2–4 July 2015:
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management,
Tinos island, Greece

ISWM - TINOS 2015

ANAEROBIC CO-DIGESTION AND WASTEWATER TREATMENT

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PRESENTATION OVERVIEW

- INTRODUCTION:

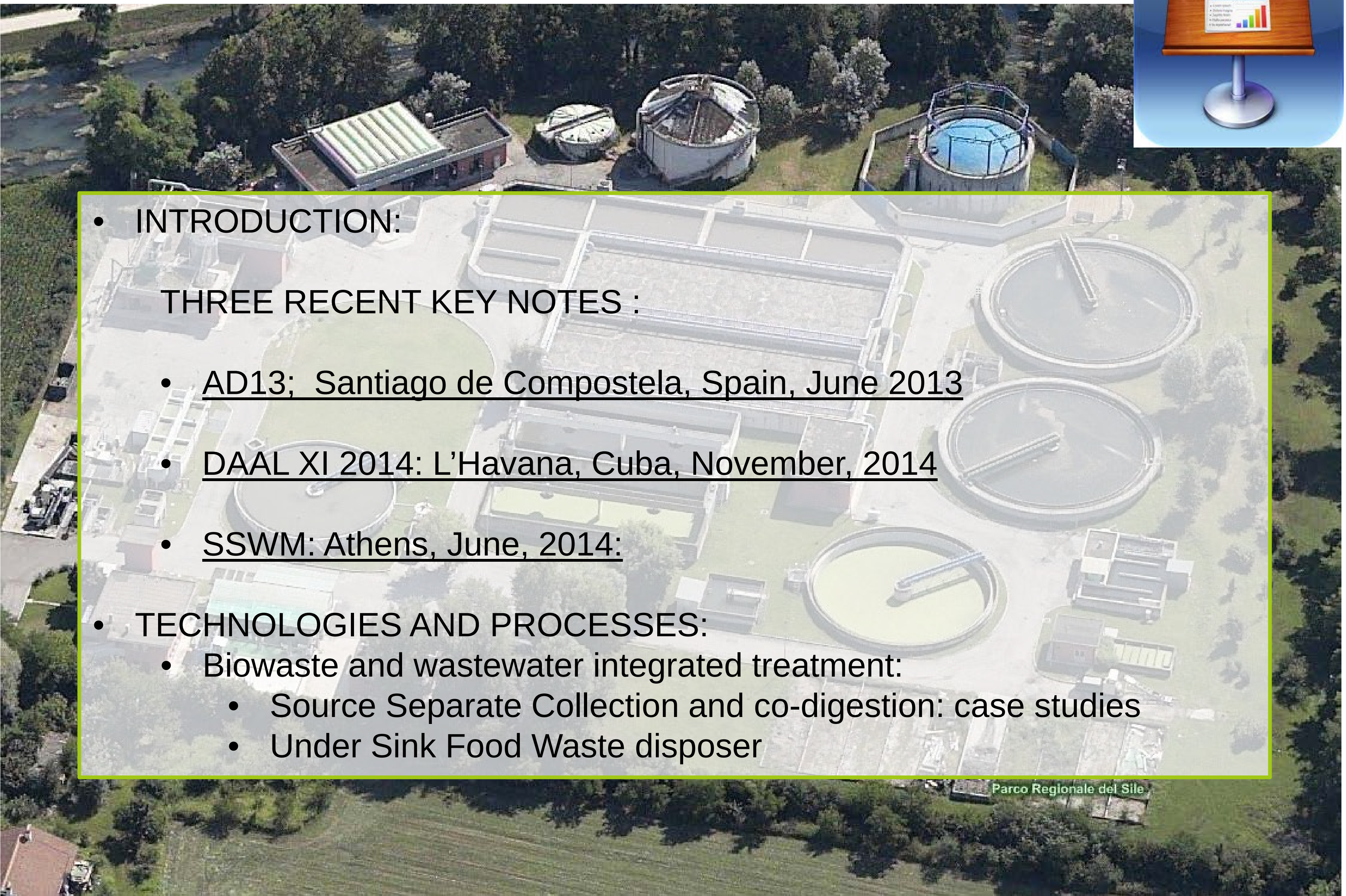
  THREE RECENT KEY NOTES :

  - AD13; Santiago de Compostela, Spain, June 2013

  - DAAL XI 2014: L’Havana, Cuba, November, 2014

  - SSWM: Athens, June, 2014:

- TECHNOLOGIES AND PROCESSES:
  - Biowaste and wastewater integrated treatment:
    - Source Separate Collection and co-digestion: case studies
    - Under Sink Food Waste disposer



About AcoD 3 key-note speeches were recently presented:

Anaerobic co-digestion: a review of achievements and perspectives

Juan Mata-Alvarez et al., AD13 2013 World Congress,

Domestic food waste and sewage sludge combined treatment implementing household food waste disposer

Fernando Polanco et al., DAAL XI 2014 Latin America Congress,

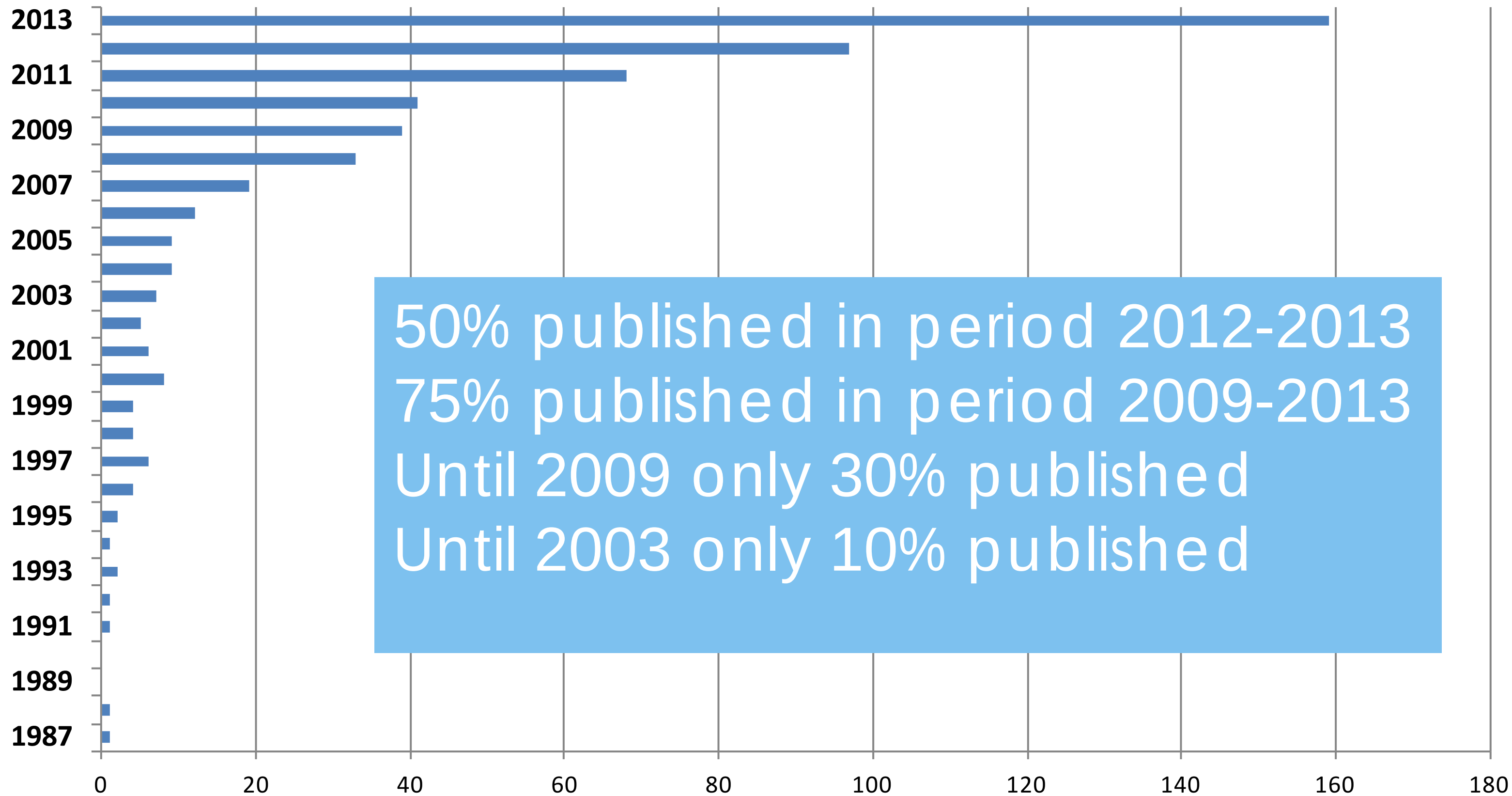
Anaerobic digestion of bio-waste: a territorial and environmental friendly process

Franco Cecchi and Cristina Cavinato, Athens 2014 Sustainable Solid Waste Management

INTRODUCTION

- AD13: **Anaerobic co-digestion: a review of achievements and perspectives**

The number of papers pubblished with the word co-digestion or codigestion in its title shows the grow of interest in this topic/approach



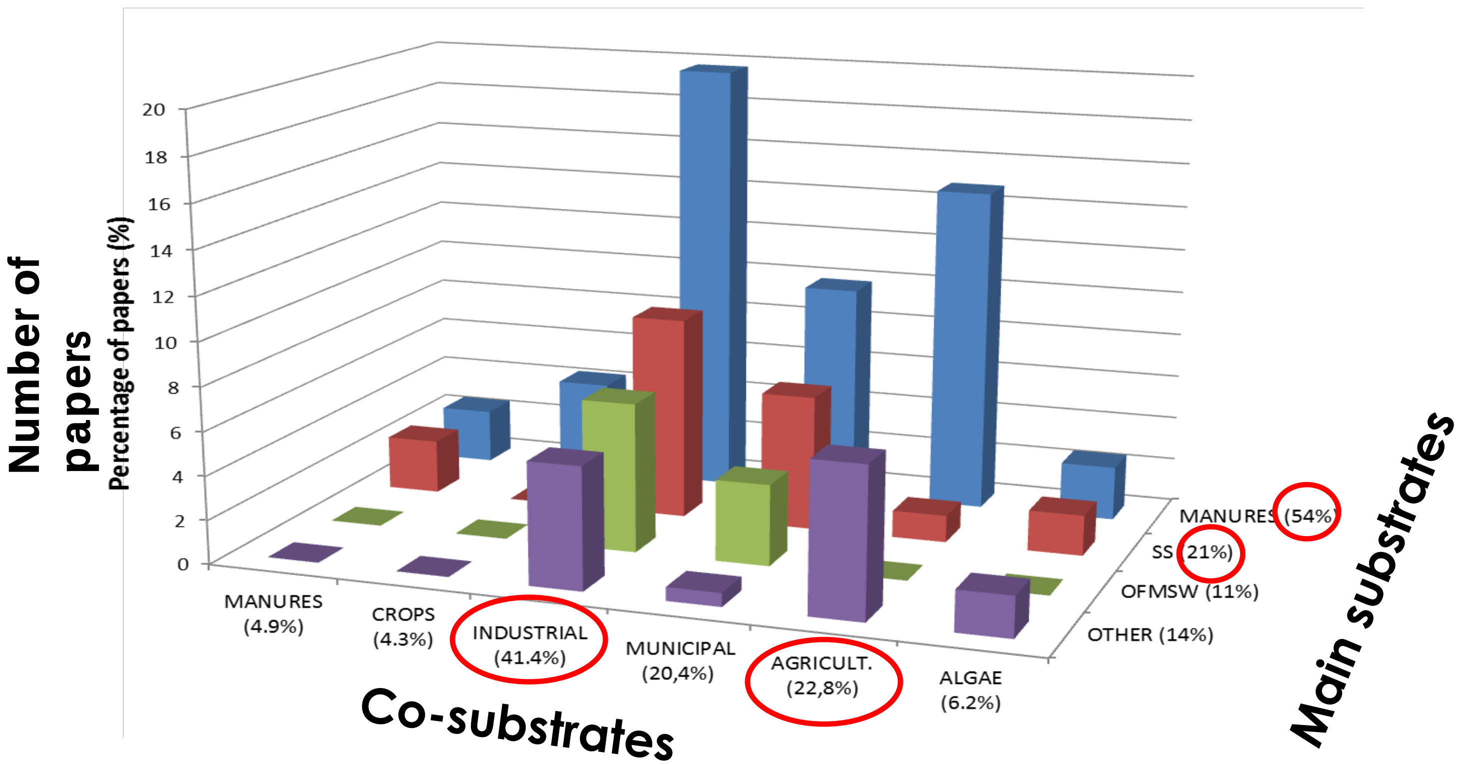
50% published in period 2012-2013
75% published in period 2009-2013
Until 2009 only 30% published
Until 2003 only 10% published

