Digestates: Quality and Use

Anne Trémier
Dr-Ing., Cemagref, Rennes, France
Cécile Teglia
PhD student, Cemagref, Rennes, France

Cemagref

Public research institute (EPST)

- **9 centres** + 2 branches (Strasbourg and Martinique)
- Workforce of **1400** including **500 scientists**, **200** doctorate and **40** post-doctorate students
- **110 M€** budget including **79 M€** Core Budget (salaries) and **31 M€** contracts (2010)

Competences

Land, water and environmental technologies
Fields directly related to the **needs of Society**

Scientific and technical support for **public policy** in the form of research, science advice, models and operational tools

An **engineering** approach that includes **multi-disciplinary components**

Cemagref
Sciences, eaux & territoires

Research group SOWASTE – Cemagref Rennes

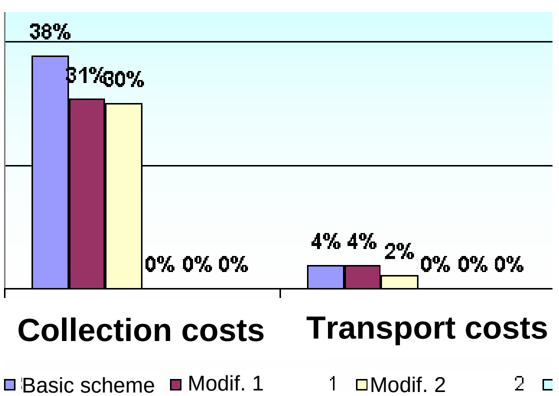
Management and biological treatment of solid waste

From collection to treatment: environmental, technical and economical efficiency

- Characterization of waste, compost and digestate.
- Study of collection efficiency.
- Expertise of treatment plants.
- Assessment of process costs.
- Financing terms.
- LCA, Carbon footprint, etc.

Composting: process design and optimisation

- Biodegradation, respirometry.
- Porosity and permeability of waste porous medium.
- Composting pilot.
- Heat and mass transfer, link with gaseous emissions.
- Modelling and process engineering.



Context: Waste, Legislation

► Production of waste in Europe

2.9 10^9 T of waste produced in 2006 in Europe (EU27)

