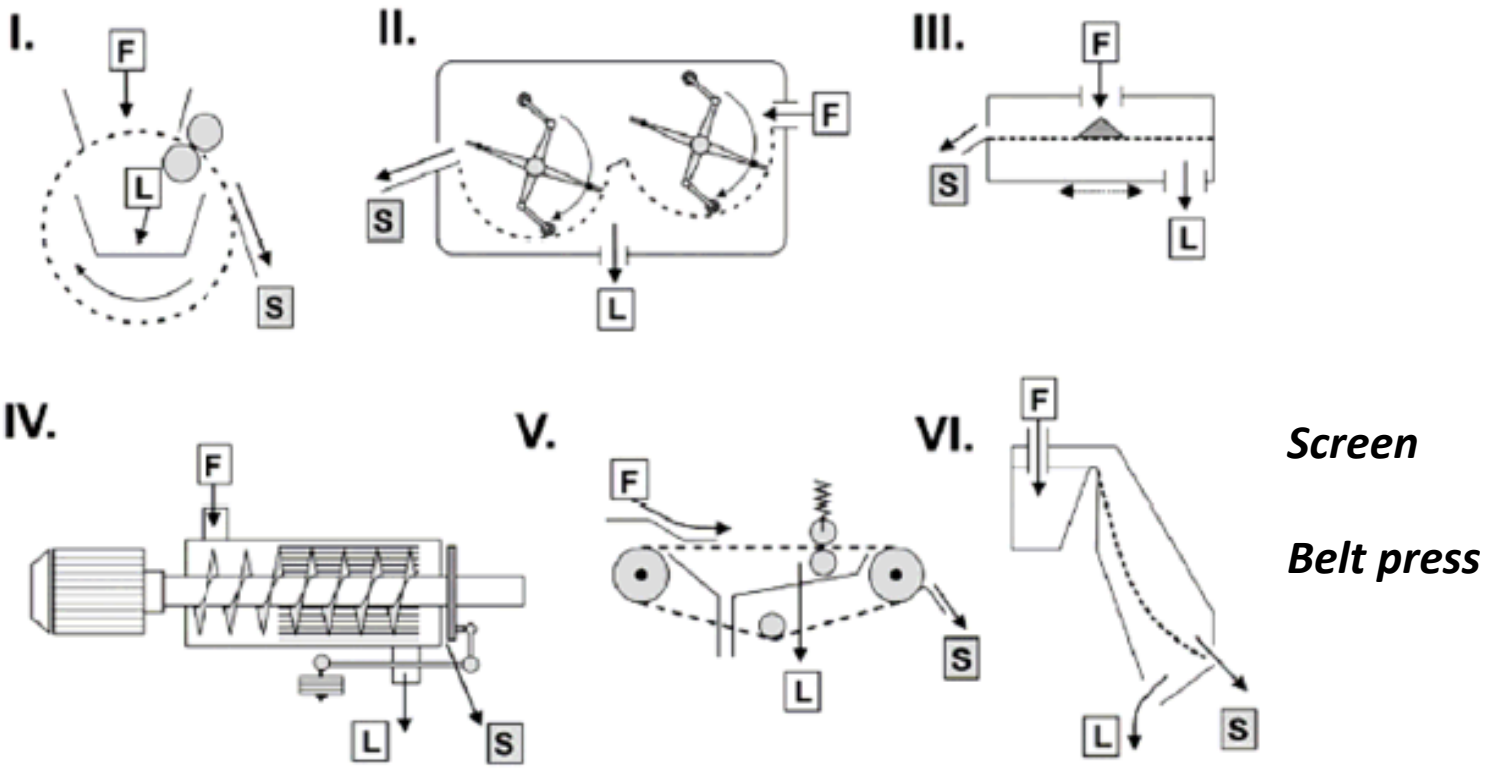



*(Fuchs W et al,2010)*

## SOLID/LIQUID SEPARATION

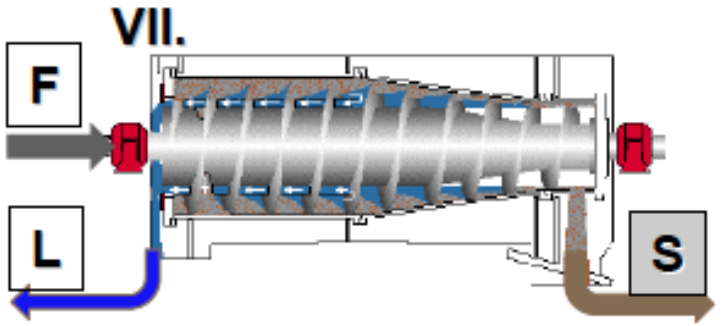
- Screw
- Screw press
- Decanter
- Centrifuge
- Membrane filtration

# SOLID-LIQUID SEPARATION




***Screen***

***Belt press***




***centrifuge***

*(BURTON, 2007)*

# SOLID-LIQUID SEPARATION

✓ Not very different from direct spreading

✓ the liquid fraction is the major part of the material and contains most of the nutrients

✓ transportation makes sense only for distance < 30 km

✓ does not solve the problem of ammonia in the liquid phase

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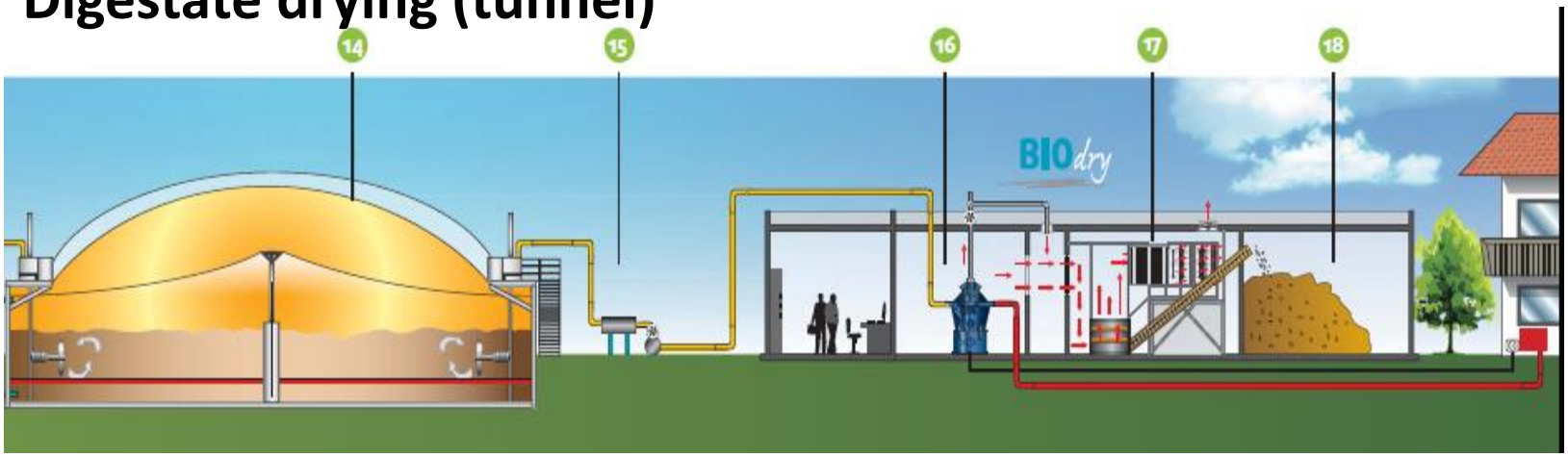
## Digestate drying (tunnel)