Mata-Alvarez J, Dosta J, Macé S, Astals S (2011), Crit. Rev. Biotechnol. 31:99-111

INTRODUCTION

- AD13: **Anaerobic co-digestion: a review of achievements and perspectives**

AcoD papers in the last 2010-2013



Mata-Alvarez J, Dosta J, Macé S, Astals S (2011), Crit. Rev. Biotechnol. 31:99-111

INTRODUCTION

- AD13: **Anaerobic co-digestion: a review of achievements and perspectives**

Co-digestion between SS and OFMSW

First reported in 1988, a pioneering study of co-digestion by Cecchi et al. at Treviso WWTP

Mata-Alvarez J, Dosta J, Macé S, Astals S (2011), Crit. Rev. Biotechnol. 31:99-111

INTRODUCTION

- AD13: **Anaerobic co-digestion: a review of achievements and perspectives**

Mixture // Temperature	Mono-digestion	Co-digestion	Location	Reference
PS + FVW (Mesophilic)	0.55 m^3 biogas/kg OS	0.57 m^3 biogas/kg OS	WWTP of Frutigen (Switzerland)	Edelmann et al. 2000. Wat. Sci. Technol. 41(3)
SS + starch-rich waste from potato processing facility (Mesophilic)	-	0.6 m^3 biogas/kg VS	-	Murto et al. 2004. Journal of Environmental Management 70
SS + SS-OFMSW (Mesophilic)	0.13 m^3 biogas/ kg VS	0.43 m^3 biogas/ kg VS	WWTP of Treviso (Italy)	Bolzonella et al. 2006. Wat. Sci. Technol. 53(8)
SS + SS-OFMSW (Mesophilic)	0.21 m^3 biogas/kg VS	0.26 m^3 biogas/kg VS	WWTP of Viareggio (Italy)	Bolzonella et al. 2006. Wat. Sci. Technol. 53(8)
SS + Aircraft deicing waste PS + Food flavorings prod. waste (Mesophilic)	0.69 m^3 CH_4/kg VS 0,39 ML biogas/t TS	0.5 m^3 CH_4/kg VS 0,55 ML biogas/t TS	Municipal WWTP (Wisconsin)	Zitomer et al. 2008. Water Environment Research 80(3)
SS + SS-OFMSW (Mesophilic)	0.39 m^3 biogas/kg VS	0.60 m^3 biogas/kg VS	WWTP of Velenje (Slovenia)	Zupancic et al. 2008. Biomass and bioenergy 32
PS + SS-OFMSW (Mesophilic)	4,370 m^3 CH_4 /day (2.0 kg VS/(m^3 day))	19,500 m^3 CH_4/day (3.9 kg VS/(m^3 day))	Kayseri WWTP (Turkey)	Dereli et al. 2010. Waste Manag Res. 28(5)
WAS + FVW (Mesophilic)	-	Biogas production 8-17% higher than the historical	WWTP in Prince George (Canada)	Park et al. 2011. Wat. Sci. Technol. 64(9)
SS + SS-OFMSW (Mesophilic) SS + SS-OFMSW (Thermophilic)	-	0,35 m^3 biogas/kg VS 0,55 m^3 biogas/kg VS	WWTP of Treviso (Italy)	Cavinato et al. 2013. Renewable Energy 55

Mata-Alvarez J, Dosta J, Macé S, Astals S (2011), Crit. Rev. Biotechnol. 31:99-111

Typically, AcoD has been implemented for improving digester yields, than energy production from renewable sources, but even process stability improve with respect to mono-feed

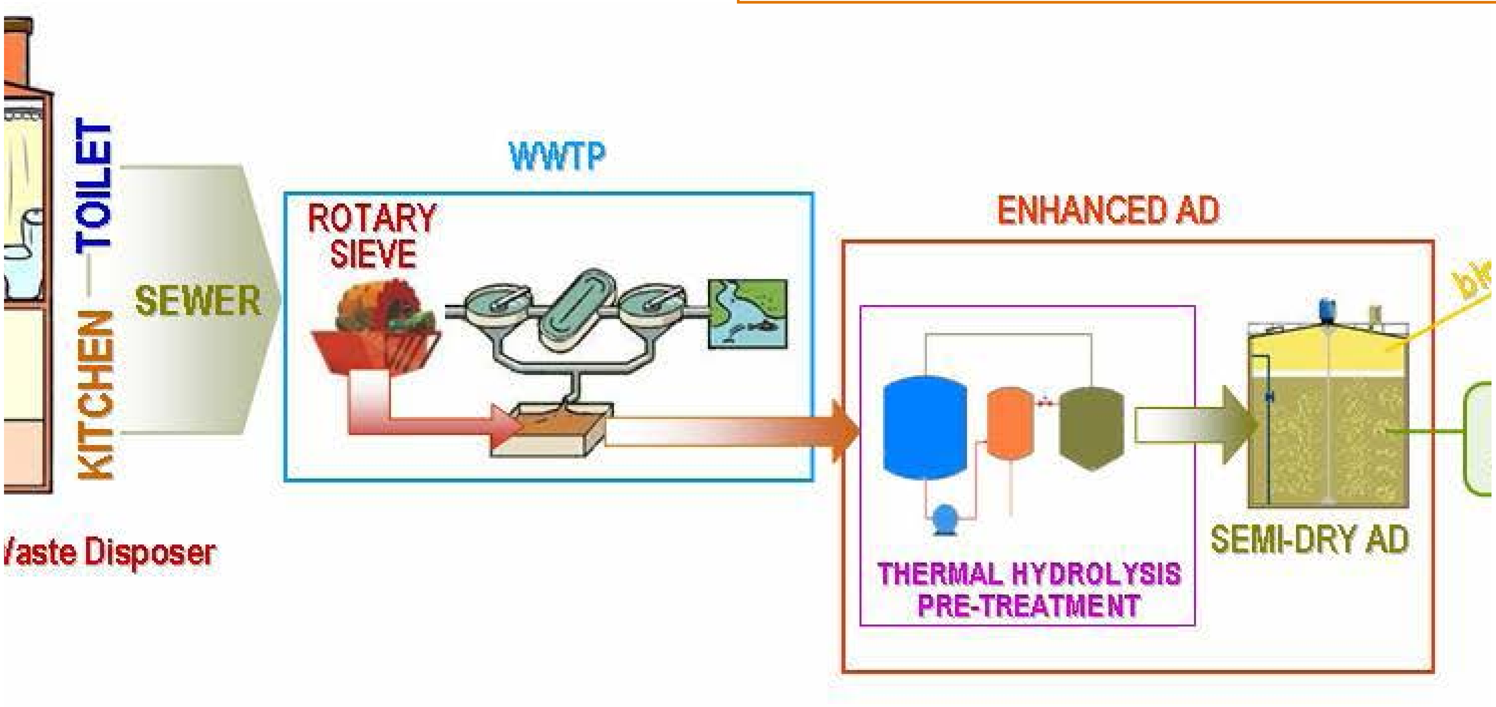
However no many reports are related to full scale AcoD of SS and OFMSW

INTRODUCTION

- DAAL XI 2014 **Domestic food waste and sewage sludge combined treatment implementing household food waste disposer**

New WWTP concept:

1. Food waste disposers in households → FW + WW
2. Rotary sieve
3. Short HRT in the activated sludge reactor
4. Thermal hydrolysis pretreatment to enhance AD
5. Semi-dry AD (10-15% TS)



Credit: Prof. Fernando Polanco

INTRODUCTION

- DAAL XI 2014 **Domestic food waste and sewage sludge combined treatment implementing household food waste disposer**

Some Conclusions of Prof. Polanco key-note speech:

- ✓ Domestic OFMSW and sewage sludge combined treatment by FWD is a feasible alternative.
- ✓ Beside the application of thermal hydrolysis, it creates a new advanced anaerobic digestion concept.
- ✓ By implementing FWD in half of the households, full energy self-sufficiency is reached in the WWTP.
- ✓ If 100% extent of FWD is achieved, 1.85 M€ net benefits are generated annually with a payback period of 10 years

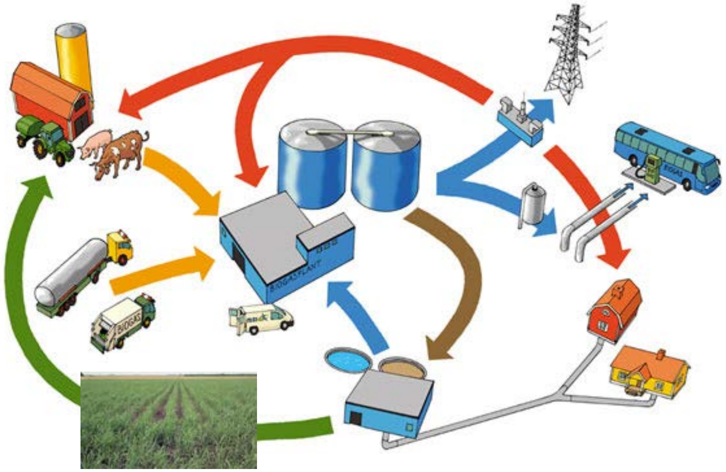
Highlighted the energy related aspects

INTRODUCTION

- Athens 2014 **Anaerobic digestion of bio-waste: a territorial and environmental friendly process**

Two strategic approaches:

- The Anaerobic Digestion as a service for agricultural and farming sector
- The Anaerobic Digestion as a territorial service for citizens



Overall view of a sustainable and environmental friendly approach

A service for society in terms of energy and material recovery.

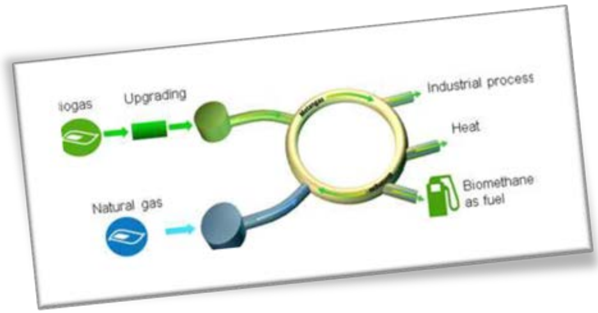
Cecchi and Cavinato (2015), Waste Management and Research

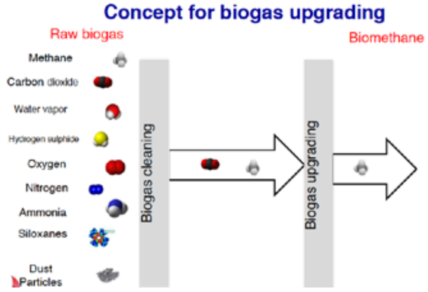
INTRODUCTION

- Athens 2014 **Anaerobic digestion of bio-waste: a territorial and environmental friendly process**

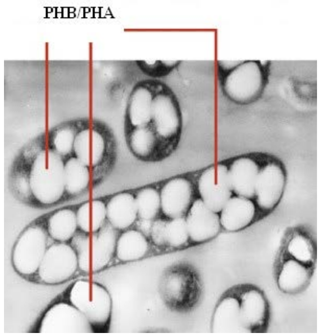
Advanced treatment of bio-waste: energy and materials recovery

- Bio-methane: biogas upgrading technology for automotive purpose or direct injection into the methane network