1995 : 460 kg MSW/hab/y

2008 : 524 kg MSW/hab/y

2020 : 680 kg MSW/hab/y

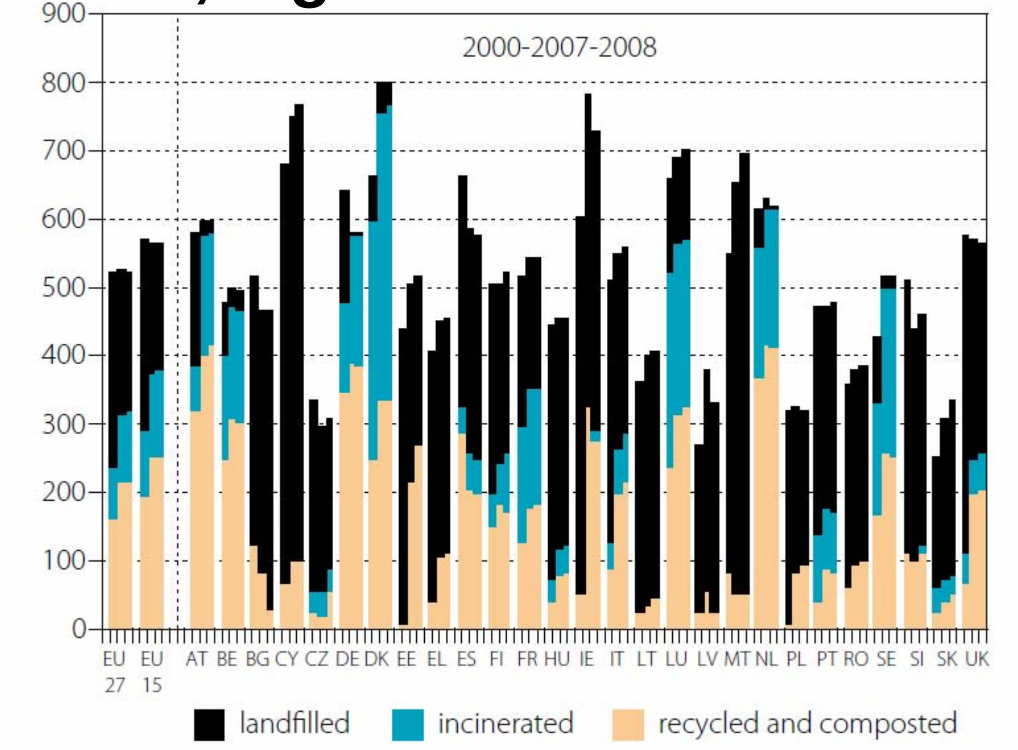
Environmental Policy Review 2009

► Regulatory framework of waste management in Europe

- *75/442/EC: reduction of waste production and restriction of waste landfilling*
- *1999/31/EC: limits in biodegradable municipal wastes quantities to be landfilled*
- *2006/12/EC: recycling of organic substances (biological transformation processes)*
- *Revision of Waste Framework Directive (17/06/08): waste hierarchy*
- *Communication of the European commission on bio-waste management (May 2010)*

Context: Waste, legislation

- **Predominant management ways for waste: landfilling and incineration**



Data source: European Commission, Eurostat..

- **To fulfil recycling and reuse objectives for 2020 (2008/98/EC)**

Promotion of biological treatments for organic and biodegradable waste

Composting

Anaerobic digestion

Context: anaerobic digestion

- **Last twenty years, major development of anaerobic digestion (AD)**

Organic matter (soluble, colloïdale, solid)