Bio-dry® by BTS

# *DRYING SYSTEMS*

✓ allows for the use of thermal energy coming from the CHP unit (air at 80-90 ° C)

✓ allows for the recovery of a small amount of solid material easy to store and transport

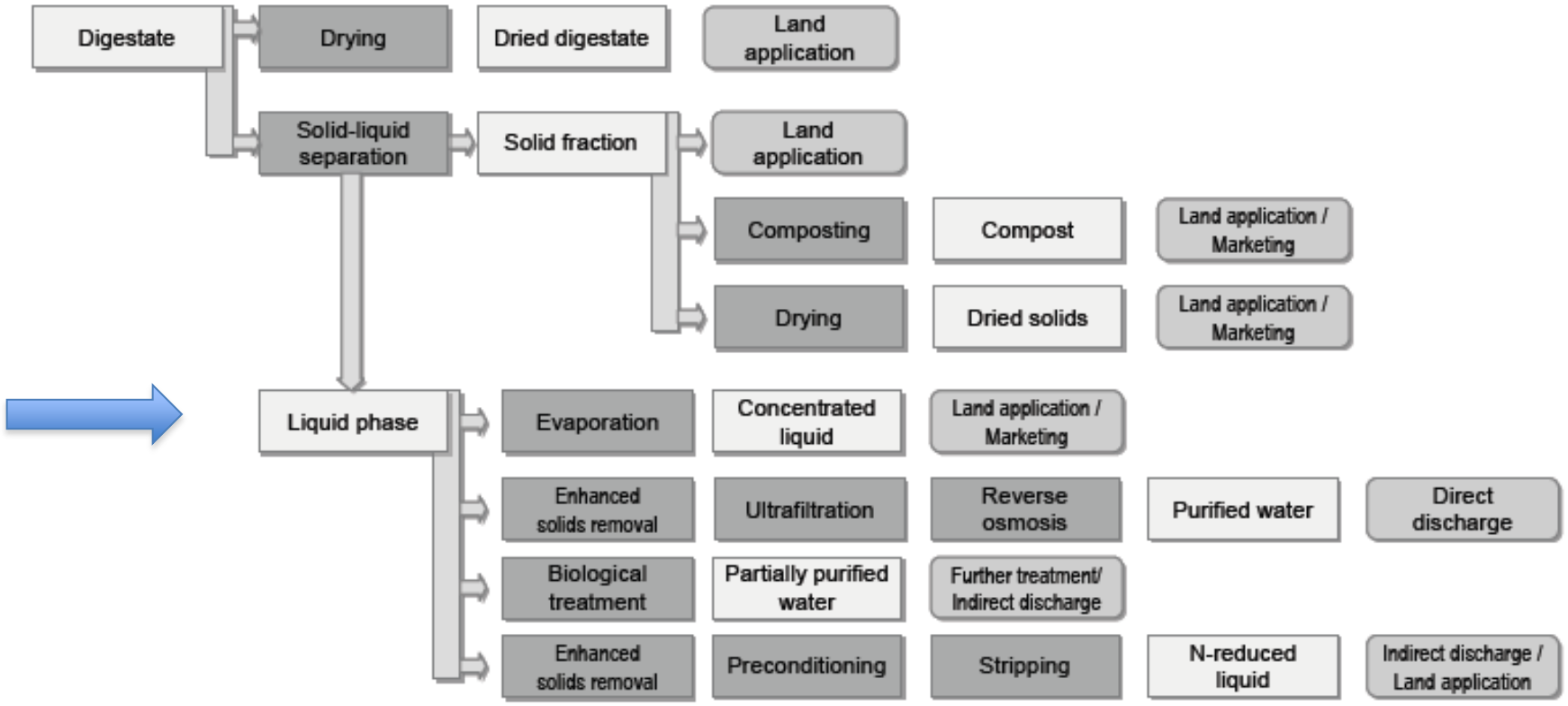
✓ Needs for exhaust gas treatment for ammonia recovery

✓Possible production of a pellet as fertilizer

✓Prior to drying digestate must be separated (about 20-25%TS)