- Bio-Hythane: two-phase hydrogen and methane production



- Bio-polimers: biological accumulation of PHA

INTRODUCTION

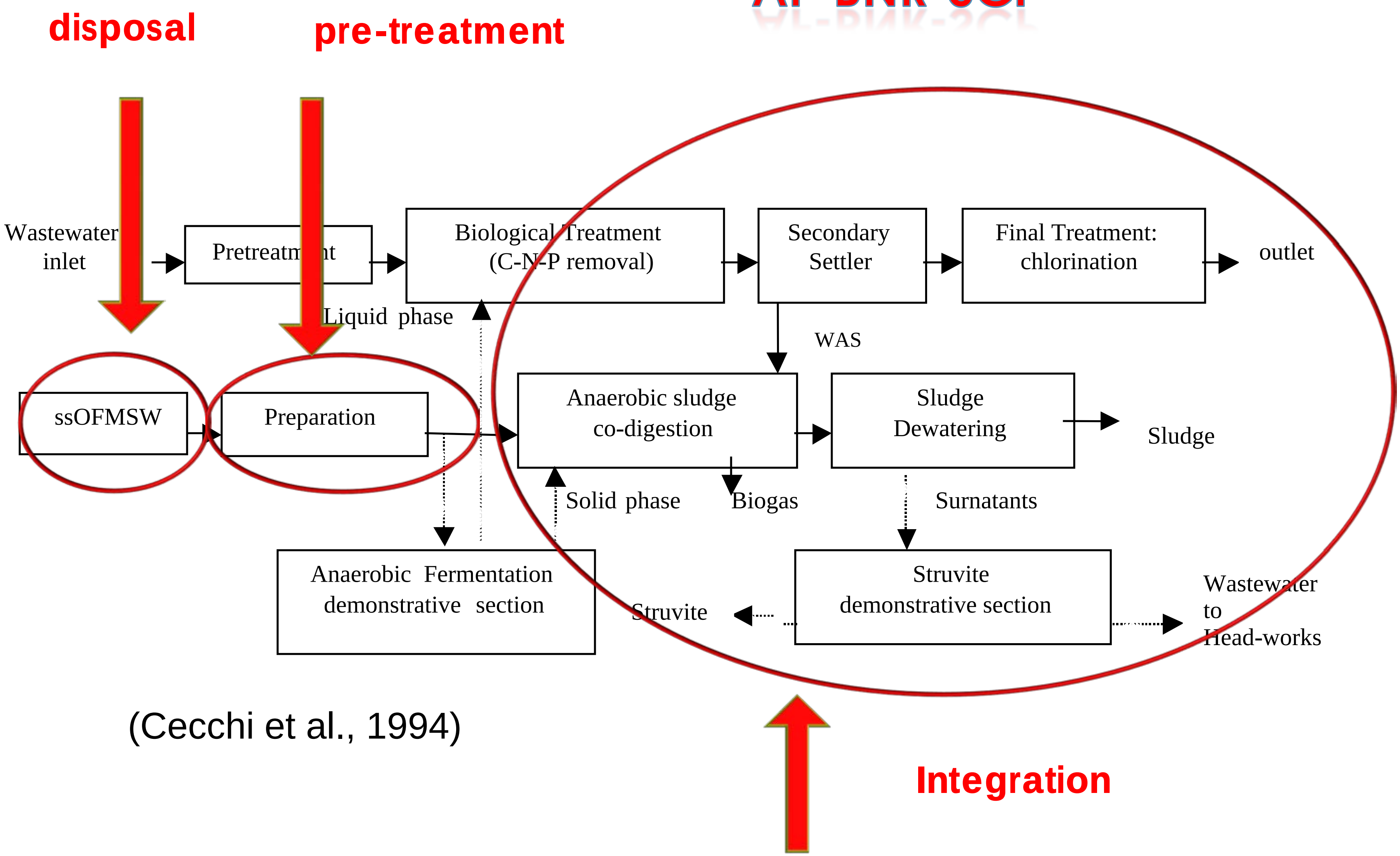
WHAT WE NEED TO KNOW?

Considering the pioneering works on integrated organic waste and wastewater treatment and the increasing of co-digestion studies, we can conclude that this approach is mature both from the process and technological point of view, than we can try to give a panoramic in terms of

TECHNOLOGIES AND PROCESSES

INTRODUCTION

BIOWASTE AND WASTEWATER INTEGRATED TREATMENT AF-BNR-SCP



(Cecchi et al., 1994)

TECHNOLOGIES

BIOWASTE DISPOSAL

Source Separate Collection

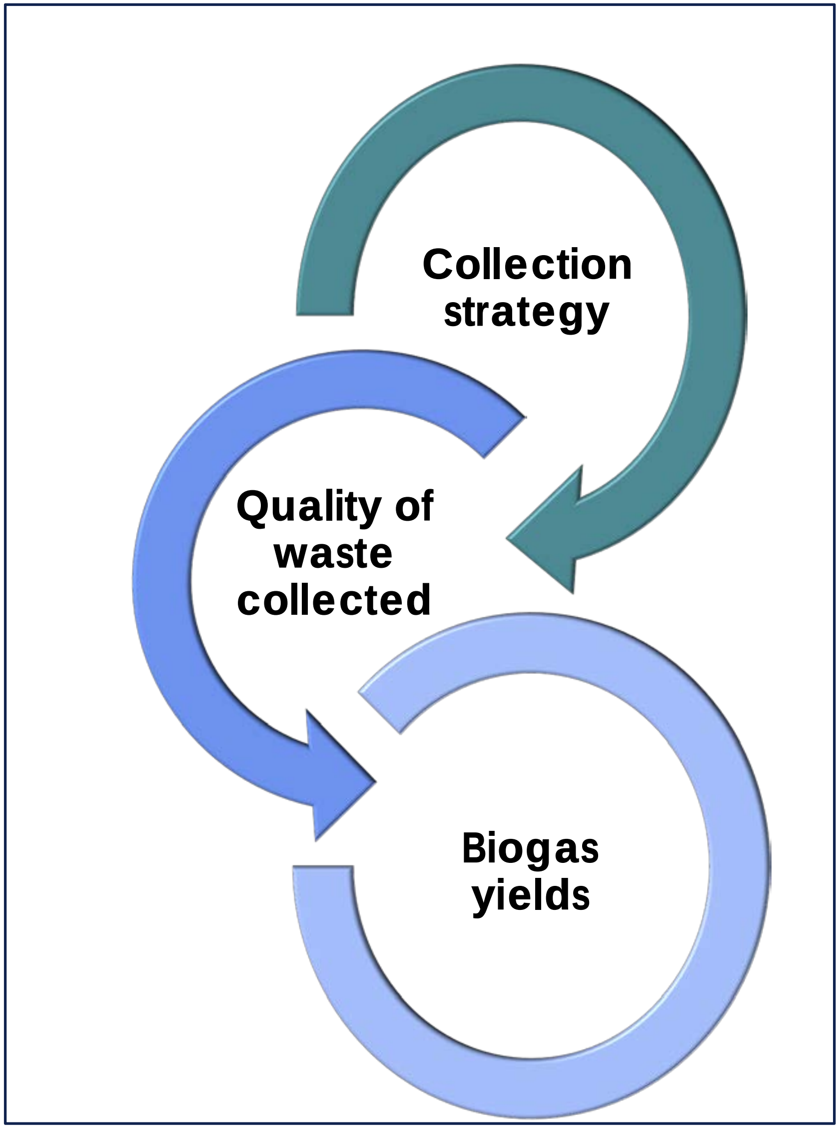
Door to door collection

Residential area collection

Street collection

Feedstock quality

- MS-OFMSW: mechanically selected
- SS-OFMSW: source sorted
- SC-OFMSW: separate collected



Main characteristics of the biowaste treated and comparison with literature data (Mata-Alvarez, 2003).

	Total solids, %	Volatile fraction, %TS	Organic fraction, % (putrescible+paper)	Ref
Rovereto (TN)	20-24	80-90	na	
Camposampiero (PD)	29	80	90 – 95	Bolzonella et al., 2005a
Treviso	30	76	70 – 75	Bolzonella et al., 2006a
SS-biowaste	16 – 20	88 – 90	na	Mata-Alavarez, 2003
SC-biowaste	29 – 31	63 – 70	na	Mata-Alavarez, 2003
MS-biowaste	75	45	55	Mata-Alavarez, 2003

SS-biowaste shows a better quality compared to SC-biowaste and MS- definetively have to be rejected as approach

TECHNOLOGIES

BIOWASTE PREPARATION AND TRANSPORT

1) Source Separate Collection

2) Under Sink Food Waste disposer

WWTP

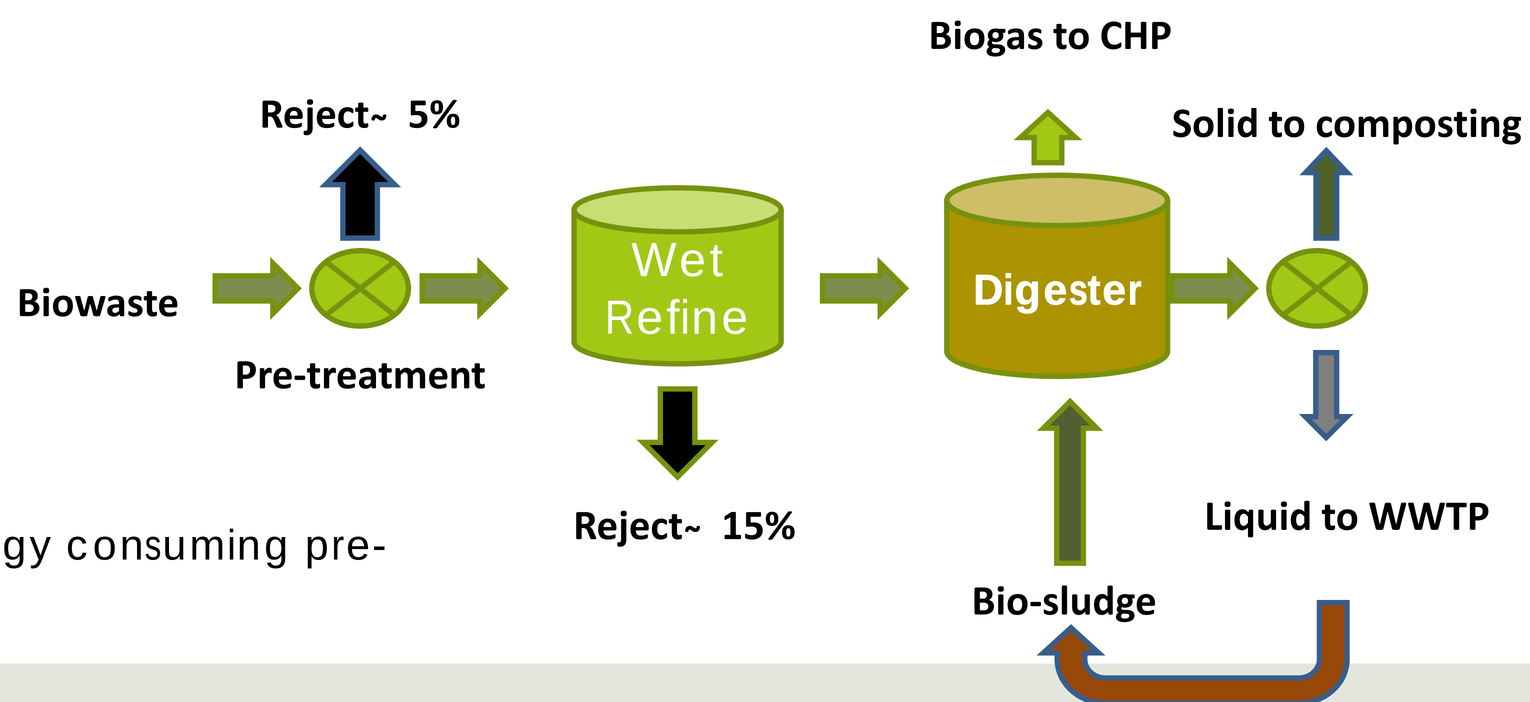
TECHNOLOGIES

Biowaste pre-treatments: Case Studies

Treviso (Italy)

Wet Refine (AcoD Process)

Design capacity, t/y	14.500 SC-biowaste 50.000 sludge (5% TS)
Process	Wet
Reactors	1 x 2200 m^3
Temperature	Mesophilic/Thermophilic



