Il trattamento dei fanghi efficace ai fini del recupero in agricoltura

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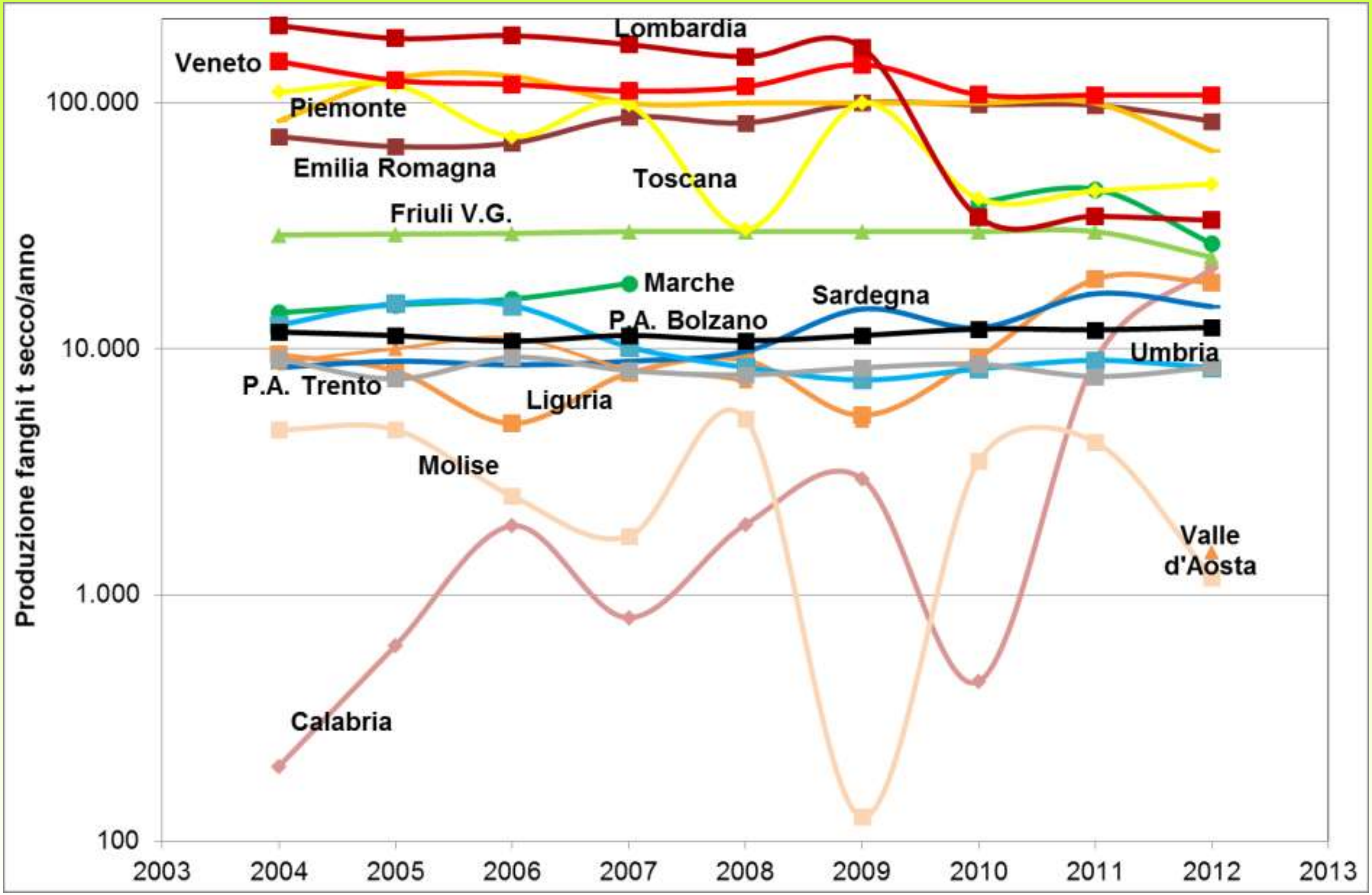
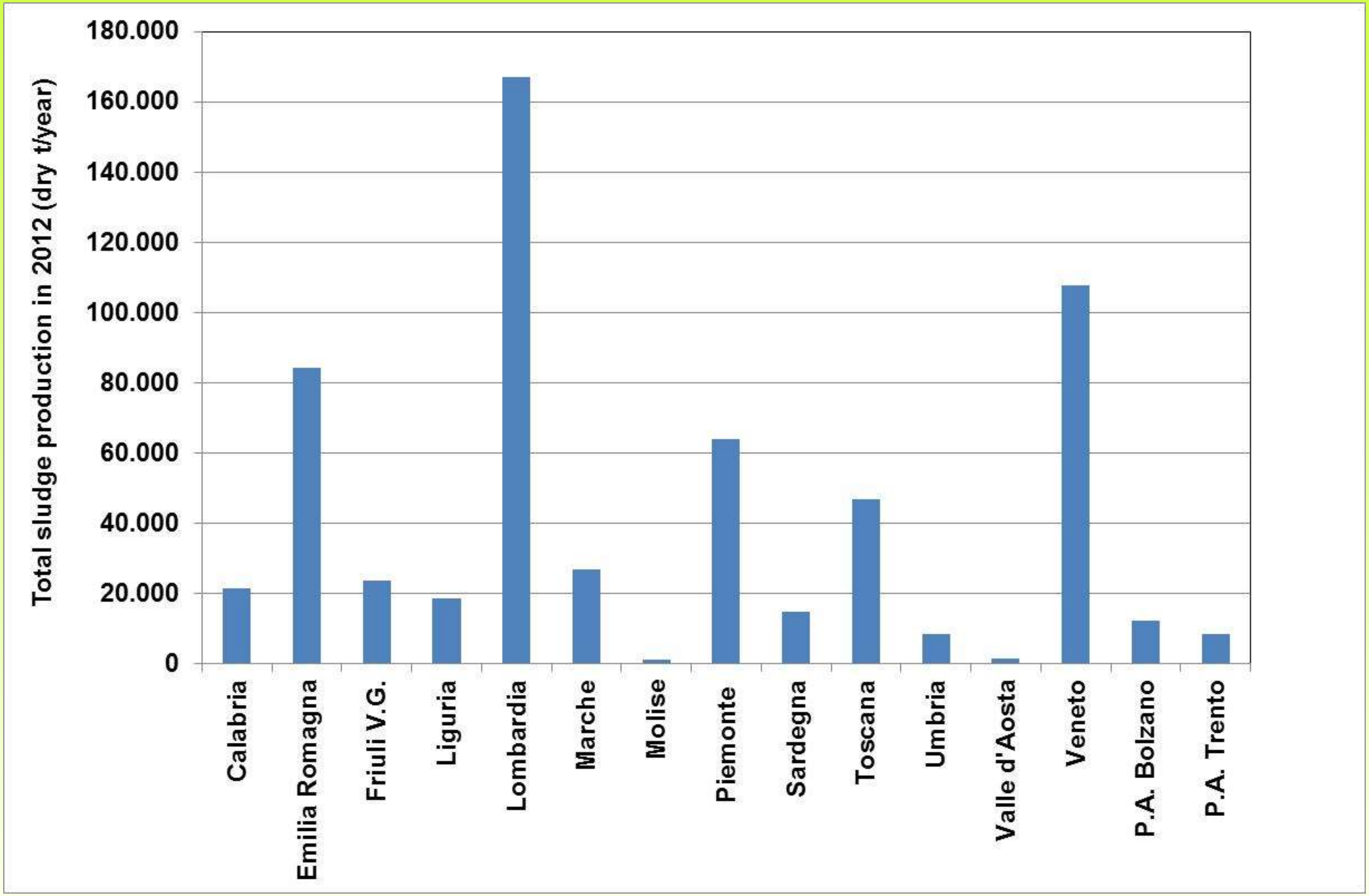
Acqua e Fanghi di Depurazione: Quali possibili riutilizzi?