✓Can reach 80-85% of TS

# DIGESTATE TREATMENTS




## FOCUS ON NUTRIENT RECOVERY

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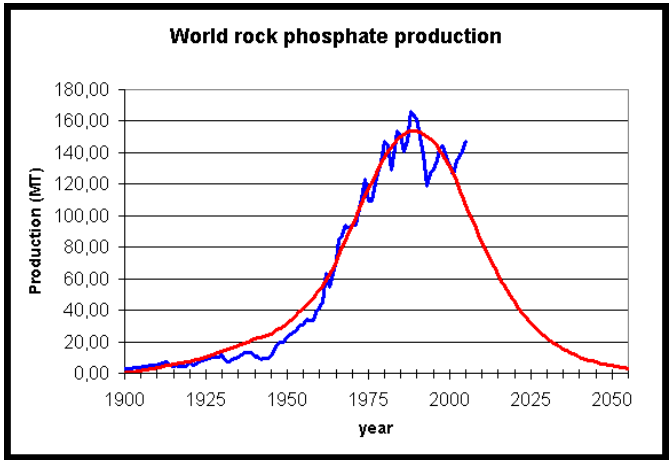
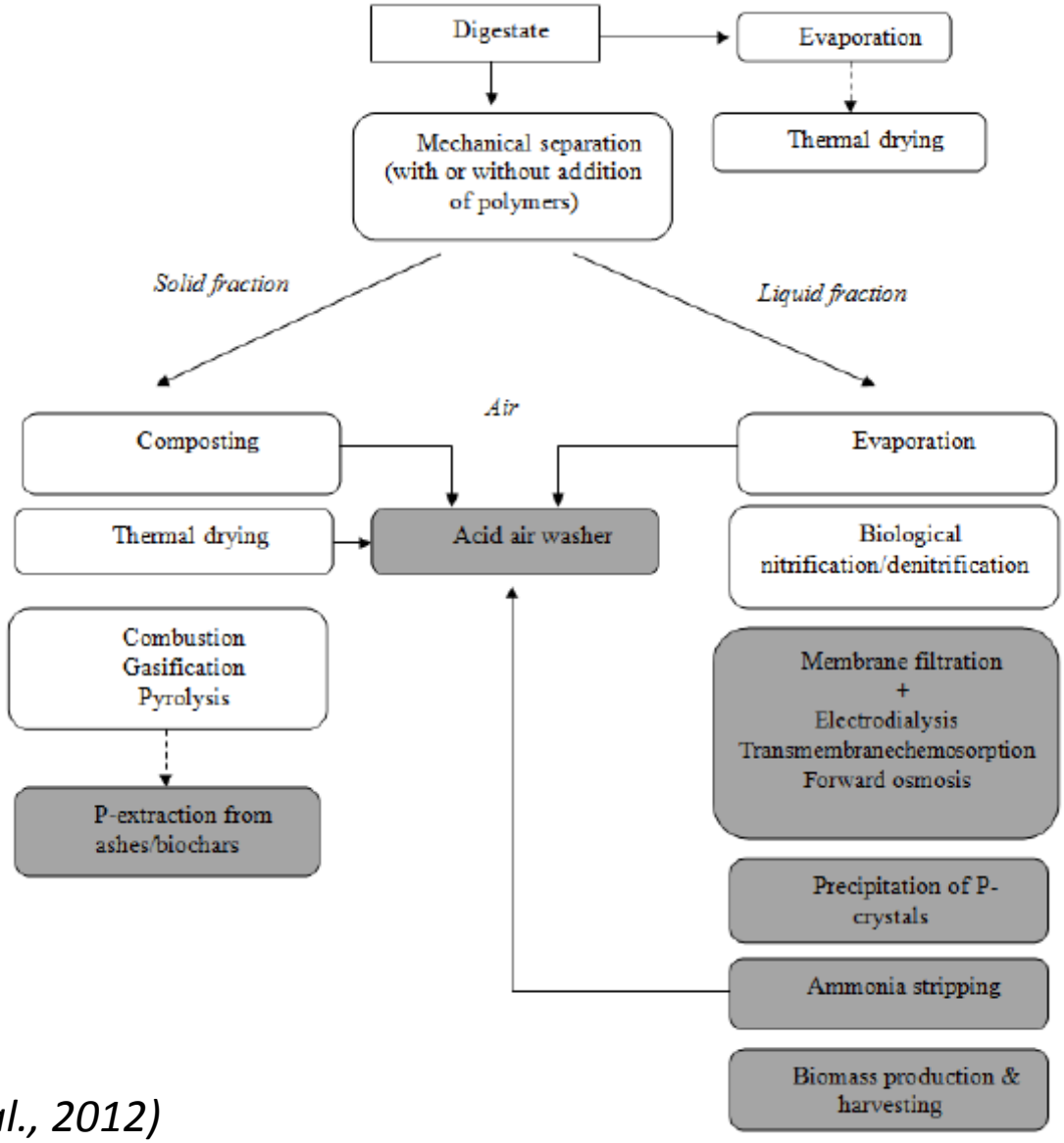
## WHY RECOVER NUTRIENT?




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

how can digestate be valorized as a valuable source of nutrients?
how can digestate be turned into a „green" substitute for artificial fertilizers?

# NUTRIENT RECOVERY




*(Lebuf et al., 2012)*

# *NUTRIENT RECOVERY*

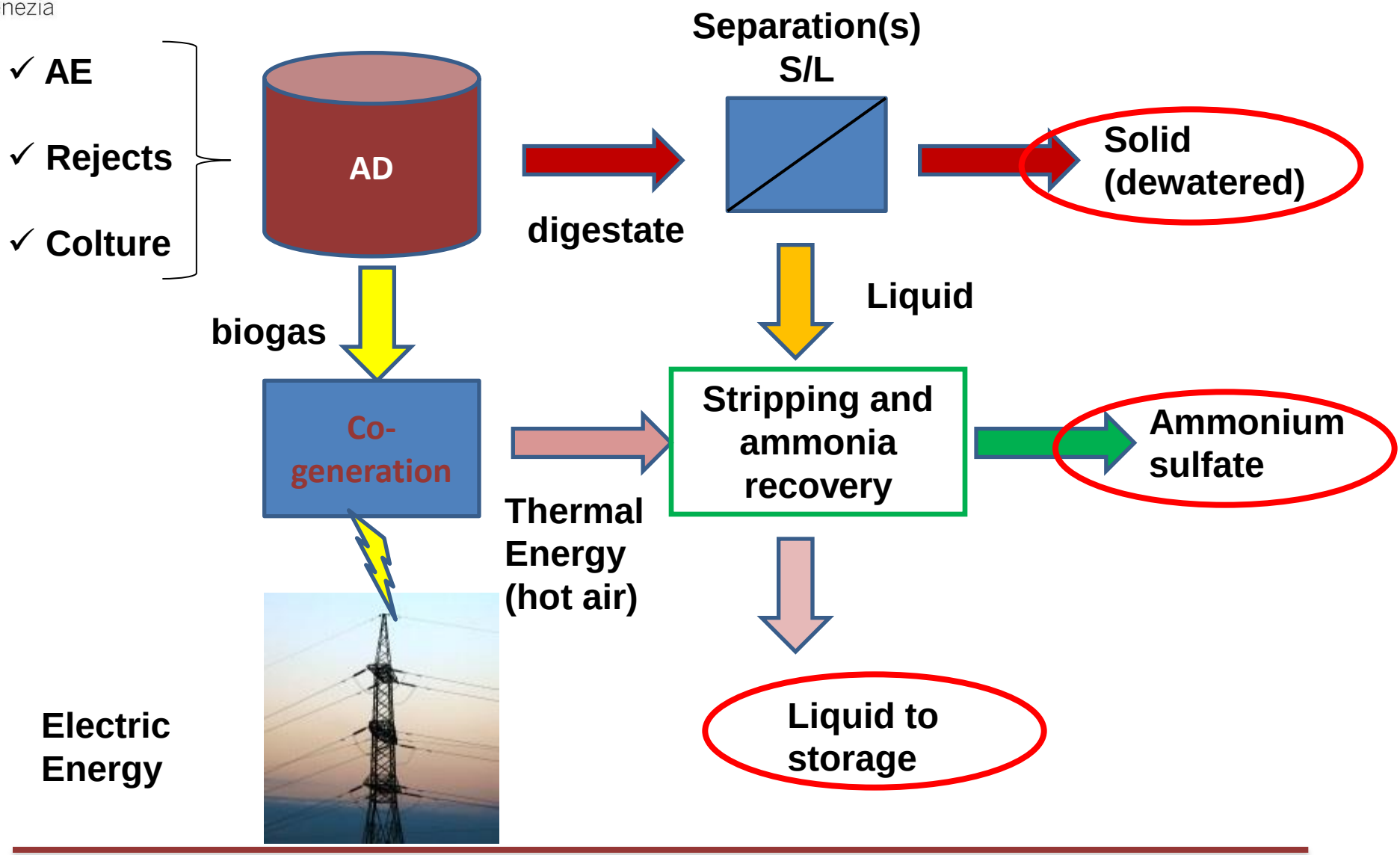
- ✓ Ammonia stripping and recovery as ammonium-sulfate
- ✓ Membrane technology
- ✓ Struvite crystallization for N & P recovery
- ✓ Evaporation