+

Anaerobic microorganisms

→

Microorganisms

+

$CH_4 + CO_2$

Biogas

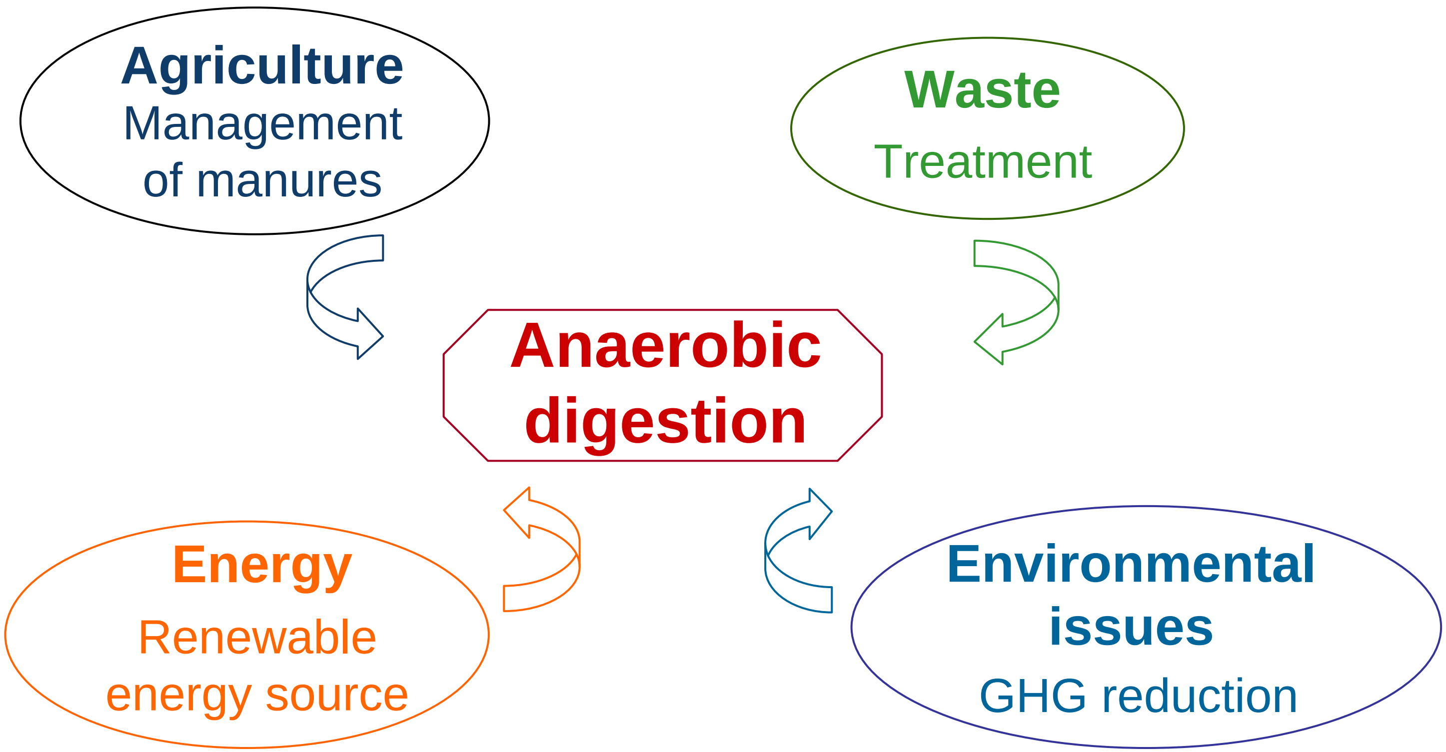
+

Residue: DIGESTATE

- **AD is the only energetic treatment that can be counted as recycling because of the use of digestate on land**

Context: anaerobic digestion

- **Key factors for AD development:**



Context: anaerobic digestion

- **Disincentive factors**
  - **High investment costs**
  - **Efficiency of the process**
  - **Quality and use of digestates**

Multiple types of digestates
Lack of available data
Particular properties (moisture, biological stability, status of maturity) ⇔ which agricultural use?

Needs for better characterisation of digestates

Context: which statute for digestates?

- **Digestate: waste or product?**
  - **Existing national standards in some european countries:**
    - ***Germany:***
      - **RAL GZ 245 Digestate from biowaste**
      - **RAL GZ 246 Digestate from energy crops**
    - ***Sweden:***
      - **SPCR 120 Biowaste digestion residues**
    - ***UK:***
      - **PAS 110**

↳ Definition of product quality parameters and use

↳ Linked with QAS systems: list of positive input materials, processing parameters, and analytical methods

Context: which statute for digestates?

- **Digestate: waste or product?**
  - **Digestate: still a waste without post-treatment?**
    - ***Exemple of 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.

Context: which statute for digestates ?

- Digestate from biowaste as a product : end-of-waste criteria?
  - Position of the European Comission: « compost and digestate from biowaste are under-used materials […] offering an excellent contribution to the improvement of carbon depleted soils. »
    - *Need of standards to enable free circulation on the international market*
    - *End-of-Waste criteria : Material shall cease to be a waste if*
      - The substance is commonly used for specific purposes
      - A market or demand exists
      - The substance fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products
      - The use of the substance will not lead to overall adverse environmental or human health impacts.
    - *Digestate is primarily used as organic fertilizer*

Cemagref
Sciences, eaux & territoires

Which indicators to characterize digestates ?

- **Required quality to apply organic matter on soil: three mains aspects**
  - **Organic amendment properties:**
    - ***Dry matter, Organic matter***
    - ***Carbon and nitrogen content***
    - ***Biochemical fractionation***
    - ***Humic substances***
    - ***Cation exchange capacity***
  - **Fertilizing effects**
    - ***C, N, P, K***
    - ***Other mineral content***

Cemagref
Sciences, eaux & territoires

Which indicators to characterize digestates ?

- **Required quality to apply organic matter directly on soil: three mains aspects**
  - **Innocuousness**
    - ***Inorganic impurities***
    - ***Heavy metals***
    - ***Organic pollutants***
    - ***Biological stability***
    - ***pH, salinity, conductivity***
    - ***Phyto-toxicity***
    - ***Pathogens***

Which indicators to characterize digestates ?

- **Characterization of treatability through an aerobic post-treatment**
  - **Biodegradable potential**
    - ***Respirometric measurements***
    - ***Organic matter content***
    - ***Carbon and nitrogen content***
    - ***Biochemical fractions***
  - **Biodegradation rates**
    - ***Respirometric measurements***
  - **Physical parameters (for composting)**
    - ***Particle size***
    - ***Porosity***
    - ***Permeability***

Agronomic quality of digestates

- **Liquid digestate from agro-plants**

	Austrian digestate (140)	French, Belgian and Luxemburg digestate (4)
Dry matter (%)	3,3 – 8,3	4,7 - 8
Nitrogen (N Total – kg/m³)	2,6 – 6,1	3,5 – 4,5
NH_4^+ (% of N Total)	29 - 56	42,8 – 57,6
Phosphorus (P_2O_5 Total – kg/m³)	0,7 – 2,7	1,2 – 2,0
Potassium (K_2O Total – kg/m³)	3,0 – 6,1	2,7 – 5,0
pH		7 – 8,25