Produzione di fanghi nelle regioni (t secco/anno)

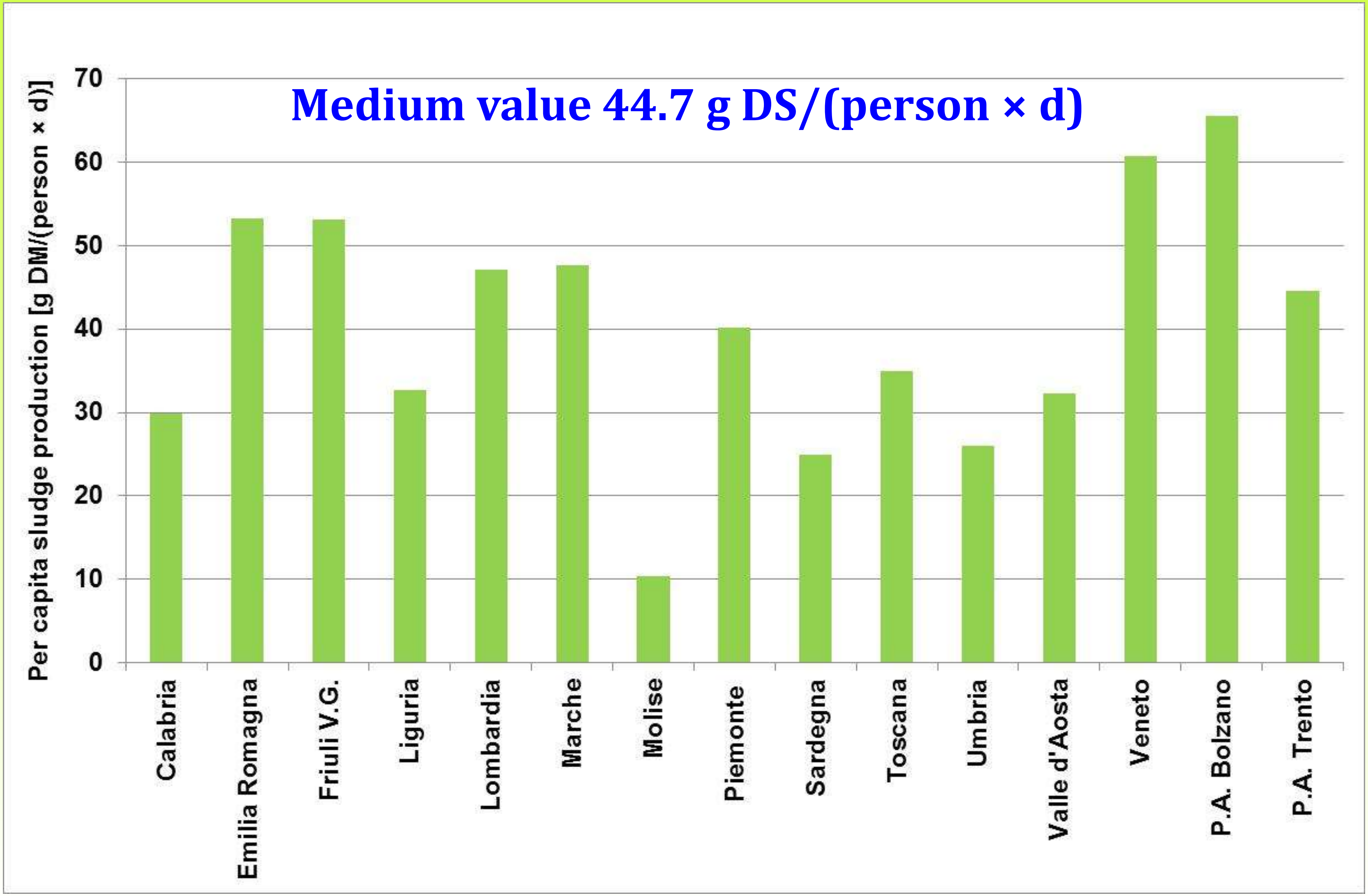


Total sludge production in 2012

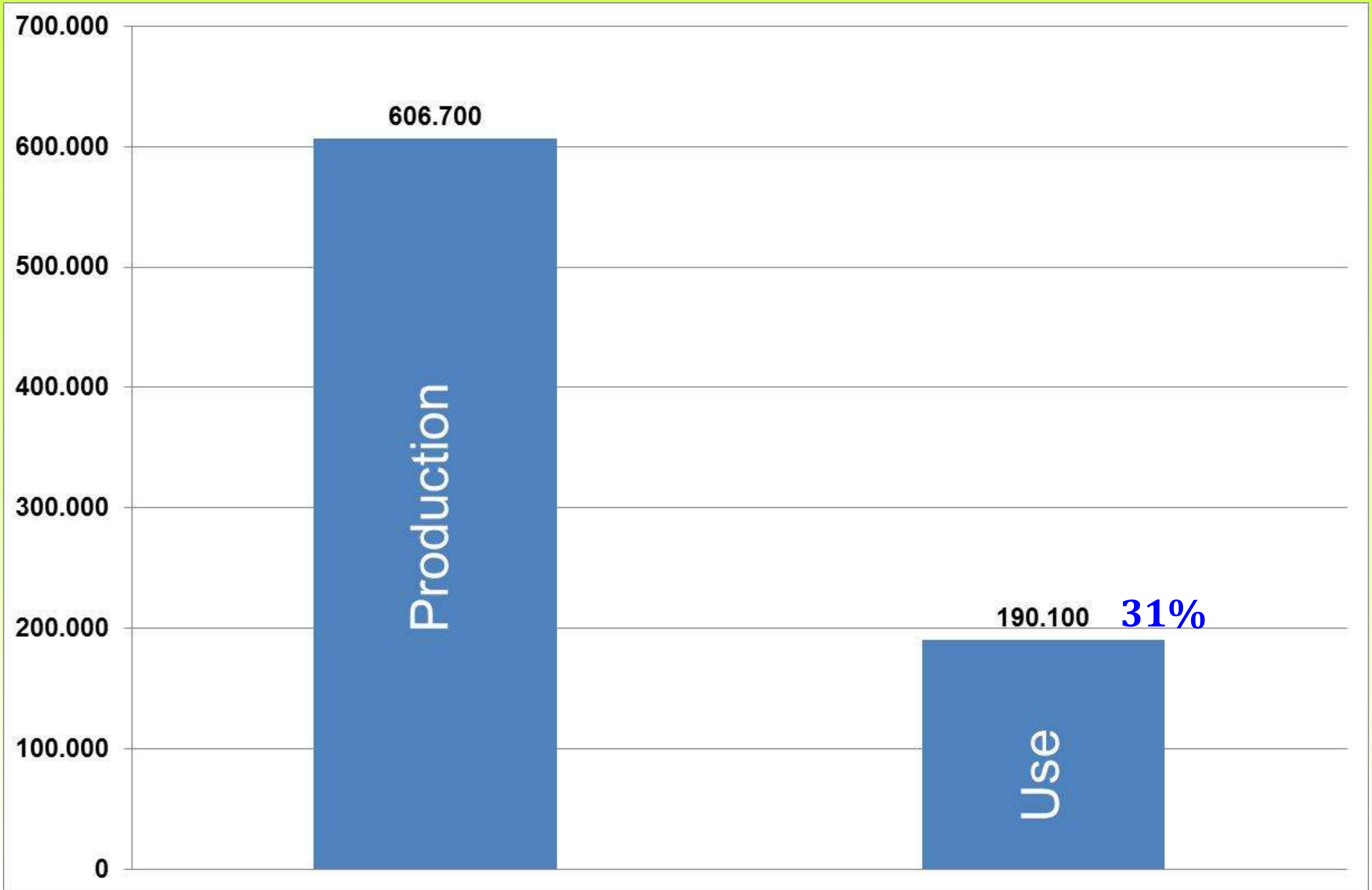


Production from 15 regions out of 21, accounting a population of 37.196.000, i.e. 63% of total=607.000 t. Expected total production 969.000 t