## Ammonia stripping and recovery as ammonium-sulfate

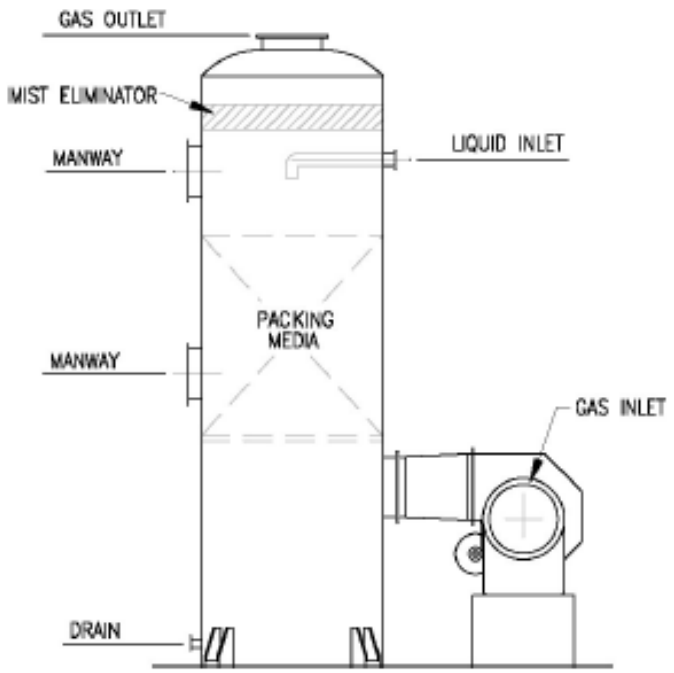
It is a two-step process, where ammonia is stripped out from the liquid phase (digestate) first and then dissolved into sulfuric acid to obtain ammonium sulfate.

Stripping can be obtained in "warm" conditions, w/o chemicals addition or in "cold" conditions, after pH increase

# Ammonia stripping and recovery as ammonium-sulfate

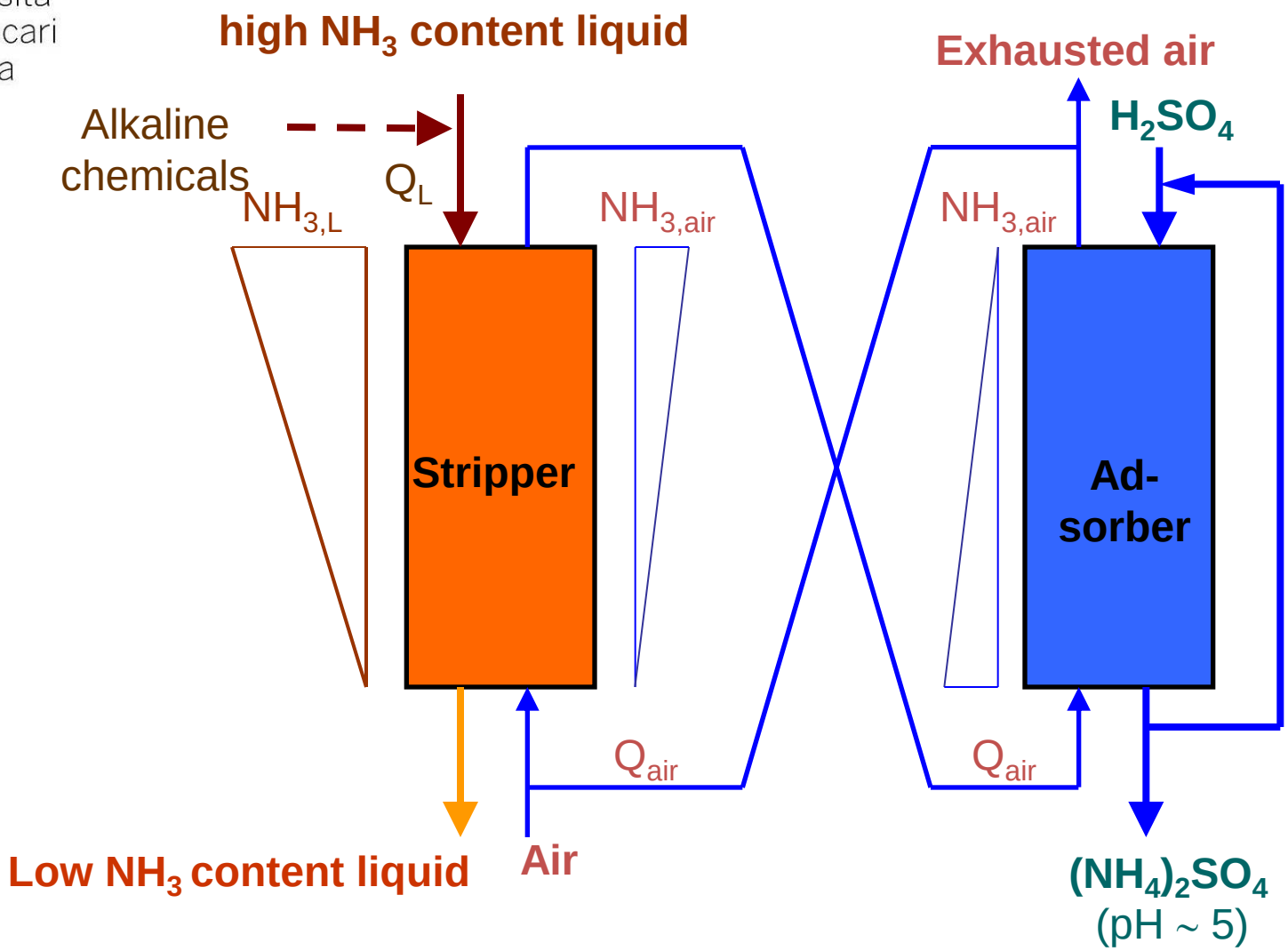


# Ammonia stripping and recovery as ammonium-sulfate




ammonia is stripped out from the digestate using the counter-current exhaust air from the CHP unit (some 80-90° C) and then recovering ammonium sulfate in the second step of the process.