➩Equivalent content of fertilising elements

Cemagref Sciences, eaux & territoires

Agronomic quality of digestates

- **Solid digestate (data from France, Belgium and Switzerland)**

	Dig. from sludge 1	Dig. from sludge 2	Dig. from agro-indus. waste	Dig. from agricultural waste	Dig. from biowaste 1	Dig. from biowaste 2	Dig. from biowaste 3	Dig. from mixed MSW1	Dig. from mixed MSW2
DM (%WW)	20.9	18.9	20.3	24.0	42.5	45.7	55.9	20.2	42.4
OM (%DM)	56.7	59.9	75.4	68.8	38.6	74.1	49.7	55.8	32.4
OM (%WW)	11.9	11.3	15.3	16.5	16.4	33.9	-	11.3	13.7
CT (mg/gOM)	548	539	522	516	554	539	-	584	578
NT (mg/gOM)	63.8	86.8	35.8	31.3	36	21.7	30.4	34.2	27.8
NH_4^+ (mg/gOM)	13.6	n.d	11.4	8.6	10.3	5.1	0.9	27.5	16.5
CEC (meq/100g)	30.6	53.4	22.9	22.6	22.6	20.3	-	20.5	16.6
CaO (g/kgDM)	12.5	8.1	4.2	5.6	11.0	12.6	-	12.5	13.6
MgO (g/kgMS)	1.2	1.7	5.1	4.4	1.8	1.4	-	1.4	1.6
K_2O (g/kgDM)	0.99	1.86	2.98	45.8	6.41	10.40	12.6	14.80	6.34
Na_2O (g/kgDM)	0.64	1.58	2.66	6.67	2.72	5.65	-	14.40	4.60
Mn (mg/kgDM)	27.2	3.5	12.5	29.7	31.1	14.5	-	14.5	12.7

Agronomic quality of digestates

- Few data available on physico-chemical characterization
- Rare information concerning efficiency on crops growth
- On available data: comparable characteristics among liquid digestate and solid digestate respectively
  - Less difference between digestate obtained from the AD of different waste than between the raw waste themselves
  - Assessment of potential fertilizing effect
  - Lack of data concerning innocuousness

Cemagref
Sciences, eaux & territoires

Interest of a post-treatment for digestates

- When considering areas with nutrients structural surpluses, digestates can not be directly spread on land
  - Needs of reducing nutrients contents: treatment
  - Costs of transport induce need of reducing weight and volume: treatment and drying

- Digestates needs to fulfil standards requirements in order to be considered as a marketable product
  - Example of the French soil improver standards:
    - *DM > 30 % of WW*
    - *OM > 20 % of WW*