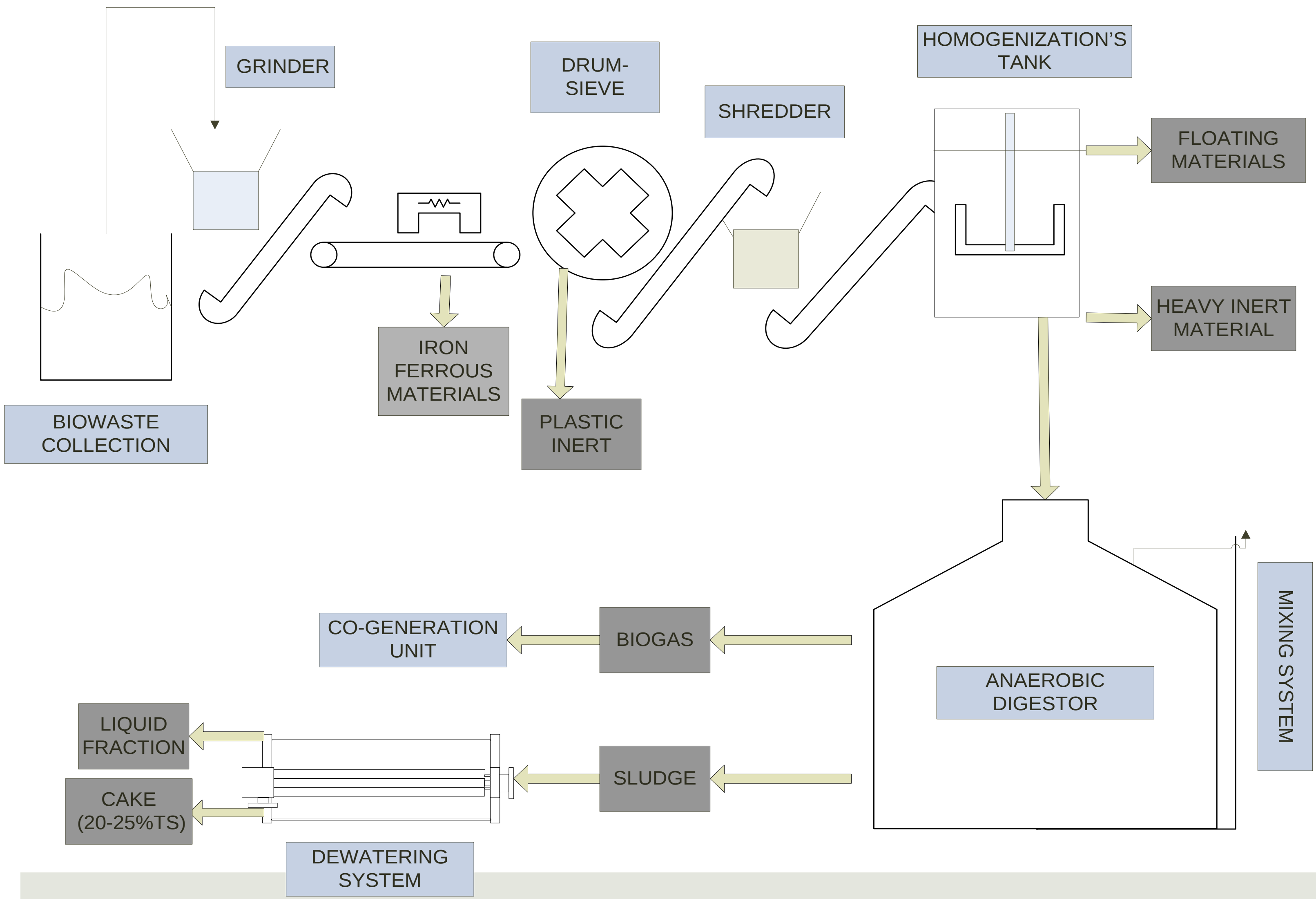
"SOFT" energy consuming pre-treatment

TECHNOLOGIES

Biowaste pre-treatments: Case Studies

Treviso (Italy)

Wet Refine (AcoD Process)



Biowaste pre-treatments: Case Studies

Treviso (Italy)

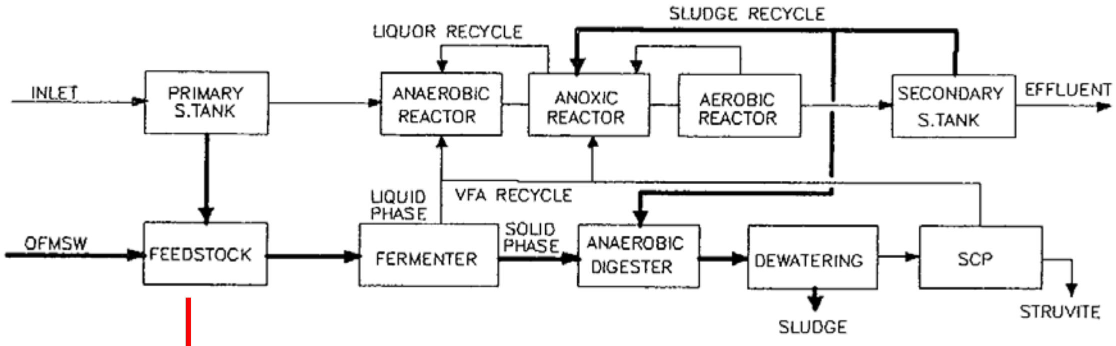


Fig. 1. Flow-sheet of the integrated AF-BNR-SCP process.

Biowaste pre-treatments: Case Studies

Treviso (Italy)

	Treviso
Feed characteristics	
Flow, m^3/d	10 biowaste + 100 sludge
TS, %	4,2
TVS, %TS	70
Operational parameters	
OLR, $kgVS/m^3d$ (total)	1.5
OLR, $kgVS/m^3d$ (biowaste)	0.8
HRT, d	20-24
Temperature, °C	35-37
Yields	
Biogas, Nm^3/d	950
Methane, %	60-66
Specific, Nm^3/t biowaste	100
SGP, $Nm^3/kgVS$ (% biowaste)	0.43 (55% bw)
TS removal, %	28
VS removal, %	39

Biowaste pre-treatments: Case Studies

Treviso (Italy)

Comparison between 3 different process condition

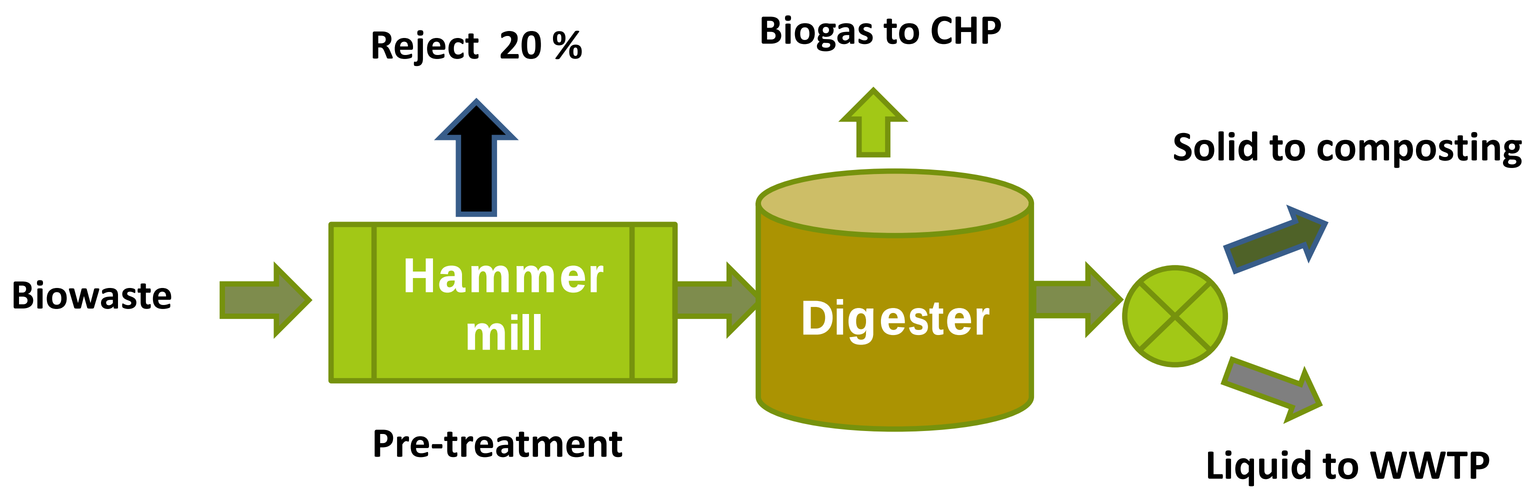
	Sludge only	Full Scale Mesophilic Codigestion	Full scale Thermophilic Codigestion
HRT, d	37.2	35.6	22
OLR, kgTVS/m^3d	0.53	0.78	1.28
SGP, m^3/kgTVSa	0.13	0.43	0.55
GPR, m^3/m^3d	0.10	0.34	0,70
pH	6.9	7.2	7.6
TA(pH 4), mg$CaCO_3$/l	1,865	3,058	2,533

Biowaste pre-treatments: Case Studies

Rovereto (TN, Italy)

Hammer Mill

Design capacity, t/y	5.000 SS-biowaste 110.000 sludge (5% TS)
Actual Capacity, t/y	3.000 SS-biowaste 70.000 sludge (x% TS)
Process	Wet
Reactors	2 x 2.500 m^3
Temperature	Mesophilic



"MEDIUM" energy consuming pre-treatment

Biowaste pre-treatments: Case Studies

Rovereto (TN, Italy)

Biowaste pre-treatments: Case Studies

Rovereto (TN, Italy)

Biowaste pre-treatments: Case Studies

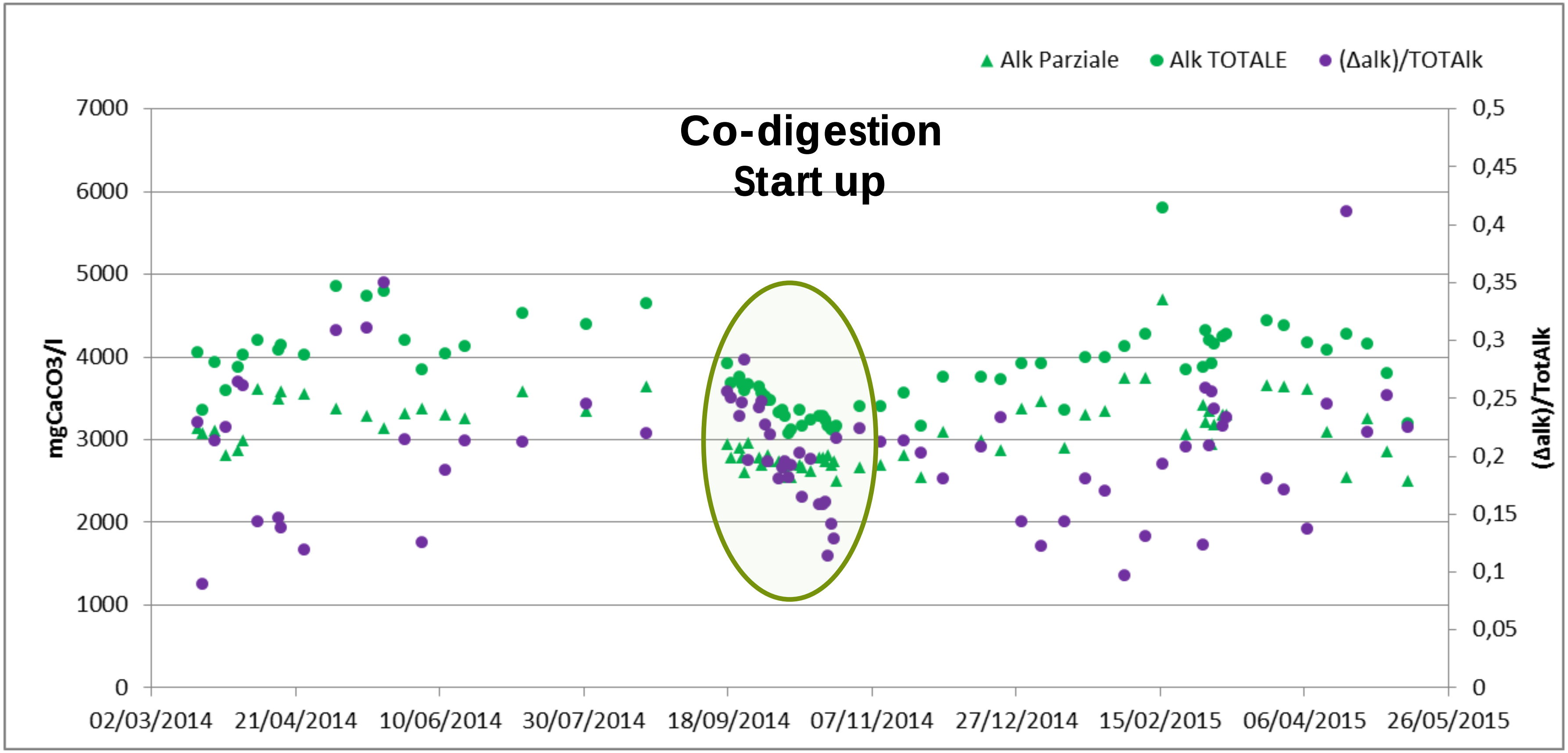
Rovereto (Italy)