# Ammonia stripping and recovery as ammonium-sulfate



# Ammonia stripping and recovery as ammonium-sulfate

Recovery tower

Gaseous ammonia is then recovered by dissolving in liquid sulfuric acid to give ammonia sulfate in a second reactor:

$$2NH_{3(g)} + H_2SO_{4(aq)} \rightarrow (NH_4)_2SO_{4(aq)}$$

# Ammonia stripping and recovery as ammonium-sulfate

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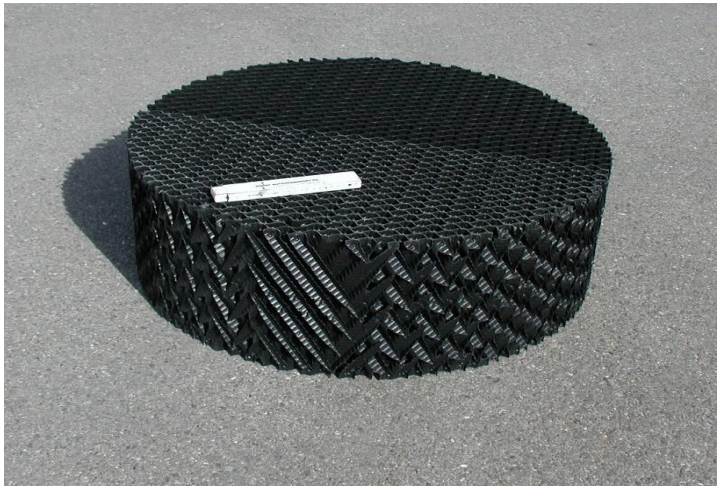
***WARM STRIPPING***

- ✧ High temperature (60-70° C) of Air improve ammonia removal
- ✧ High pH of digestate avoid the use of chemicals (expensive and cause salts precipitation)
- ✧ High exchange surface both in Liquid/Gas (stripping) and Gas/Liquid (adsorber)



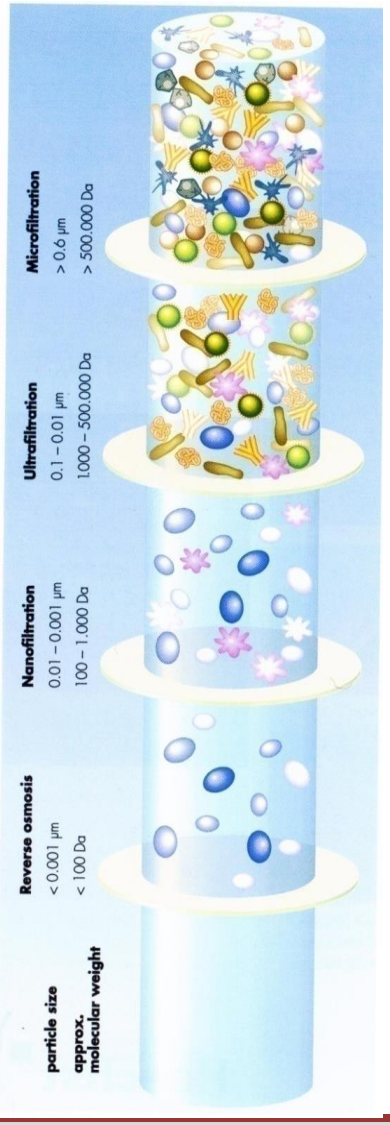
*Courtesy H.R Siegrist EAWAG Zurich, Switzerland*

## *WARM STRIPPING*

- It is a proven technology in other fields
- Allows for the recovery of ammonium sulfate
- High capital and operating costs
- Needs for a very effective solids removal step