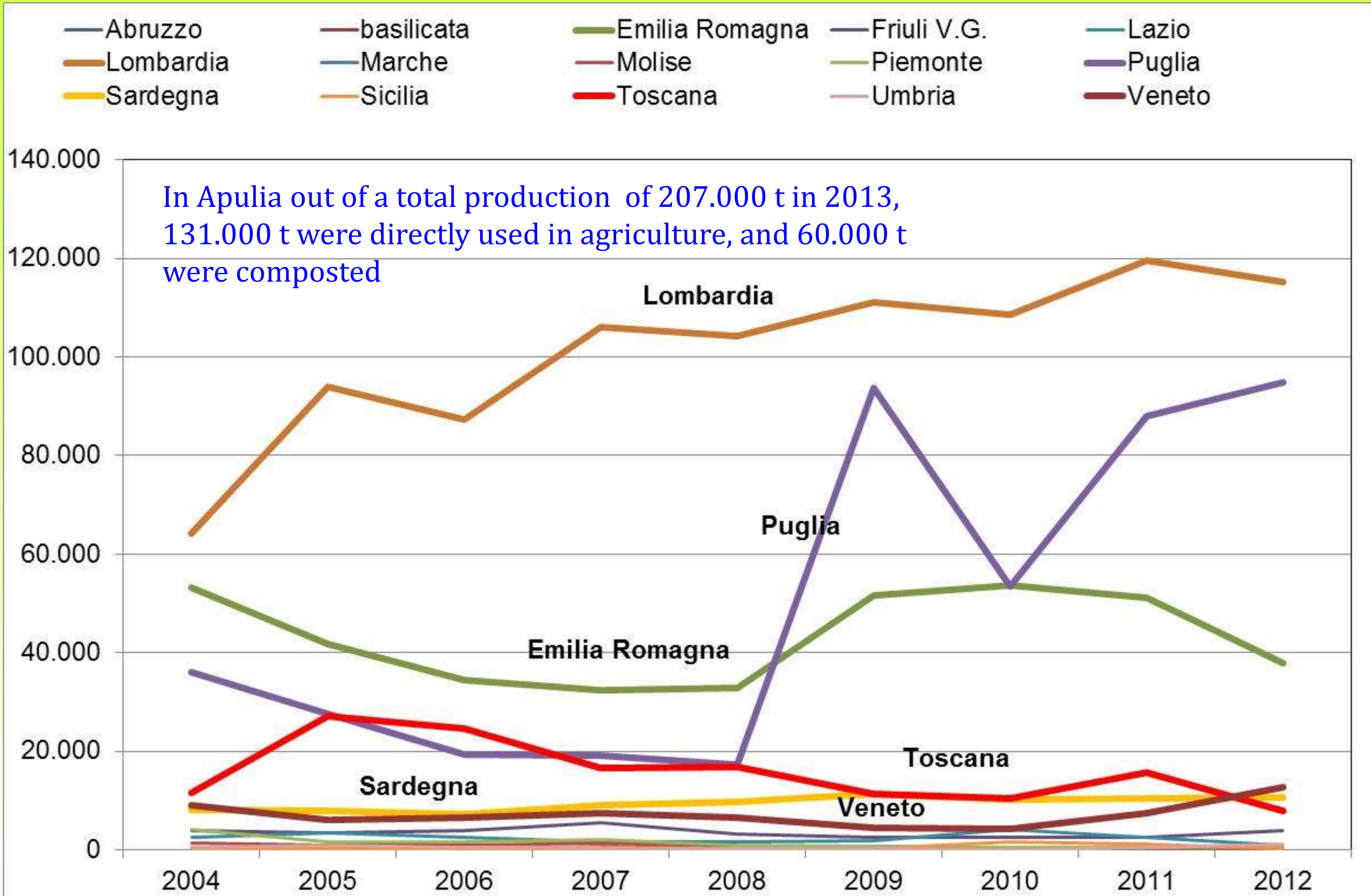
Per capita sludge production in 2012



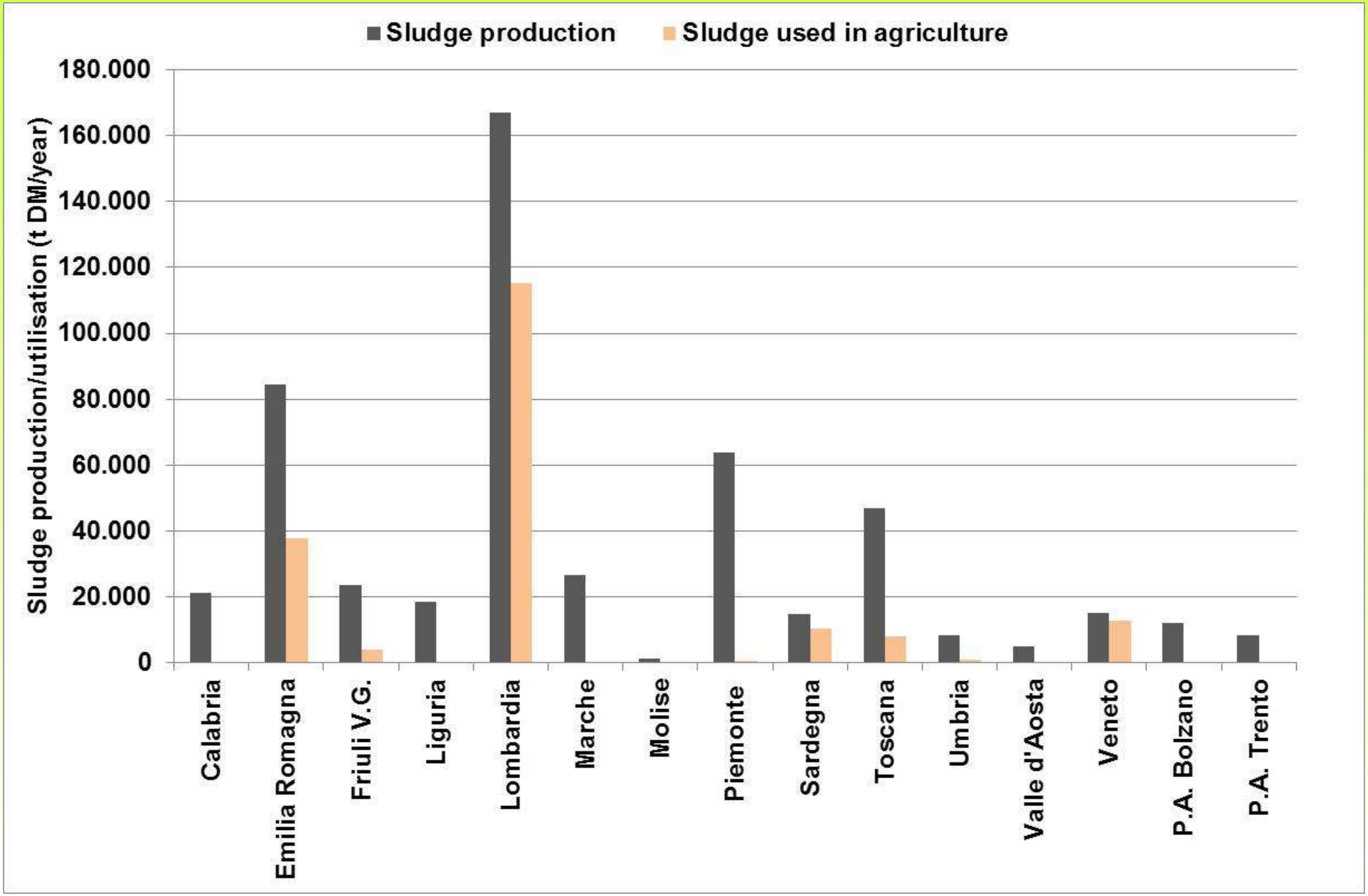
Comparison between production and utilisation in 2012