	Rovereto
Feed characteristics	
Flow, m^3/d	7.8 biowaste + 195 sludge
$TS_{biowaste}$, %	5.2
TVS, %TS	82
TS_{sludge}, %	5.1
TVS, %TS	79
Operational parameters	
OLR, $kgVS/m^3d$ (total)	1.01
OLR, $kgVS/m^3d$ (biowaste)	0.19
HRT, d	12-25
Temperature, °C	35-37
Yields	
Biogas, Nm^3/d	2,697
Methane, %	54-69%
Specific, Nm^3/t biowaste	169
SGP, $Nm^3/kgVS$ (% biowaste)	0.54
TS removal, %	56
VS removal, %	69

TECHNOLOGIES

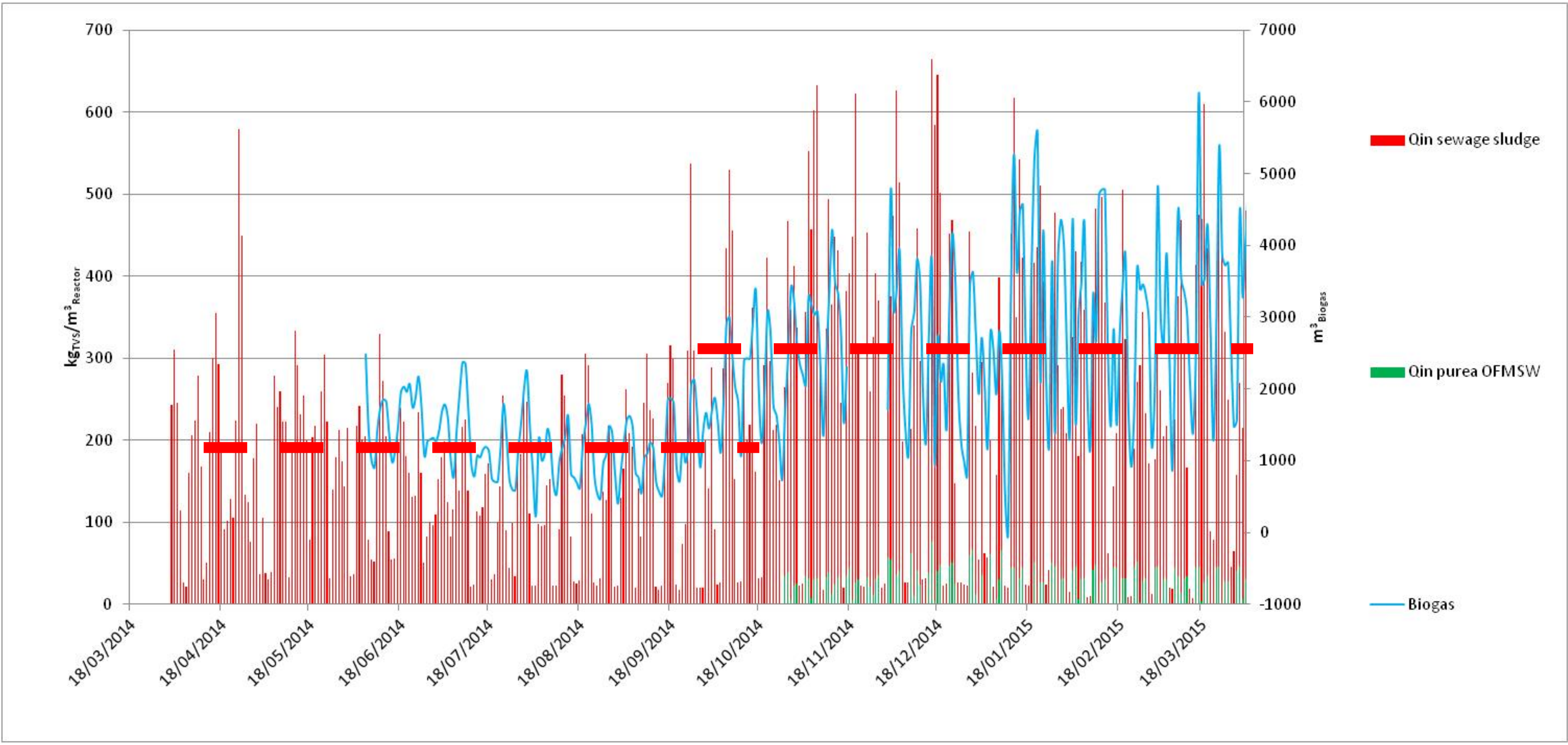
Biowaste pre-treatments: Case Studies

Co-digestion of sludge and pretreated OFMSW, focus on start up (1-2 ton/d of OFMW)



Biowaste pre-treatments: Case Studies

Co-digestion of sludge and pretreated OFMSW (Rovereto, TN, Italy)



Biowaste pre-treatments: Case Studies

Co-digestion of sludge and pretreated OFMSW (Rovereto, TN, Italy)

	Sludge	Co-digestion sludge-OFMSW
Hydraulic retention time, (HRT, d)	20-30	15-25
Organic loadin rate (OLR, kgVS/m^3 per day)	0,82±0,62	0,98±0,78
Gas production (GP, m^3/d)	1257±489	2260±950
Specific gas production (SGP, m^3/kgVS)	0,30	0,46
Gas production rate (GPR, m^3/m^3d)	0,25±0,10	0,45±0,19
Sludge diposed (t/d)	10-11	11-12

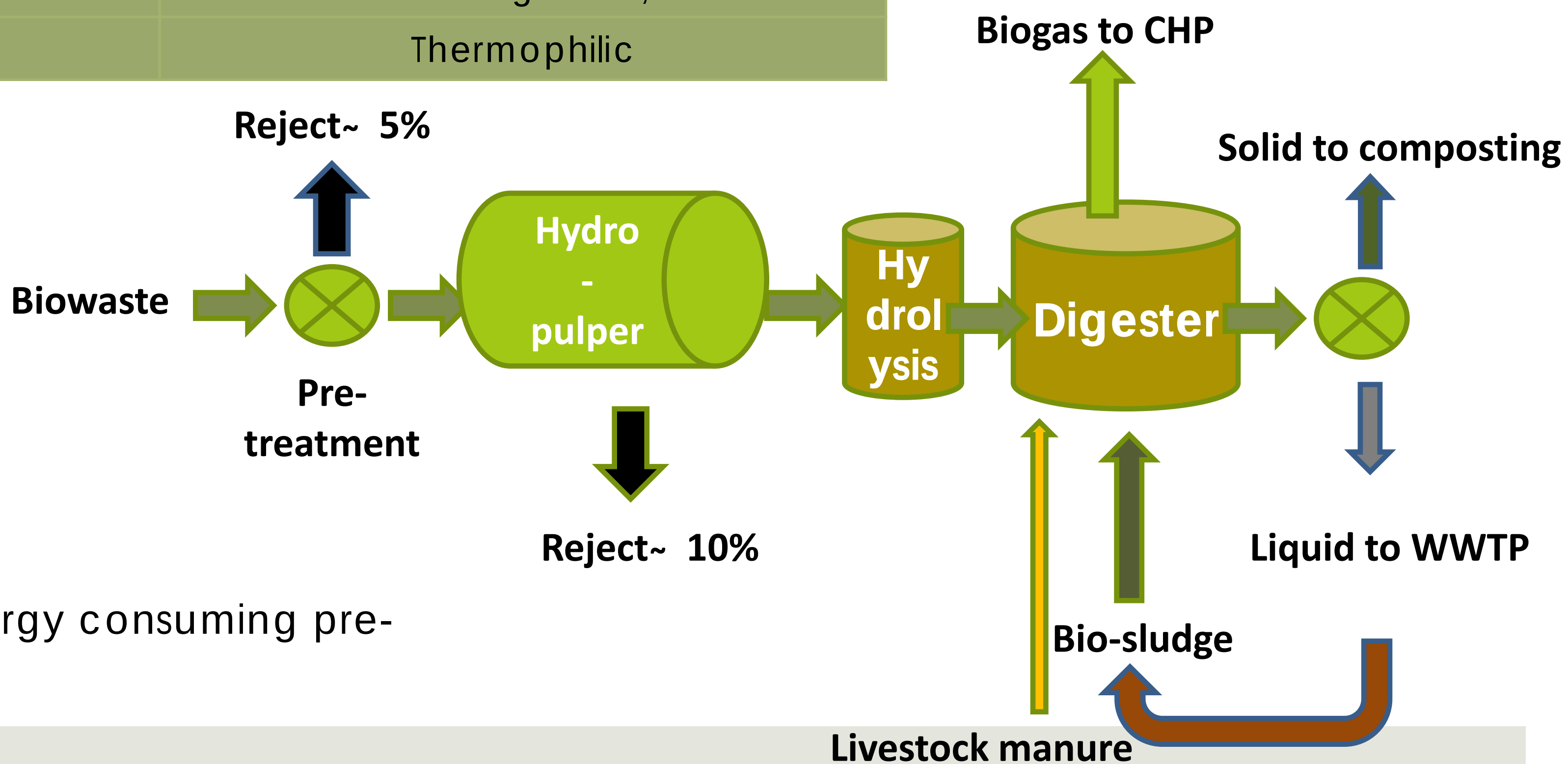
TECHNOLOGIES

Biowaste pre-treatments

Camposampiero (PD, Italy)

Hydropulper

Design capacity, t/y	16.000 SS-biowaste 25.000 manure 7.800 sludge (8% TS)
Actual capacity, t/y	13.000 SS-biowaste 3.000 manure 7.800 sludge (8% TS)
Process	Wet, 2-phases (Linde)
Reactors	1 x hydrolysis, 750 m^3 1 x methanogenesis, 3300 m^3
Temperature	Thermophilic