# Membrane technology

## *NUTRIENT RECOVERY*




MICROFILTRATION

ULTRAFILTRATION

NANOFILTRATION

REVERSE OSMOSIS

Suspended Solids

Bacteria

Emulsions

Macro-molecules

Colloids

Virus

Proteins

Low MW

Ions

# Membrane technology

*NUTRIENT RECOVERY*

- ✓ AE
- ✓ Reject
- ✓ Colture

Digestor

digestate

Separation(s) S/L

Solid

Solid

UF

RO

Permeate: drinking water like

Concentrate

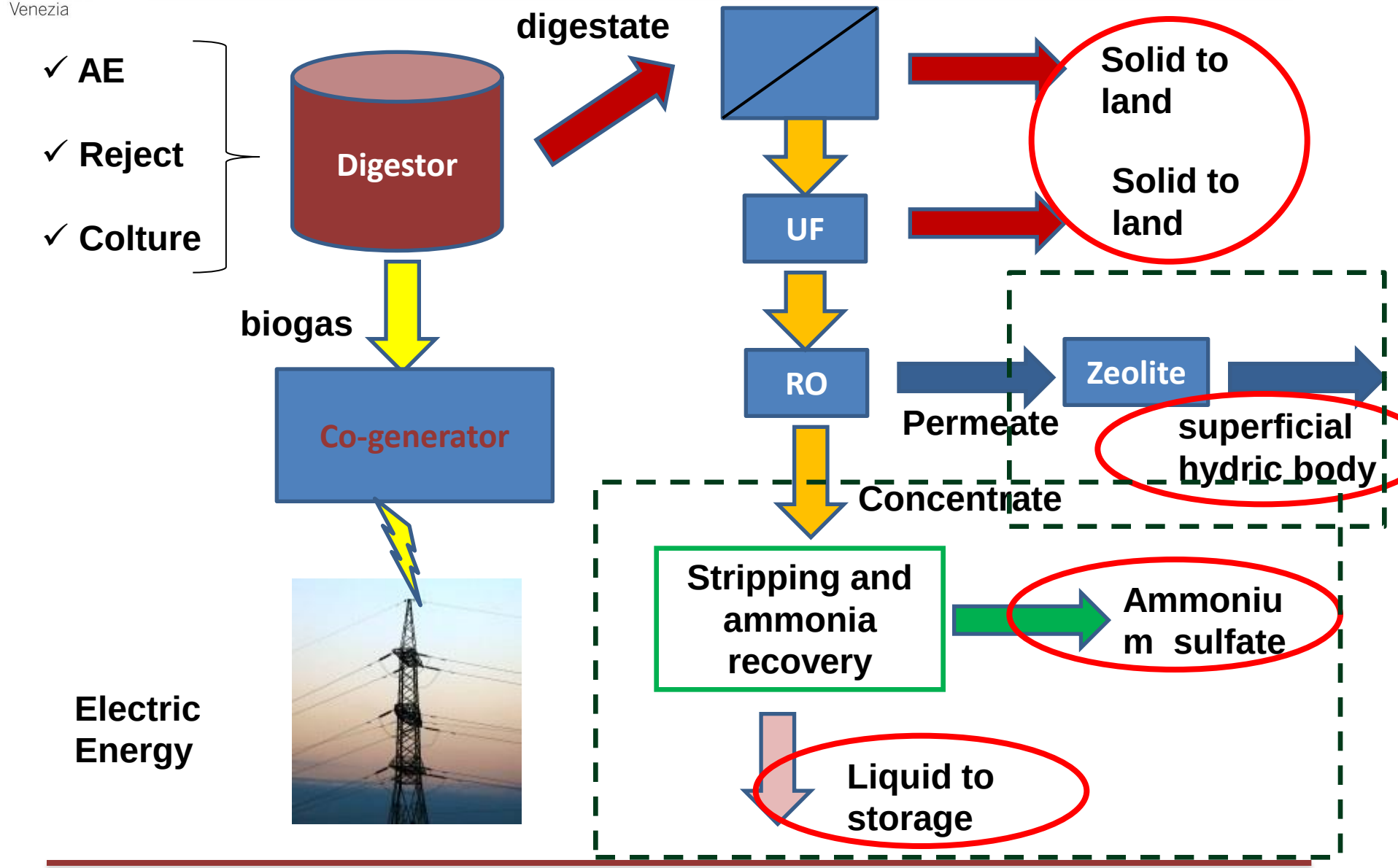
biogas

Co-generator

Electric Energy

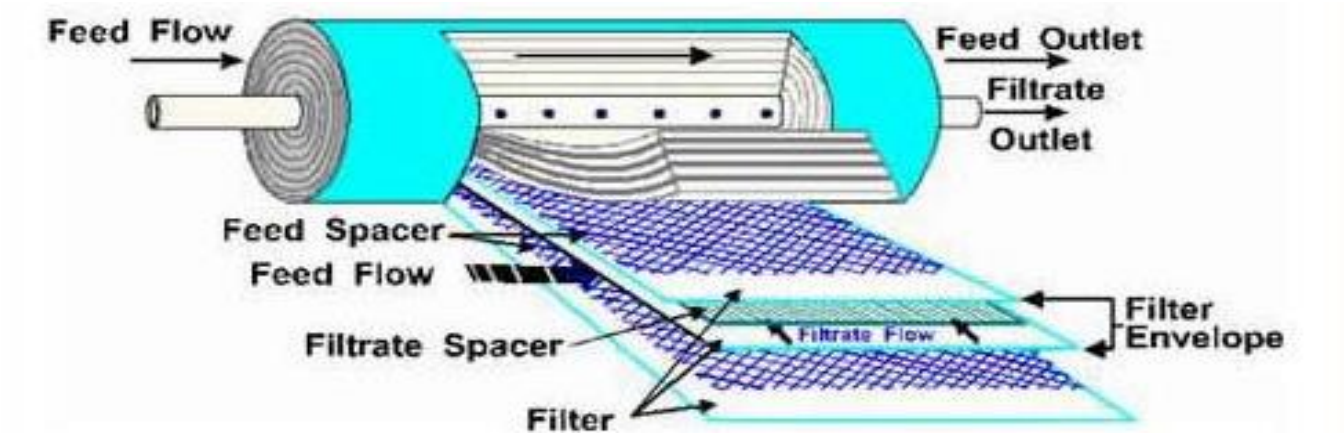
# Membrane technology

## *NUTRIENT RECOVERY*



# Membrane technology






# Membrane technology




Ultrafiltration

Reverse Osmosis

# Membrane technology

*NUTRIENT RECOVERY*


CH1: liquid effluent from the solid/liquid separation
CH2: liquid effluent from the centrifuge
PER1 : UF permeate
PER2 : RO permeate

# Membrane technology



- Membrane processes are extremely efficient in removing different compounds
- Membranes have not been used for a long time yet and the "life-time" for a membrane module is still not clear
- Membrane modules needs for highly efficient pre-treatments for solids removal (enhanced removal)
- High capital costs are needed for the membranes modules
- High running costs are requested for energy (RO works at 20 bars or similar) and chemicals

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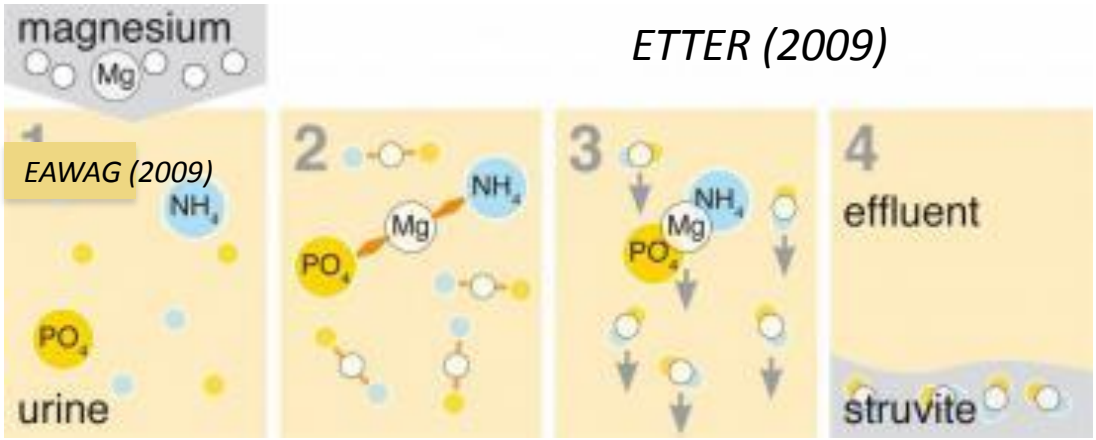
# Struvite crystallization for N & P recovery

The removal of ammonia from digestate supernatant after separation of the liquid and solid fractions can be achieved by the formation of ammonium magnesium phosphate (struvite):