Agricultural use in different regions (t DM/year)



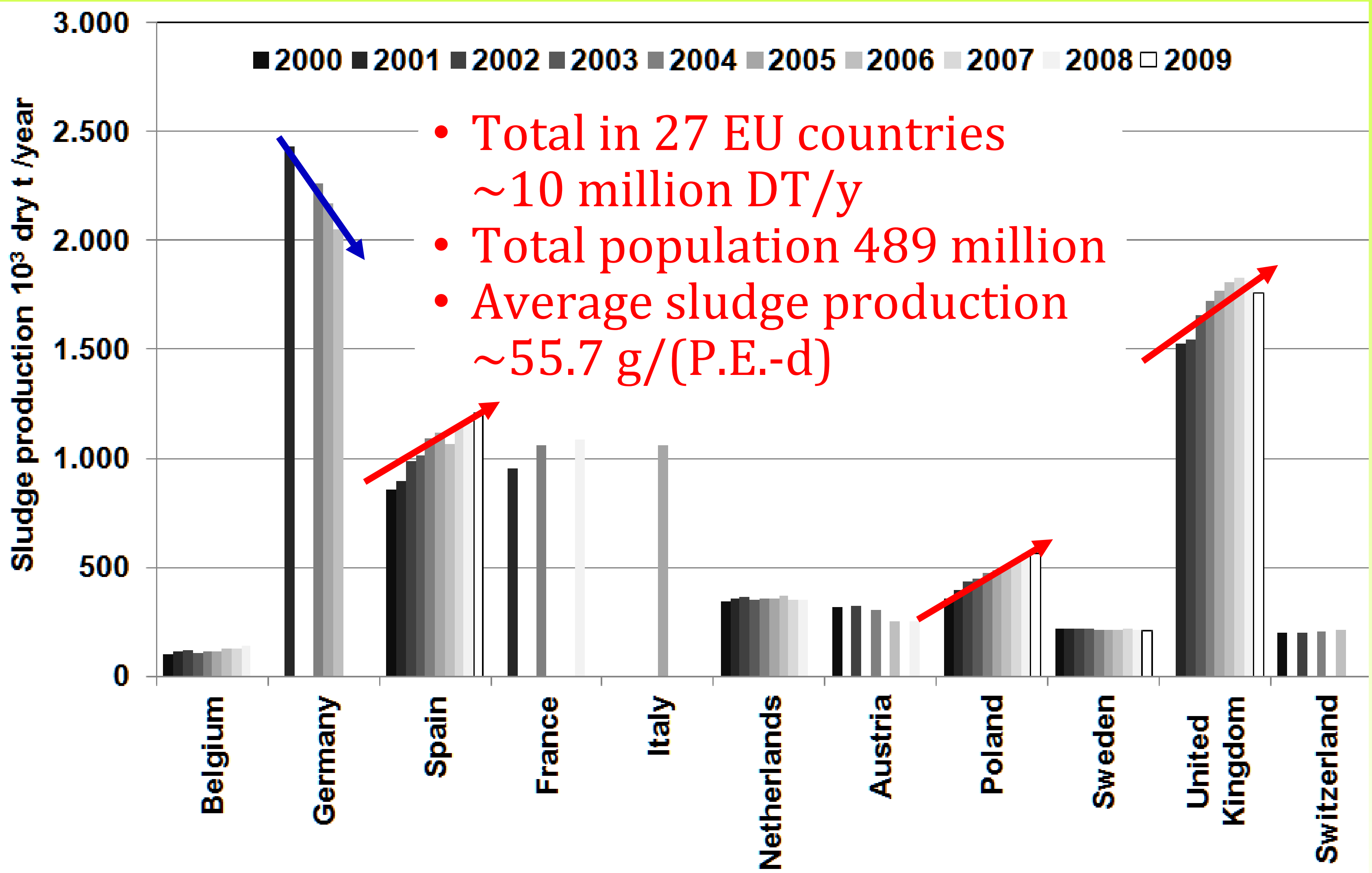
Sludge production and utilisation in 2012



Sludge quality
(mean values for all the Italian regions)