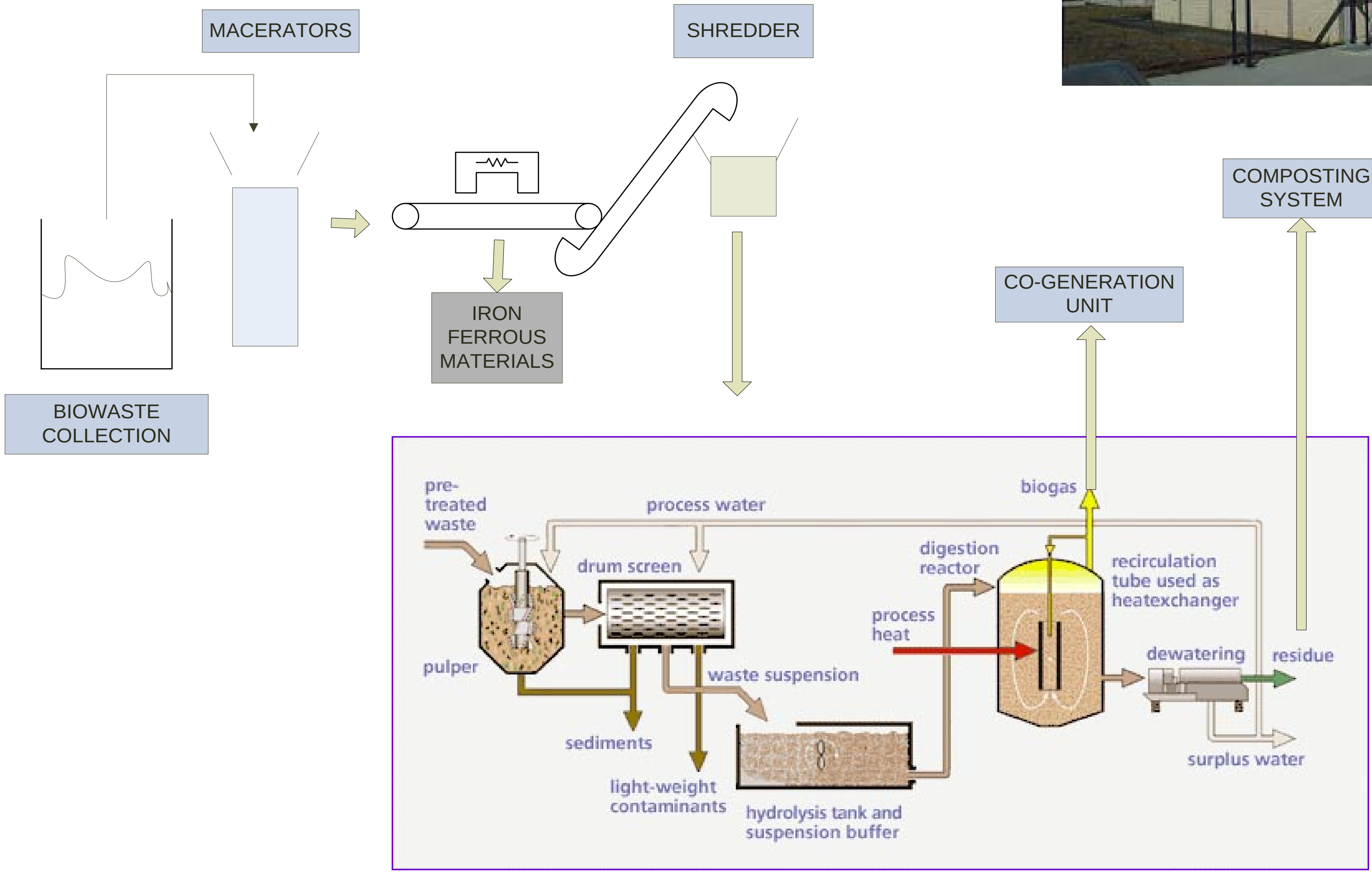
“HIGH” energy consuming pre-treatment

TECHNOLOGIES

Biowaste pre-treatments

Camposampiero (PD, Italy)

Hydropulper



LINDE PROCESS

TECHNOLOGIES

Biowaste pre-treatments: Case Studies

Camposampiero (PD, Italy)

Biowaste pre-treatments: Case Studies

Camposampiero (Italy)

	Camposampiero
Feed characteristics	
Flow, m^3/d	37 biowaste + 8 manure + 22 sludge
TS, %	7
TVS, %TS	82
Operational parameters	
OLR, $kgVS/m^3d$ (total)	3.5
OLR, $kgVS/m^3d$ (biowaste)	2.5
HRT, d	22
Temperature, °C	52-55
Yields	
Biogas, Nm^3/d	4,900
Methane, %	58-60
Specific, Nm^3/t biowaste	143
SGP, $Nm^3/kgVS$ (% biowaste)	0.67 (67% bw)
TS removal, %	56
VS removal, %	70

Under Sink Food Waste Disposer

The under sink food waste disposer was invented by John Hammes, 1927

TODAY ARE 110 ML The UNDER SINK DISPOSER INSTALLED IN THE WORLD

10-15%	AUSTRALIA, JAPAN, BRAZIL and CENTRAL AMERICA,
20%	NEW ZEALAND.
5%	UNITED KINGDOM
60-70%	USA

Under Sink Food Waste Disposer: Case Studies

Application problems:

- Sewage sewer: settling, clogging
- Water body: pollution
- WWTP: overload, higher sludge production

What the literature refers

About sewage sewer

- No problems of clogging
- No need of extraordinary measure to the sewer system (*Technical Report, New York City Department, 1999*)
- No particular problems due to solid loads in wastewater (*University of Lund, Sweden, Nilsson et al., 1990*)
- No problem of clogging, fouling and sedimentation

  (*Technische Universiteit Delft, Holland, De Koning, Van der Graaf, 1996*)

About sewage sewer

- Sedimentation problems only due to incorrect use of FVD

  (*Technical Report, Gatto, 2000*)

- Partial hydrolysis and not fermentation take place;
- No methanogenic phenomena in the sewer

  (*WS&T, Pavan et al., 1998 and Environmental Technology, Bolzonella et al.,2002*)

About water body

- During raining periods, overflow draws suspended solids

  (Technical Report, *New York City Department, 1999*)

- Settling overflow systems allow to overcome the problem

  (*Technische Universiteit Delft, Holland, De Koning,*

  Van der Graaf, 1996)

About wastewater treatment plant

- Increase of O_2 demand for BOD and ammonia oxidation
- additional costs for nitrate removal
- concentration increase of main parameters: SS, COD …
- savings in the MSW disposal
- any worsening of treated wastewater quality

(Technical Report, New York City Department, 1999)

About wastewater treatment plant

- Increase of COD, BOD, SS, nitrogen and phosphorus
- increase of primary sludge (from 52 to 89 g / PE d)
- increase of energy consumption, of 9 kWh / PE y
- increase of biogas in anaerobic sludge stabilization
- increase of thermal energy produced: from 54 to 109 kWh/PE,y

(University of Lund, Sweden, Nilsson et al., 1990)

About wastewater treatment plant

- No management problem
- Increase biogas production of 17 l / d PE

(Technische Universiteit Delft, Holland, De Koning, Van der Graaf, 1996)

- Improvement biological nutrient removal
- Increase of O_2 demand
- increase biogas production with heat and EE recovery

(WS&T, Pavan et al., 1998; Environmental Technology, Bolzonella et al., 2002)

Furthermore….

- Reducing solid waste disposal (35 kg/EI y)
- Increase waste dry matter content (from 69 to 75%)
- Increase waste calorific value (from 3 to 3.85 MWh/t)
  (University of Lund, Sweden, Nilsson et al., 1990)

- savings on waste disposal
  (Technical Report, Gatto, 2000)

- Improve waste disposal with benefits for community
  (Technical Report, Bressi et al., 1998)

TECHNOLOGIES

Under Sink Food Waste Disposer: Two Case Studies

WATER RESEARCH 41 (2007) 893–903

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ELSEVIER

Application of food waste disposers and alternate cycles process in small-decentralized towns: A case study

Paolo Battistoni[a], Francesco Fatone[b,], Daniele Passacantando[a], David Bolzonella[b]*

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[b]*Department of Science and Technology, University of Verona, Strada Le Grazie 15, Cà Vignal, 37134 Verona, Italy*

Water and Environment Journal

Water and Environment Journal. Print ISSN 1747-6585

Surahammar: a case study of the impacts of installing food waste disposers in 50% of households

Tim D. Evans, FCIWEM[1], Per Andersson[2], Åsa Wievegg[2] & Inge Carlsson[2]

[1]Tim Evans Environment, Stonecroft, Ashtead, UK and [2]Surahammars KommunalTeknik AB, Surahammar, Sweden

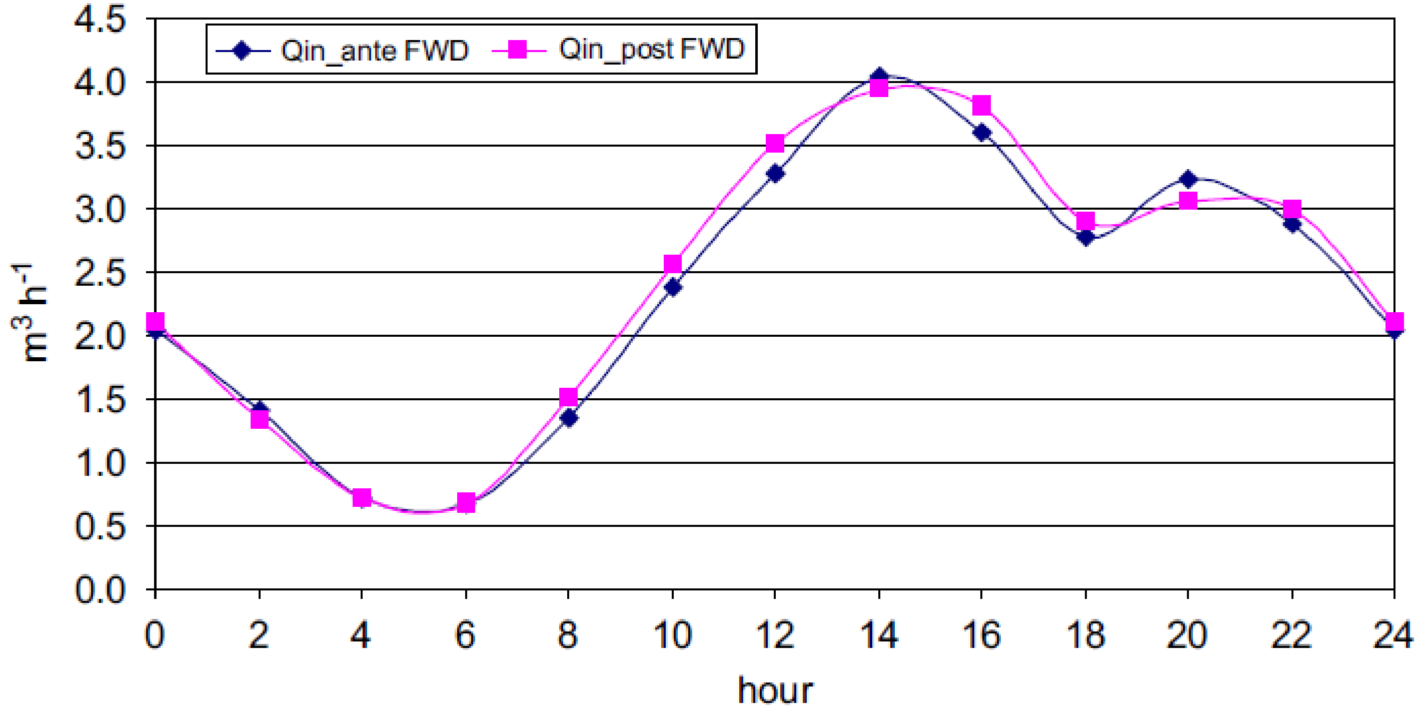
A Case Study with 67% penetration index
Small Village (Gagliole (MC) Italy), 670 inhabitants, about one year experience

Case Study with 15 years experience (penetration index 30-50%) (Surhammar, Swidish)

Under Sink Food Waste Disposer: Case Studies

Case Study: Gagliole, Italy

Typical daily fluctuations of influent to the WWTP, before and after the FWDs installations.