$Mg^{2+} + NH_4^+ + PO_4^{3-} + 6H_2O \rightarrow MgNH_4PO_4\,6H_2O$

**STRUVITE-MAP**

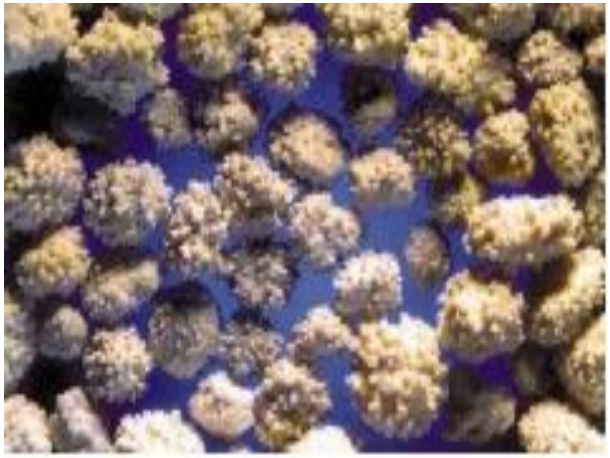
**MAP [$MgNH_4PO_4$*$6H_2O$]**

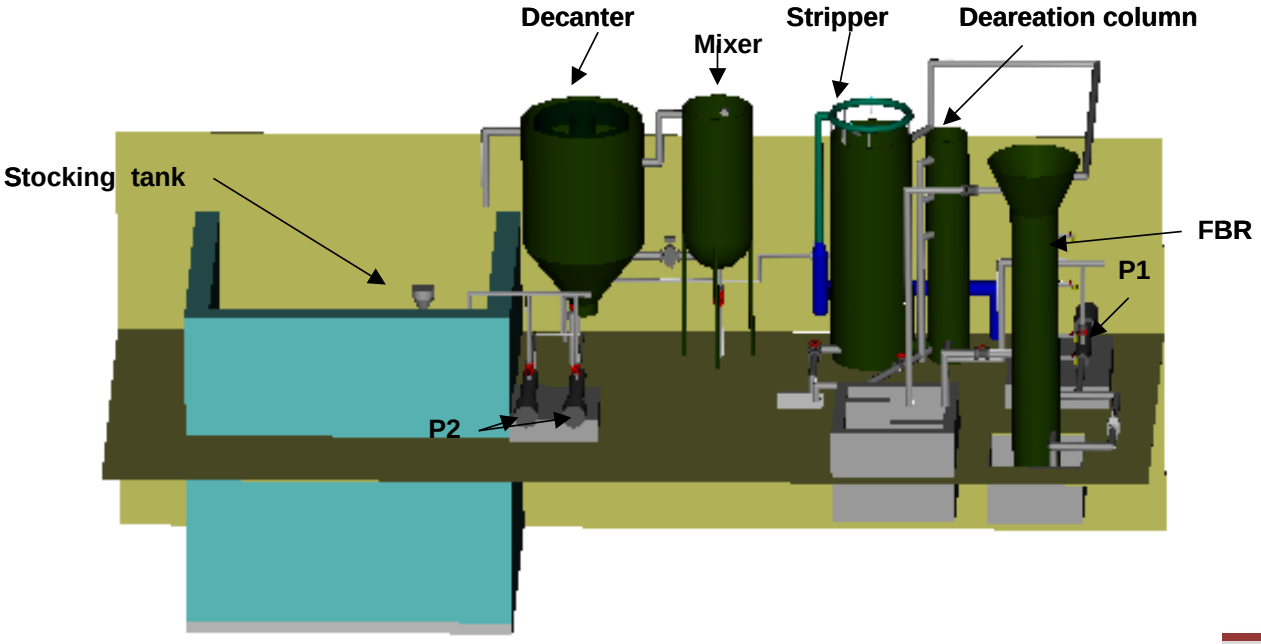



EAWAG (2009)

*ETTER (2009)*

# NUTRIENT RECOVERY





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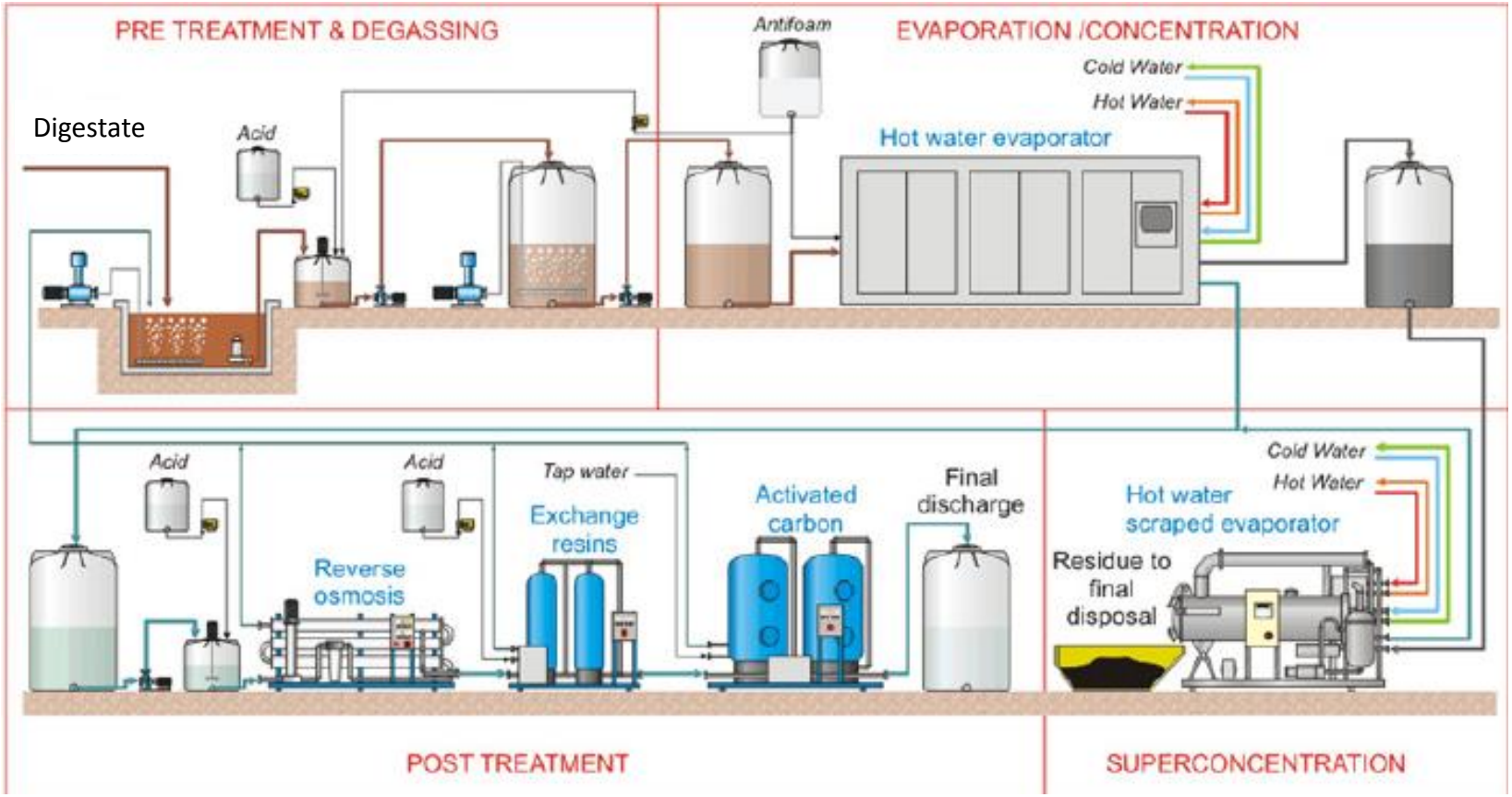
## *Evaporation*