      => Most of solid digestates need to be dried

Cemagref
Sciences, eaux & territoires

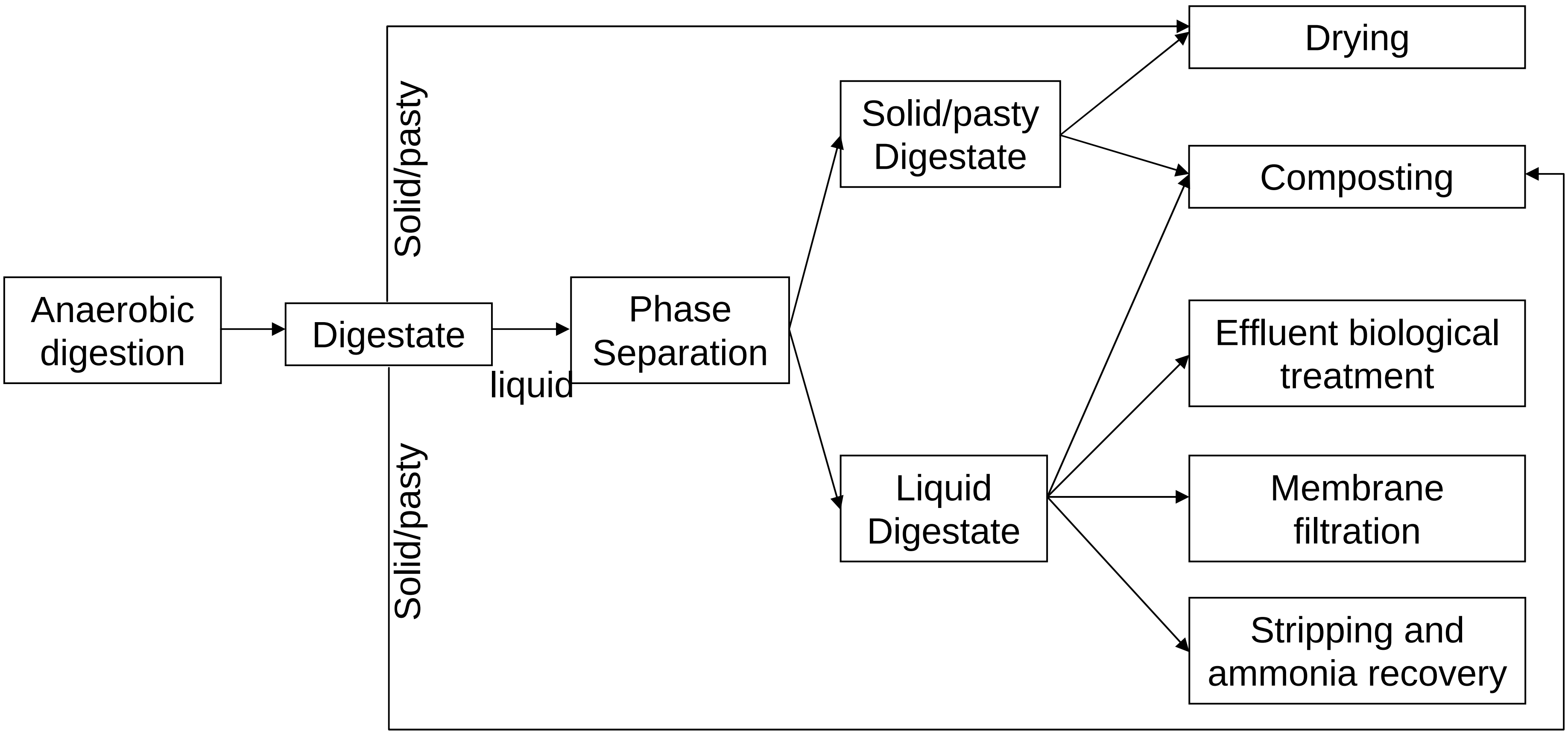
Interest of a post-treatment for digestates

- **Digestates still contain biodegradable organic matter**

- **Post-treatment: different aims depending on the type of digestate and the proposed use**
  - Drying
  - Improving biological stability
  - Reducing N and P content
  - Reducing phyto-toxicity
  - Improving humus content

Interest of a post-treatment for digestates

- **Example of post-treatment scheme**



Digestates' treatability: example of composting

Materials and Methods

► **Six digestates from different materials**

- *sludge from waste water treatment plant ($WWTS_1$ and $WWTS_2$)*
- *food-processing effluents (FPW)*
- *agricultural solid wastes (AW)*
- *source selected organic fraction of municipal solid wastes ($SS\text{-}OFMSW_1$ and $SS\text{-}OFMSW_2$)*