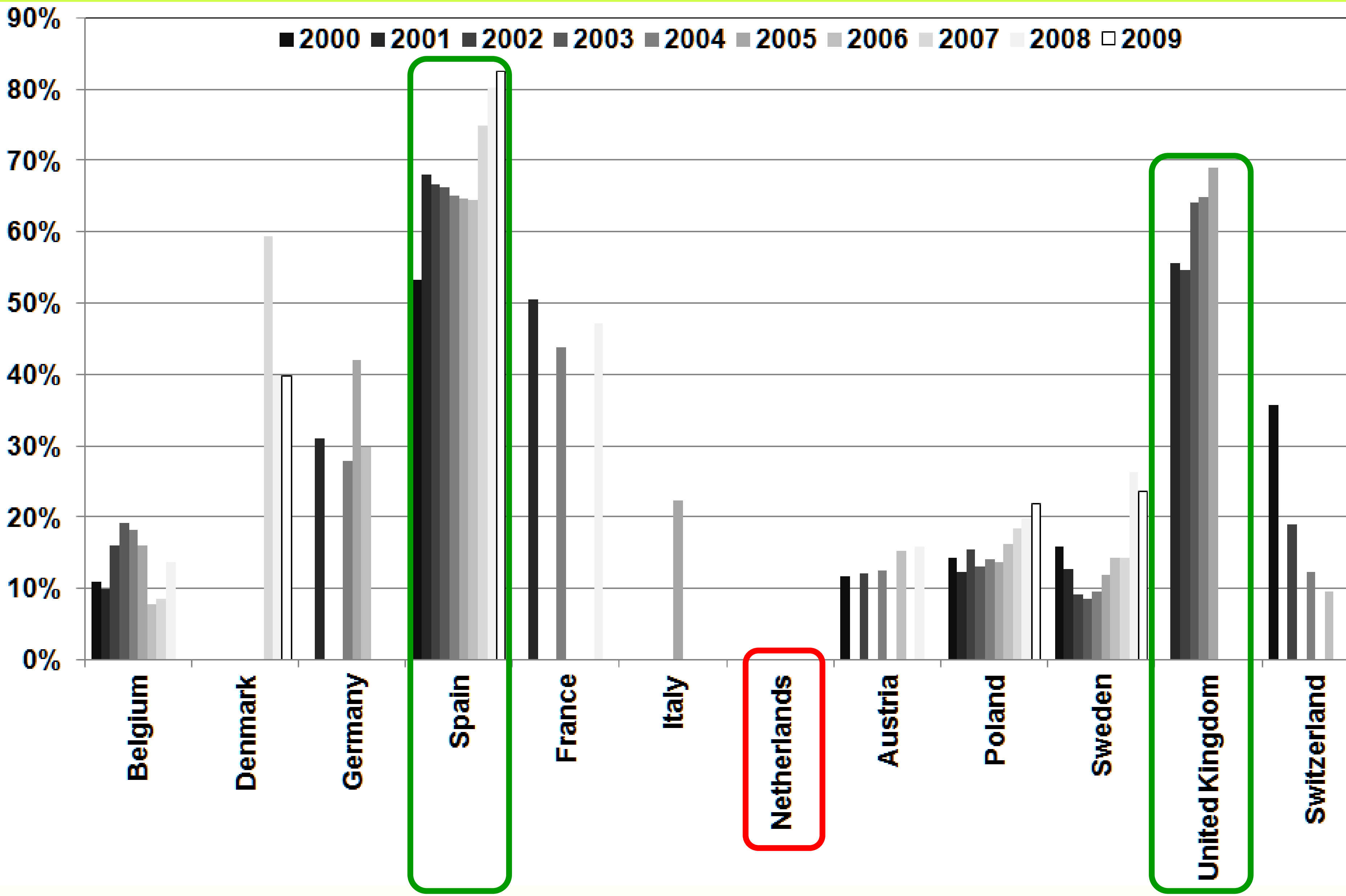
	2010	2011	2012
Cadmium (mg/kg DM)	0,84	0,77	0,80
Cupper (mg/kg DM)	139,42	166,50	176,25
Nickel (mg/kg DM)	17,65	18,25	16,71
Lead (mg/kg DM)	26,66	27,47	38,47
Zinc (mg/kg DM)	326,09	352,62	356,43
Mercury (mg/kg DM)	0,45	0,60	0,54
Chromium (mg/kg DM)	28,46	27,12	22,15
Total nitrogen (% of DM)	2,75	3,03	2,86
Total phosphorus (% of DM)	1,44	1,23	1,64