Under Sink Food Waste Disposer: Case Studies

Case Study: Gagliole, Italy

As commonly found in small systems, the influent COD, TSS, N and P during the experimentation were quite variable

Battistoni et al. 2007

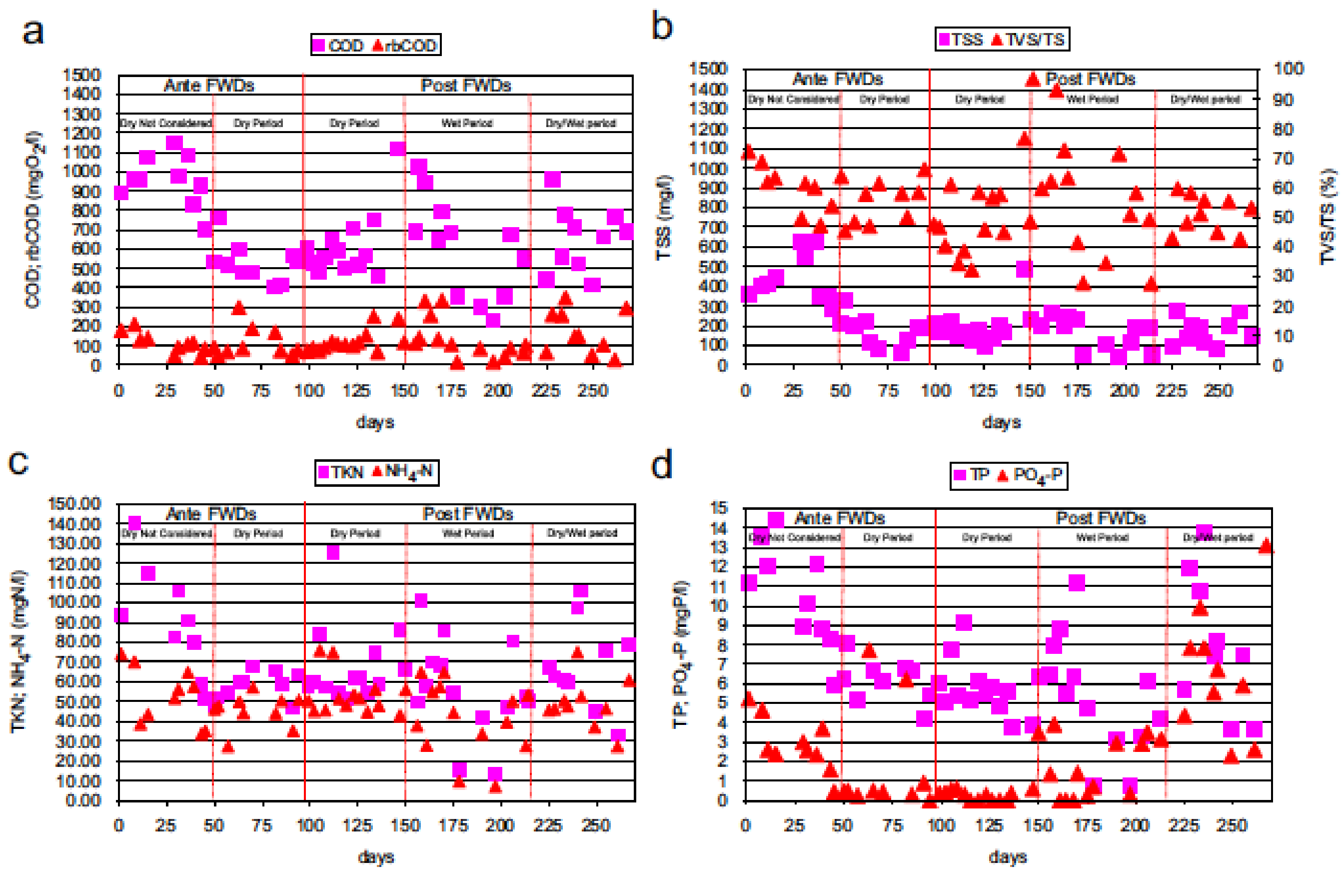


Fig. 3 – (a) COD, (b) suspended solids, (c) nitrogen and (d) phosphorus.

Under Sink Food Waste Disposer: Case Studies

Case Study: Gagliole, Italy

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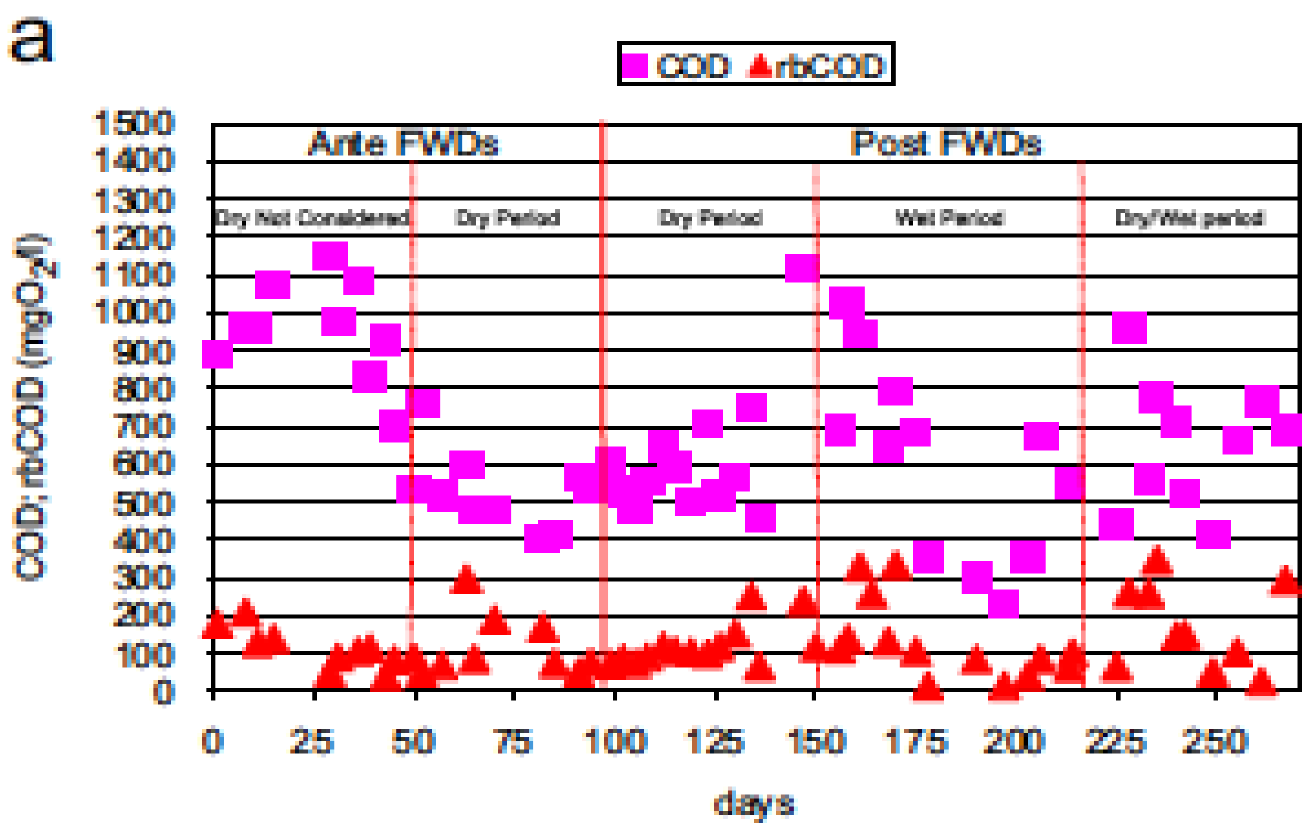

Battistoni et al. 2007

Under Sink Food Waste Disposer: Case Studies

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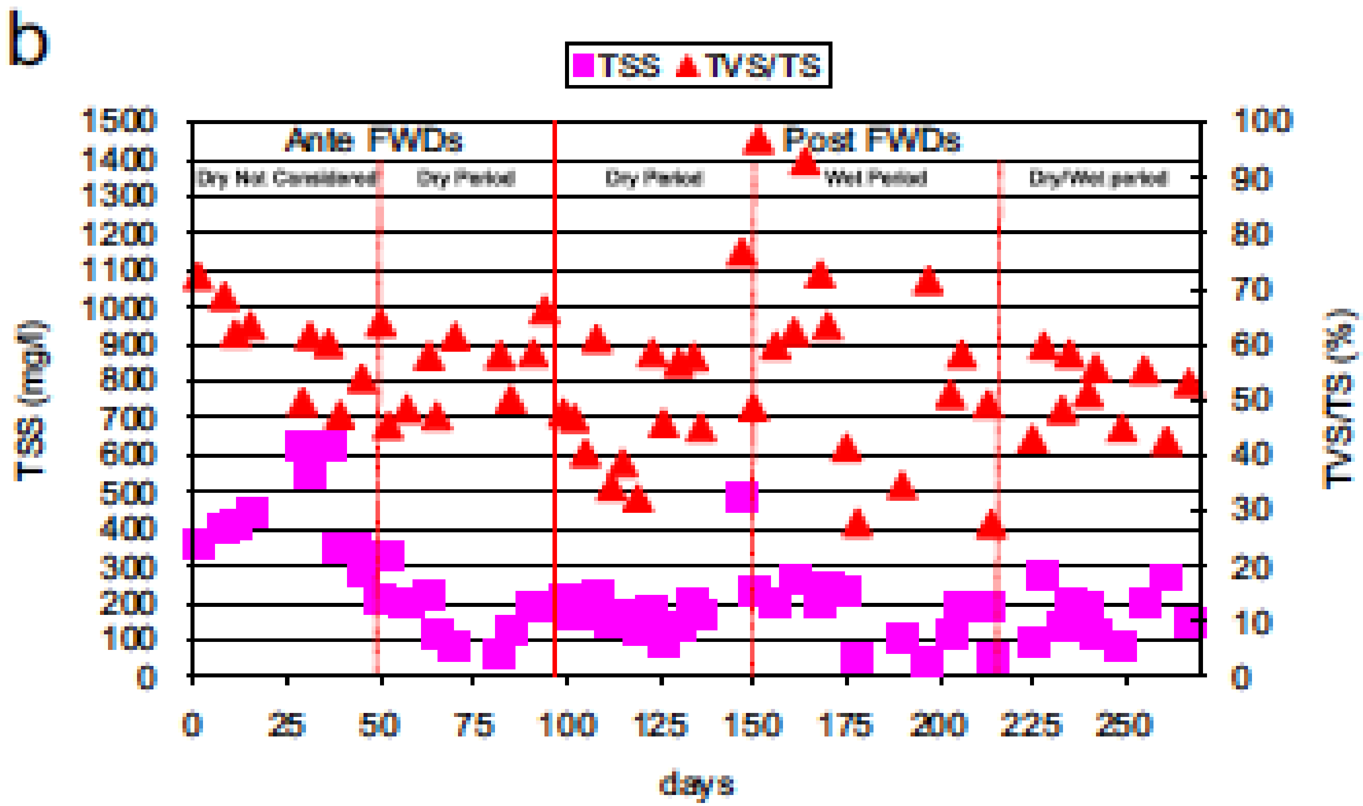