liquid digestion + centrifugation

dry digestion + centrifugation

► **Chemical analyses**

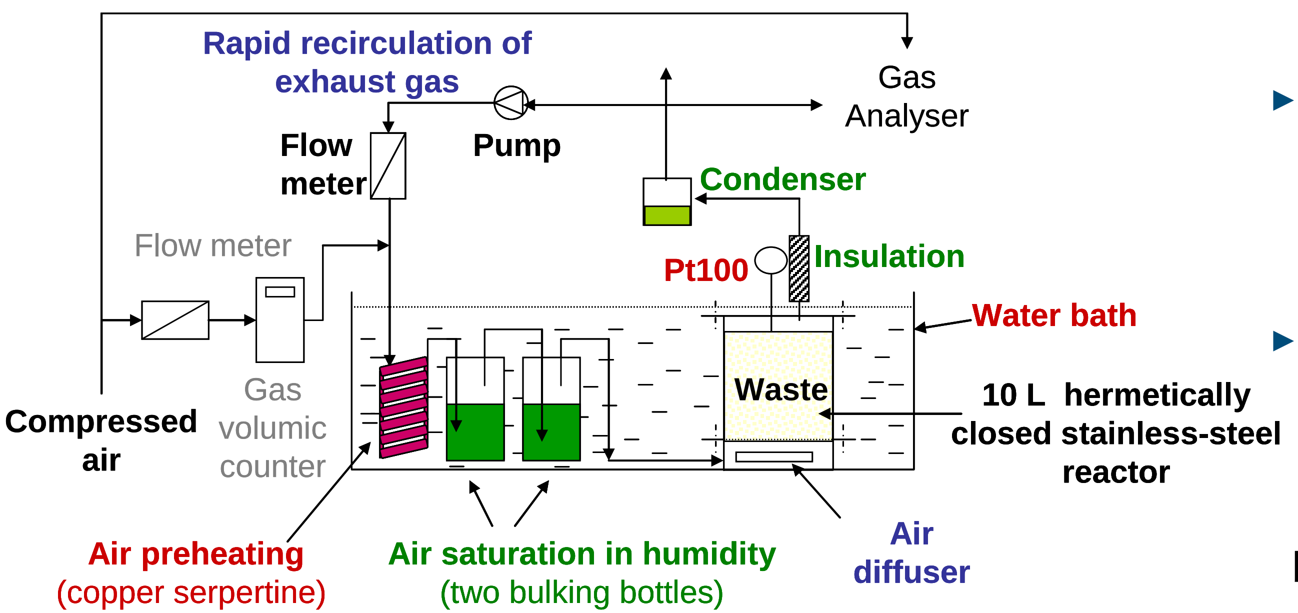
- *chemical oxygen demand (COD)*
- *total carbon content (TC)*
- *total nitrogen content (TN)*

Cemagref
Sciences, eaux & territoires

Digestates' treatability: example of composting

Materials and Methods

- **Biodegradability measurement: Respirometric device**



- 10L filled with solid sample
- forced and constant aeration

  ⇔ homogeneous and non limiting aeration
- controlled moisture and T°C

  ⇔ optimum conditions

  (50-80%, 40°C)
- oxygen consumption

  ⇔ maximum biodegradable potential, kinetic of O_2 consumption, easily biodegradable fraction of OM

Digestates' treatability: example of composting

Materials and Methods

► **Methods of composting behaviour prediction based on respirometric measurements**

- **correlation between temperature rise in pilot scale reactors and the mass of biodegradable matter introduced**
  - ΔT_{max} ⇔ maximum value of temperature rising during composting trials at lab-scale (300L)
    - ☞ $\Delta Tmax = 1.5672 *$ Biodegradable OM+ 13.682 (de Guardia et al., 2010)

- **estimation of the operational aeration needs during composting process**
  - Q_{tot} ⇔ theoritical global need in aeration supply
    - ☞ Q_{tot} = Total O_2 consumption during respirometric measurement
  - Q_{min} ⇔ minimal airflow rate to insure non limiting conditions for biodegradation
    - ☞ Q_{min} = Maximal OUR during respirometric measurement

- **residual biodegradable potential (RBP)**
  - t_{stab} ⇔ minimum time to achieve full stabilization

Digestates' treatability: example of composting

Results: Residual biodegradability and composting feasibility

- *digestates still present residual biodegradability*

  - **SS-OFMSW ⬄ comparable to wastes after an active phase of composting**
    ⇨ post-treatment = simple aerobic maturation?

  - **WWTS, FPW and AW ⬄ moderately biodegradable raw wastes**
    ⇨ post-treatment = complete composting?

	$WWTS_1$	$WWTS_2$	FPW	AW	SS-$OFMSW_1$	SS-$OFMSW_2$
C/N	8.6	6.2	14.6	16.5	15.4	24.8
O_2/COD (%)	11.7	22.0	12.8	17.9	10.8	6.7

Cemagref
Sciences, eaux & territoires

Digestates' treatability: example of composting

Results: Residual biodegradability and composting feasibility

► *carbon and nitrogen are essential for biodegradation: C/N ⇔ equilibrium for suitable biodegradation*

- **C/N = 30 ⇔ biological optimum for metabolic use**
  ⇨ imbalance in C content: addition of co-substrate?