Mass production in the EU, 2000-2009

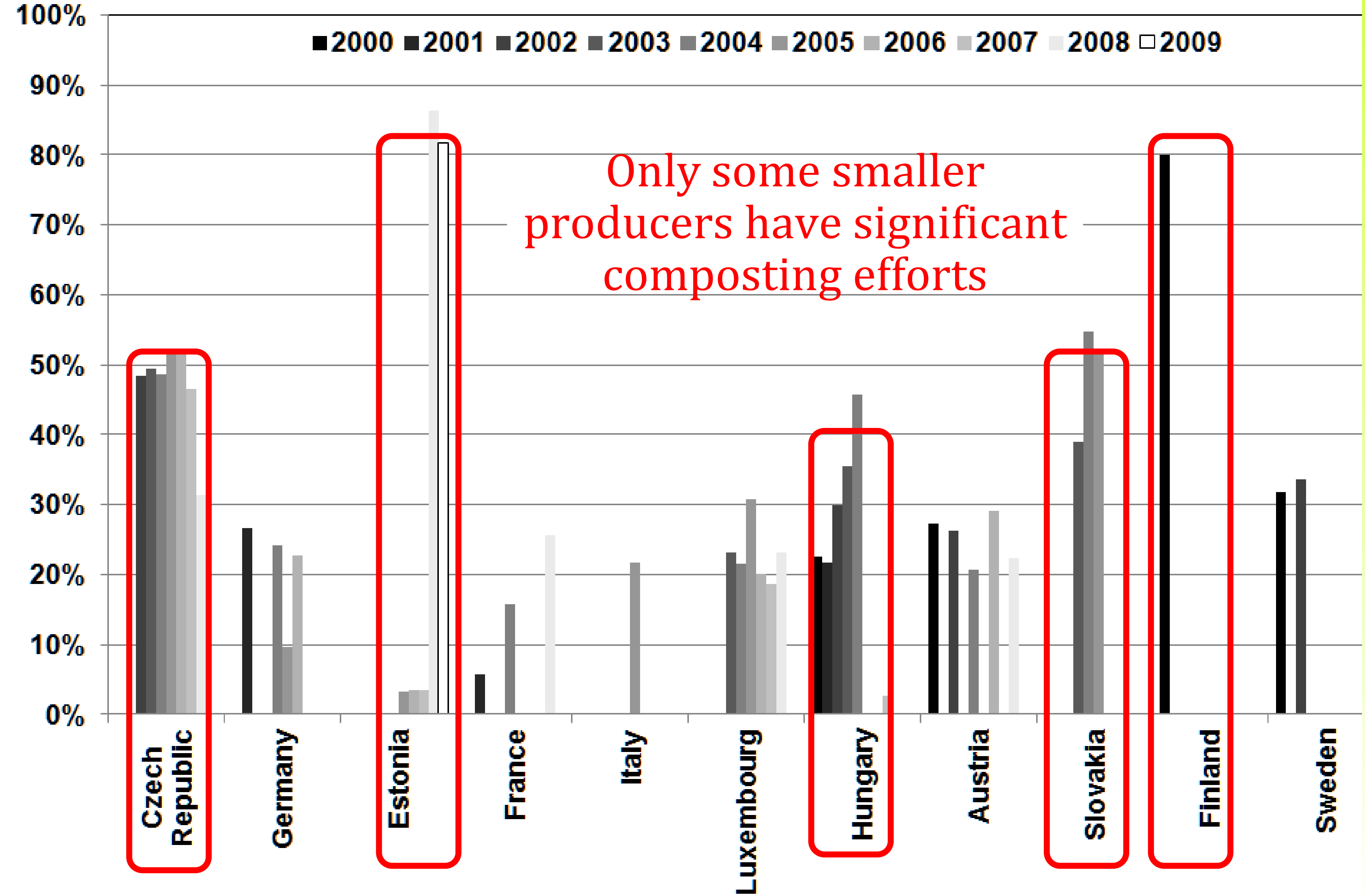


- Total in 27 EU countries ~10 million DT/y
- Total population 489 million
- Average sludge production ~55.7 g/(P.E.-d)

Agricultural utilization in the EU



Composting in the EU



Sludge (Biosolids) Usage in the U.S.A.

U.S. terminology:

"The term ***biosolids*** is generally used after recycling criteria have been achieved, typically at the outlet of the stabilization process.

Sludge refers to the unstabilized solids and should be used with a specific process descriptor, such as primary sludge, waste activated sludge, or secondary sludge.

For general description, solids, residuals, or another appropriate term, is preferred."

www.wef.org/Publications

Heavy metal limits for agricultural use

Within the EU, high variability for all metals – e.g. Cd, Cu

Europe	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As	Mo	Co	Se
Directive 86/278/EEC	20-40	-	1,000-1,750	16-25	300-400	750-1200	2,500-4,000				
Austria	2-10	50-500	300-500	2-10	25-100	100-500	1,500-2,000	20	20	10-100	
Belgium (Flanders)	6	250	375	5	100	300	900	150			
Belgium (Walloon)	10	500	600	10	100	500	2,000				
Bulgaria	30	500	1600	16	350	800	3,000				
Czech republic	5	200	500	4	100	200	2,500	30			
Denmark	0.8	100	1,000	0.8	30	120	4,000	25			
Finland	3	300	600	2	100	150	1,500				
France	20	1000	1,000	10	200	800	3,000				
Germany	10	900	800	8	200	900	2,500				
Greece	20-40	500	1,000-1,750	16-25	300-400	750-1200	2,500-4,000				
Hungary	10	1,000 - 1(Cr VI)	1,000	10	200	750	2,500	75	20	50	100
Italy	20		1,000	10	300	750	2,500				
Netherlands	1.25	75	75	0.75	30	100	300	15			
Poland	10	500	800	5	100	500	2,500				
Portugal	20	1,000	1,000	16	300	750	2,500				
Romania	10	500	500	5	100	300	2,000				
Slovenia	0.5	40	30	0.2	30	40	100				
Spain	20-40	1,000-1,750	1,000-1,750	16-25	300-400	750-1200	2,500-4,000				
Sweden	2	100	600	2.5	50	100	800				
United States 503 Rule											
Ceiling concentration	85	-	4,300	57	420	840	7,500	75	75		100
Exceptional quality (EQ)	39	-	1,500	17	420	300	2,800	41			100

Confronto concentrazione metalli e altre caratteristiche agronomiche

Metallo (mg/kg secco)	**Fanghi urbani (D. Lgs. 99/92)**	**Ammendanti (D. Lgs. 75/10)**	**Rapporto concentrazioni**
Piombo totale	750	140	5,4
Cadmio totale	20	1,5	13,3
Nichel totale	300	100	3,0
Zinco totale	2.500	500	5,0
Rame totale	1000	230	4,3
Mercurio totale	10	1,5	6,7
Cromo esavalente totale		0,5	