Under Sink Food Waste Disposer: Case Studies

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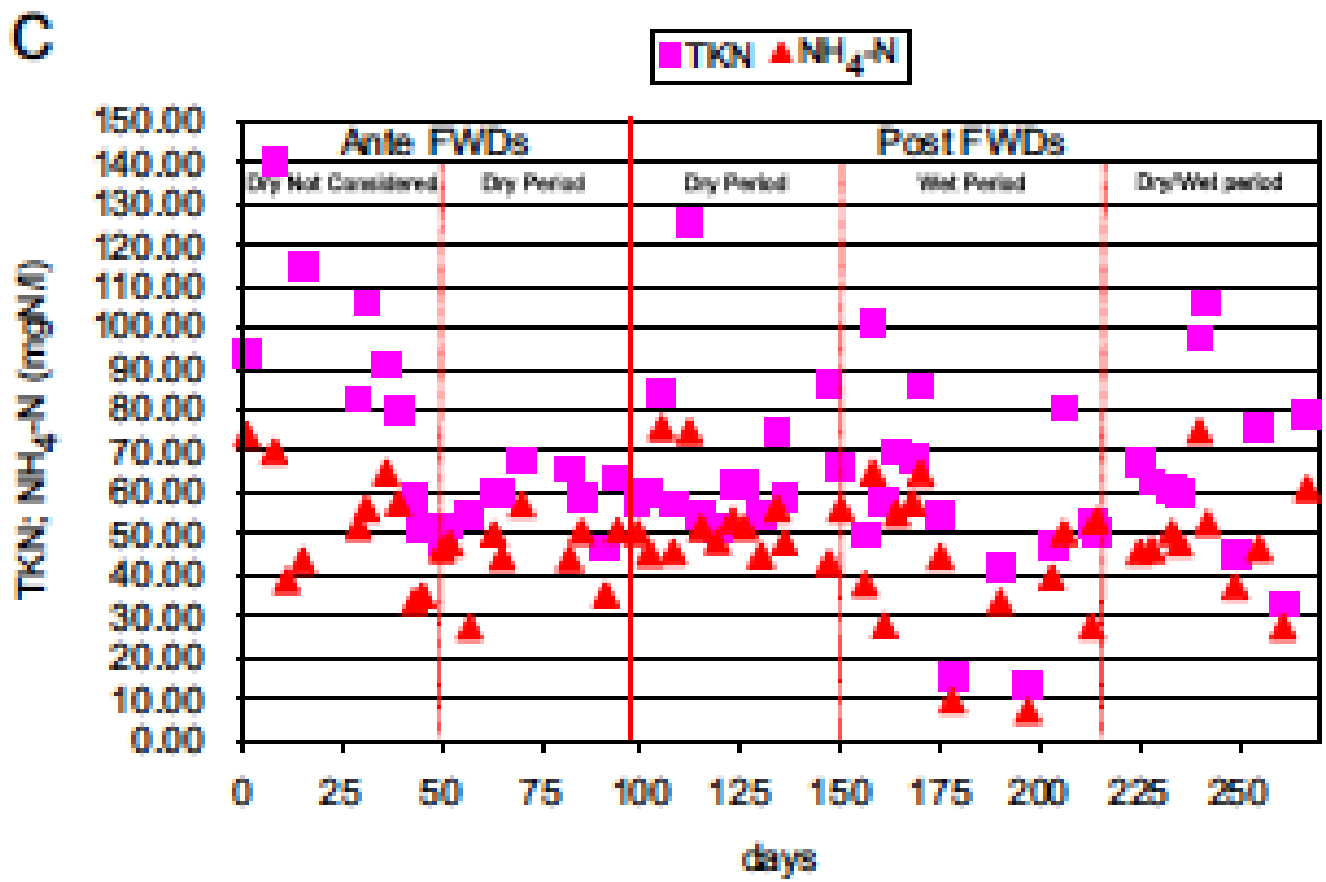

Under Sink Food Waste Disposer: Case Studies

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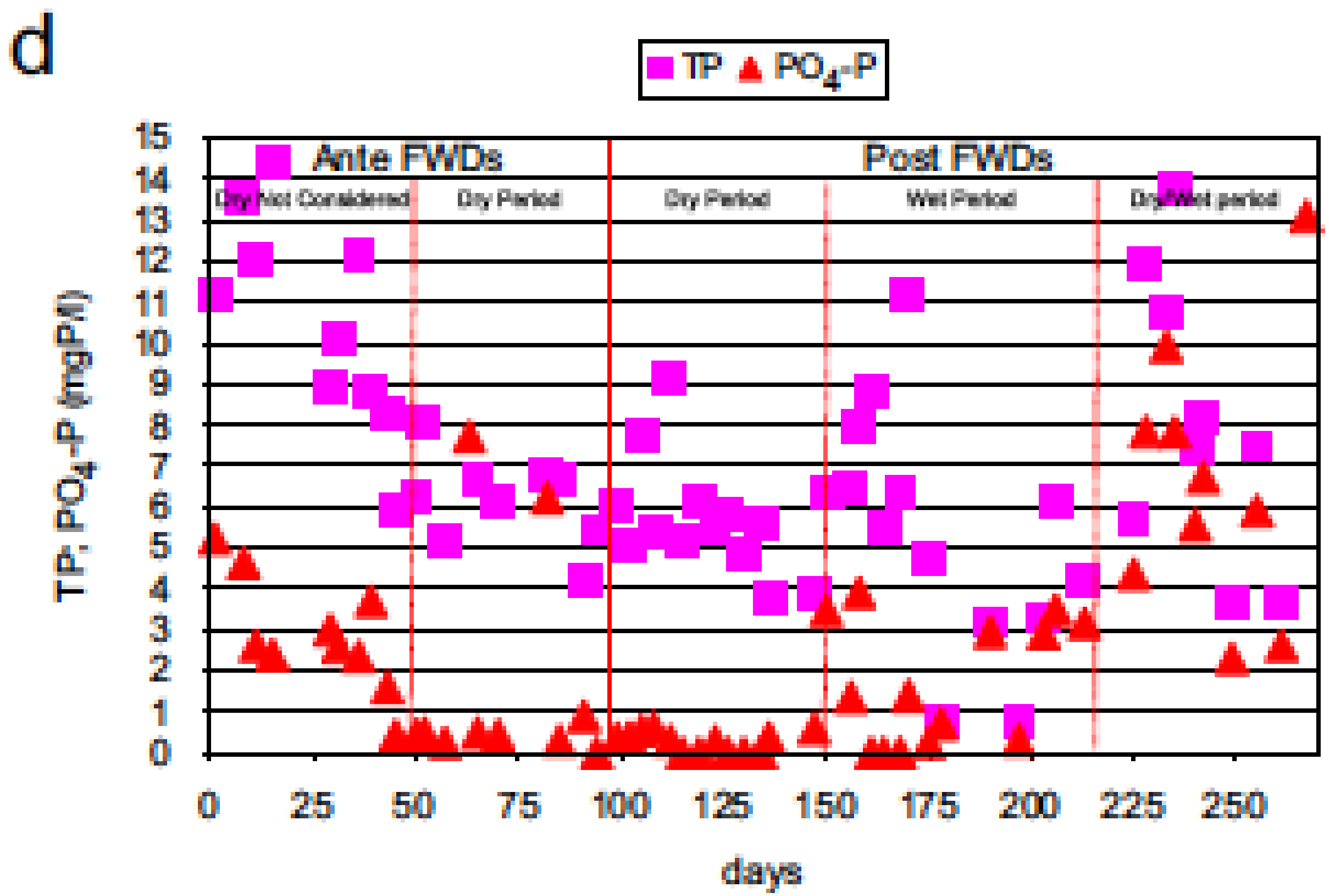
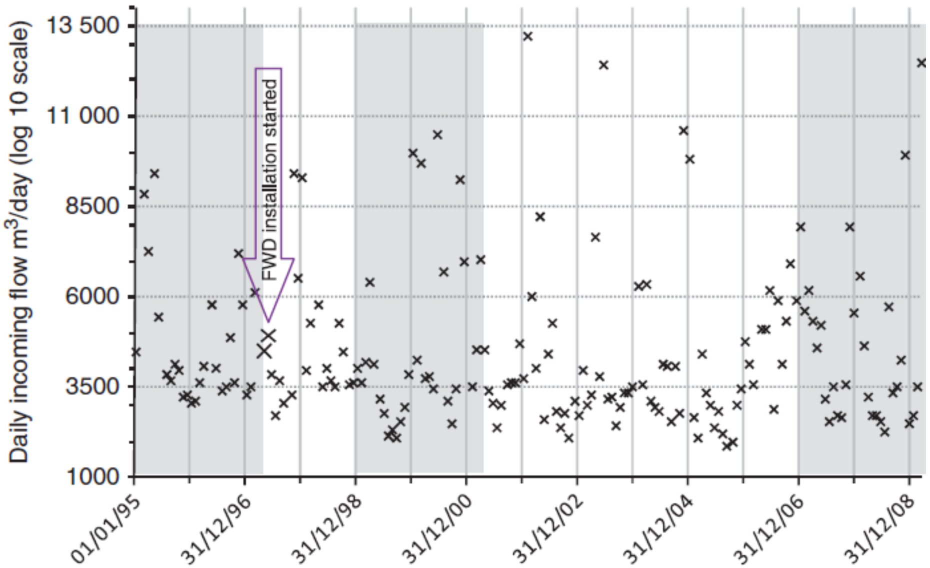
As commonly found in small systems, the influent COD, TSS, N and P during the experimentation were quite variable

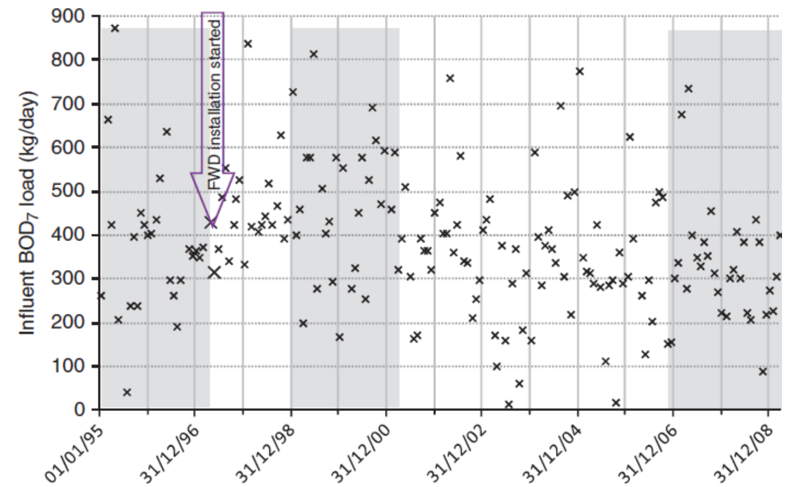
Battistoni et al. 2007

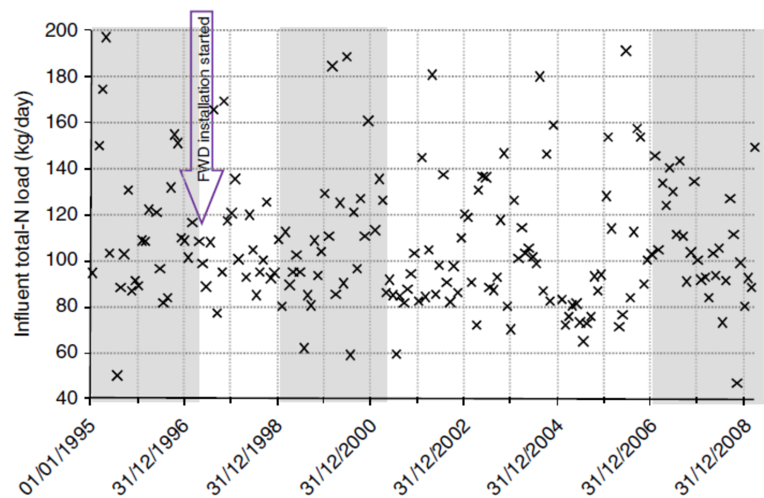


Under Sink Food Waste Disposer: Case Studies

Swedish case study (market penetration index 30-50%) (Surhammar)







The effect of the under sink disposer is not distinguishable

OFMSW characteristics and its behavior in the sewer system

SS size distribution analysis

50%	< 0.84 mm	(TVS 93%)
40%	> 0.84 < 2 mm	(TVS 98%)
10%	> 4.76 mm	(TVS 96%)

OFMSW characteristics and its behavior in the sewer system

Settling tests

- **Flotation: 30% (seasonal depending)**

- **Settling rate:**

OFMSW after Dissipation	16,0-25,0 m / h
SS sediments and sludge	1.1-1.8 m / h
Sands	40,0-60,0 m / h

Settling of Dissipated Biowaste mainly occurs in primary settling thank or secondary, inside the WWTP

Under Sink Food Waste Disposer: Case Studies

Case Study Gagliole, ITALY

10.000 PE		Integrated system with US disposer	Traditional collection
Investment cost per year (10 anni)			
Collection organization system	€ / y	96.330 *	2.960**
Costo di gestione			
Collection+transport	€ / y	0	191.400
Transport + disposal	€ / y	6.900	47.100
Annual total cost			
	€ / y	103.200	241.460

** cost of purchase and installation of sinks ** purchase costs of collection containers*

Costs Evaluation **Economic Considerations**

GLOBAL COSTS ARE SIGNIFICANTLY LOWER THAN THOSE OF THE TRADITIONAL COLLECTION OF OFMSW AND ITS TREATMENT

CONCLUSIONS

THE ONLY CONCLUSION THAT CAN BE DRAWN IS:

BIOWASTE AND WASTEWATER HAVE TO BE TRATED IN THE SAME PLANT

2–4 July 2015:
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management,
Tinos island, Greece

ISWM - TINOS 2015

THANK YOU FOR YOUR ATTENTION!

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