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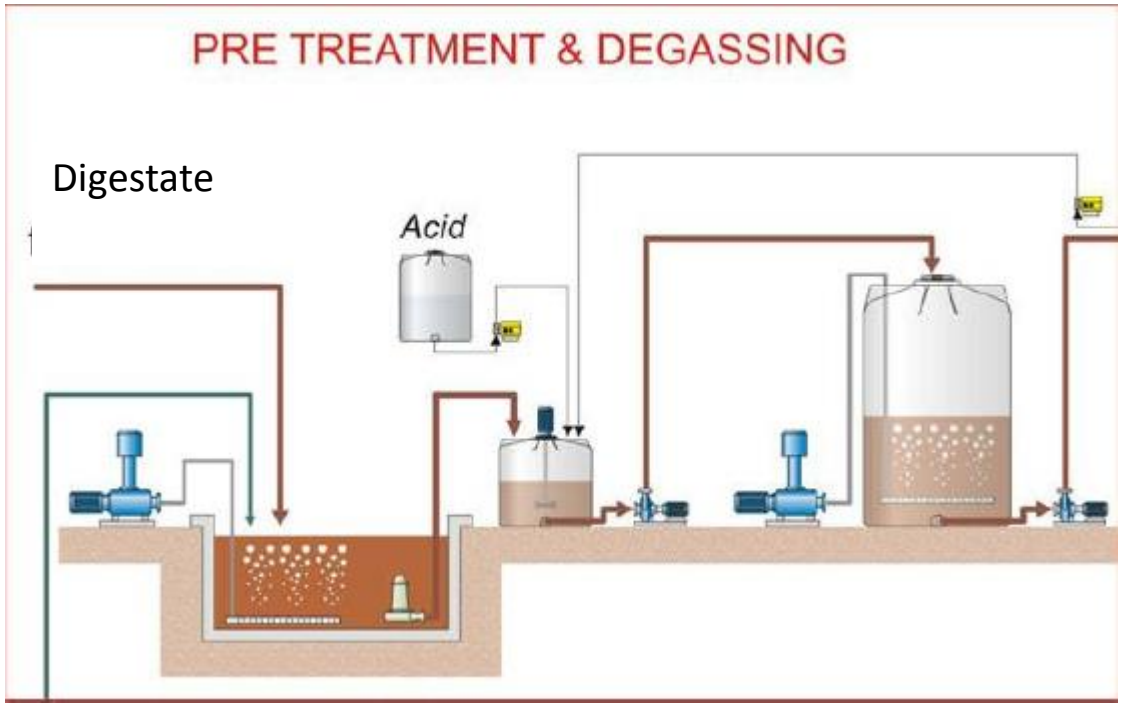
***Evaporation***

Needs for acidification ($NH_3$->$NH_4^+$) and degasing for $CH_4$ and $CO_2$ removal before concentration



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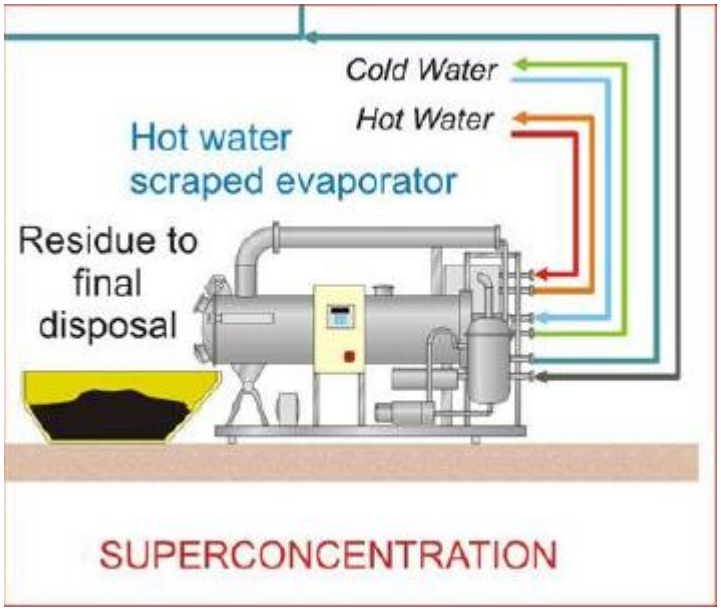
Ammonia remains in the concentrated fraction together with other nutrients during evaporation




## Evaporation

- ✓ very effective in ammonia removal (up to 95-99%) and concentration
- ✓ "distilled" water is obtained as a by-product
- ✓ other nutrients are recovered in a concentrated acidic phase
- ✓ high capital costs (up to 1 million €)
- ✓ high running costs for energy demand

***QUALITY OF DIGESTATE DEPENDS:***

1) *SUBSTRATE ALLOWED*
2) *AD PROCESS STABILITY*
3) *EU REGULATION*
4) *MEMBER STATE REGULATION*
5) *CHOOSE NUTRIENT RECOVERY THAN REMOVAL*
6) *ECONOMIC VALUE OF DIGESTATE*
7) *ECONOMIC VALUE OF RECOVERED PRODUCT*

***PUBLIC OPINION***

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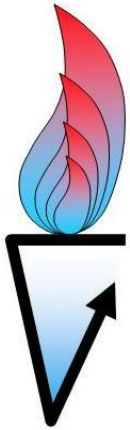

# THANK YOU!

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

*Summer School on Biogas Technology Renewable Energy Production and Environmental Benefit, 12-17 August 2013*