- **wastes with lower ratio (12) can be auto-composted**
  ⇨ FPW, AW and SS-OFMSW: C/N acceptable

	$WWTS_1$	$WWTS_2$	FPW	AW	SS-$OFMSW_1$	SS-$OFMSW_2$
C/N	8.6	6.2	14.6	16.5	15.4	24.8
O_2/COD (%)	11.7	22.0	12.8	17.9	10.8	6.7

Cemagref
Sciences, eaux & territoires

Digestates' treatability: example of composting

Results: Prediction of composting behaviour

▶ **Operational parameters**

- *ΔT estimated for «typical» composting mixtures*

  Similar ΔT_{max} ⇔ comparable to some raw compostable wastes

  Rise in temperature is quite moderate ⇔ hygienization issue?

- *different requirements in total aeration needs and minimum air flow rate* ⇨ composting process under forced aeration

- *Short time to achieve full stabilization*

	$WWTS_1$	$WWTS_2$	FPW	AW	SS-$OFMSW_1$	SS-$OFMSW_2$
ΔT_{max} (°C)	16.3	18.7	17.6	16.5	18.2	16.1
Q_{tot} (m^3/tonDM)	331	705	513	587	214	246
Q_{min} (m^3/h/tonDM)	3.7	6.4	2.8	10.1	3.6	9.3
t_{stab} (d)	13	18	19	7	10	3

Conclusion and research outlooks

- Digestate characterization
  - Lack of data
    - *Effects of the digestates on soil and environment have to be studied*
    - *Influence of the type of the digestion input and process?*
  - Dispersed standards: Need of harmonisation of the quality parameters for digestate products in Europe
    - *Depending on countries digestates may be considered as a marketable soil improver or soil fertilizer, or not*
  - Question of the need of assurance scheme for anaerobic digestion in order to guarantee the product quality from digestates (End-of-Waste thinking)

Cemagref
Sciences, eaux & territoires

Conclusion and research outlooks

- **Digestate post-treatment**
  - **Lack of data concerning the adequacy between specific use and specific post-treatment**
  - **Concerning composting**
    - ***Digestates are still biodegradable***
    - ***Characterized composting may be difficult to achieve (low temperature increase)***
    - ***Aerated curing phase ?***

Research outlooks:

Quality criteria for specific use and optimisation of digestates preparation to reach these criteria

Some references

- **KUPPER, T., FUCHS, J. – 2007.** Compost et digestat en Suisse. *Connaissance de l'environnement*, n° 0743. Office fédéral de l'environnement. Berne
- **TEGLIA, C., TREMIER, A., MARTEL, J.L. - 2010.** Characterization of Solid Digestates: Part 1, Review of Existing Indicators to Assess Solid Digestates Agricultural Use. *Waste and Biomass Valorization*, vol. 2, n° 1, p. 43 - 58
- **DE GUARDIA, A., MALLARD, P., TEGLIA, C., MARIN, A., LE PAPE, C., LAUNAY, M., BENOIST, J.C., PETIOT, C. - 2010.** Comparison of five organic wastes regarding their behaviour during composting: Part 1, biodegradability, stabilization kinetics and temperature rise. *Waste Management*, vol. 30, n° 3, p. 402 - 414
- **TEGLIA, C., TREMIER, A., MARTEL, J.L. - 2011.** Characterization of Solid Digestates: Part 2, Assessment of the quality and suitability for composting of six digested products. *Waste and Biomass Valorization*, DOI 10.10007/s12649-010-9059-x
- **AD Europe 2011** – The Future of Anaerobic Digestion in Europe: Situation, Barriers and Chances, Dublin, Ireland, 24th to 25th February 2011
- **European Compost Network** – **2011**. End-of-Waste Criteria for compost and digestate, *ECN Newsletter*, n°01, p.1 - 3

Cemagref
Sciences, eaux & territoires

ORBIT2012
12th-15th June
Rennes - France

Global assessment for organic resources and waste management

8th International Conference **ORBIT2012**
on
Global assessment for organic resources and waste management
Rennes, France - June 12-15, 2012

Abstracts (oral or poster) for this major scientific event are invited from authors from all over the world until September 30, 2011 the latest for the following topics:

- **EU policies and strategies for sustainable organic resources and waste management**
- **Climate change, waste management assessment and decision tools**
- **Collection and local management of organic wastes**
- **Energy recovery**
- **Biological treatments (composting and anaerobic digestion)**
- **Mechanical biological treatment**
- **Organic fertilisers and soil improvers for agricultural and horticultural issues (including sludge, manures, composts and digestates)**
- **Natural resources in the global context**

www.orbit2012.fr