Altri parametri (sul secco se non altrimenti specificato)	**Fanghi urbani (D. Lgs. 99/92)**	**Ammendanti (D. Lgs. 75/10)**
Umidità sul t.q.		< 50%
Carbonio organico	>20%	>20%
Fosforo totale	>0,4%	
Azoto totale	>1,5%	N org.>80% N totale
Salmonelle	$<10^3$ MPN/g	assenti
Carbonio umico e fulvico		>7%
C/N		<25

Limiti di altri metalli nei fanghi per uso in agricoltura (mg/kg secco)

	Arsenico	Molibdeno	Cobalto	Selenio
Bassa Austria			10	
Steiermark	20	20	100	
Belgio (Fiandre)	150			
Danimarca	25			
Paesi Bassi	15			
Repubblica Ceca	30			
Ungheria	75	20	50	100
Slovacchia	20			

Organic micropollutants proposed in the EU document 3rd draft of April 2000

Organic compounds	Limit values (mg/kg dm)
AOX[1]	500
LAS[2]	2 600
DEHP[3]	100
NPE[4]	50
PAH[5]	6
PCB[6]	0.8
Dioxins	Limit values (ng TE/kg dm)
PCDD/F[7]	100

Limits of organic micro-pollutants for sludge use in agriculture (mg/kg dry solids)

	AOX	DEHP	LAS	NP/NPE	PAH	PCBs	PCDD/F[3]	Others
EC (2000, 2003)[1]	500	100	2,600-5,000	50-450	6[2]	0.8 Σ of 7 congeners	100	
Lower and Upper Austria	500	-	-	-	-	0.2 Σ of 6 congeners	100	
Carinthia	500				6[2]	1	50	
Denmark (2002)		50	1,300	10	3[2]			
France					Fluoranthene: 4 Benzo(b) fluoranthene: 2.5 Benzo(a)pyrene: 1.5	0.8 Σ of 7 congeners		
Germany	500					0.2 for each congener	100	
Germany (proposed limits)	400				Benzo(a)pyrene: 1	0.1 for each congener	30	2-Mercaptobenzothiazole +2-hydroxybenzothiazole:0.6
								Tonalid:15
								Glalaxolide:10
Sweden	-	-	-	50	3[2]	0.4 Σ of 7 congeners	-	
Czech Republic	500					0.6		

[1] proposed limits
[2] sum of acenapthene, fluorene, phenanthrene, fluoranthene, pyrene, benzo(b+j+k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, indeno(1,2,3-c,d)pyrene
[3] ng/kg dry solids

Limiti di microinquinanti organici fissati nelle Fiandre (mg/kg secco)

Benzene	1,1
Ethylbenzene	1,1
Styrene	1,1
Toluene	1,1
Xylene	1,1
Benzo(a)anthracene	0,68
Benzo(a)pyrene	1,1
Benzo(ghi)perylene	1,1
Benzo(b)fluoranthene	2,3
Benzo(k)fluoranthene	2,3
Chrysene	1,7
Phenanthrene	0,9
Fluoranthene	2,3
Indeno(1,2,3cd)pyrene	1,1
Naphthalene	2,3
Dichlorobenzene	0,23
Trichlorobenzene	0,23
Tetrachlorobenzene	0,23
Pentachlorobenzene	0,23

Hexachlorobenzene	0,23
1,2-dichloroethane	0,23
Dichloromethane	0,23
Trichloromethane	0,23
Trichloroethene	0,23
Tetrachloromethane	0,23
Tetrachloroethene	0,23
Vinylchloride	0,23
1,1,1-trichloroethane	0,23
1,1,2 -trichloroethane	0,23
1,1-dichloroethane	0,23
Cis+trans-1,2-dichloroethane	0,23
Hexane	5,5
Heptane	5,5
Octane	5,5
Extractable organohalogen compounds (EOX)	20
Mineral oil	560
Polychlorinated biphenyls (PCB as Σ 7 congeners)	0,8

Standards for maximum concentrations of pathogens

	Salmonella	Other pathogens
Europe		
Denmark (only for advanced treated sludge)	No occurrence	Faecal streptococci:< 100/g
France	8 MPN/10 g DM	Enterovirus: 3 MPCN/(10 g of DM)
		Helminths eggs: 3/(10 g of DM)
Finland (539/2006)	Not detected in 25 g	Escherichia coli <1000 cfu
Italy	1000 MPN/g DM	
Luxembourg		Enterobacteria: 100/g no eggs of worm likely to be contagious
Poland	No occurrence	Number of viable helminth eggs: no occurence in 1 kg of dry solids
United States		
Class A	< 3 MPN/4 g DM	Faecal Coliforms< 1000 MPN/g DM
		Enteric Viruses < 1 PFU/4 g DM
		Viable Helminth Ova < 1/4 g DM
Class B		Faecal Coliforms <2,000,000 MPN/ g DM

Standard interni adottati nel progetto FP7 ROUTES

Concentrazione di E. coli < 500 CFU/g secco; Colifagi somatici < 10^4 PFU/g secco; Salmonella assente in 50 g di peso umido

Quality criteria for a safe agricultural use

Biological stability

Heavy metals

?

Pathogens

Organic Micropollutants Which ones?

Odours

Problems of odours

- This is a very fruitful research area.
- There are many gaps in our knowledge.
- If we can solve the odor problem, land application becomes much easier.
- We don't know why some sludges are more odorous than others but iron seems to play a role.

Sludge management for a safe agricultural use

- It seems that heavy metals are not any more a problem since their concentration in sewage sludge decrease all over Europe following a more careful control on the sewerage system avoiding unauthorized discharges.
- Any biological process increases the heavy metal concentration on dry base (mg/kg SS) considering that VS are removed by 30-50% and therefore heavy metals are concentrated in the rest of solids. After digestion heavy metal concentrations might increase up to 50%.

Sludge management for a safe agricultural use: separation of primary and secondary sludge

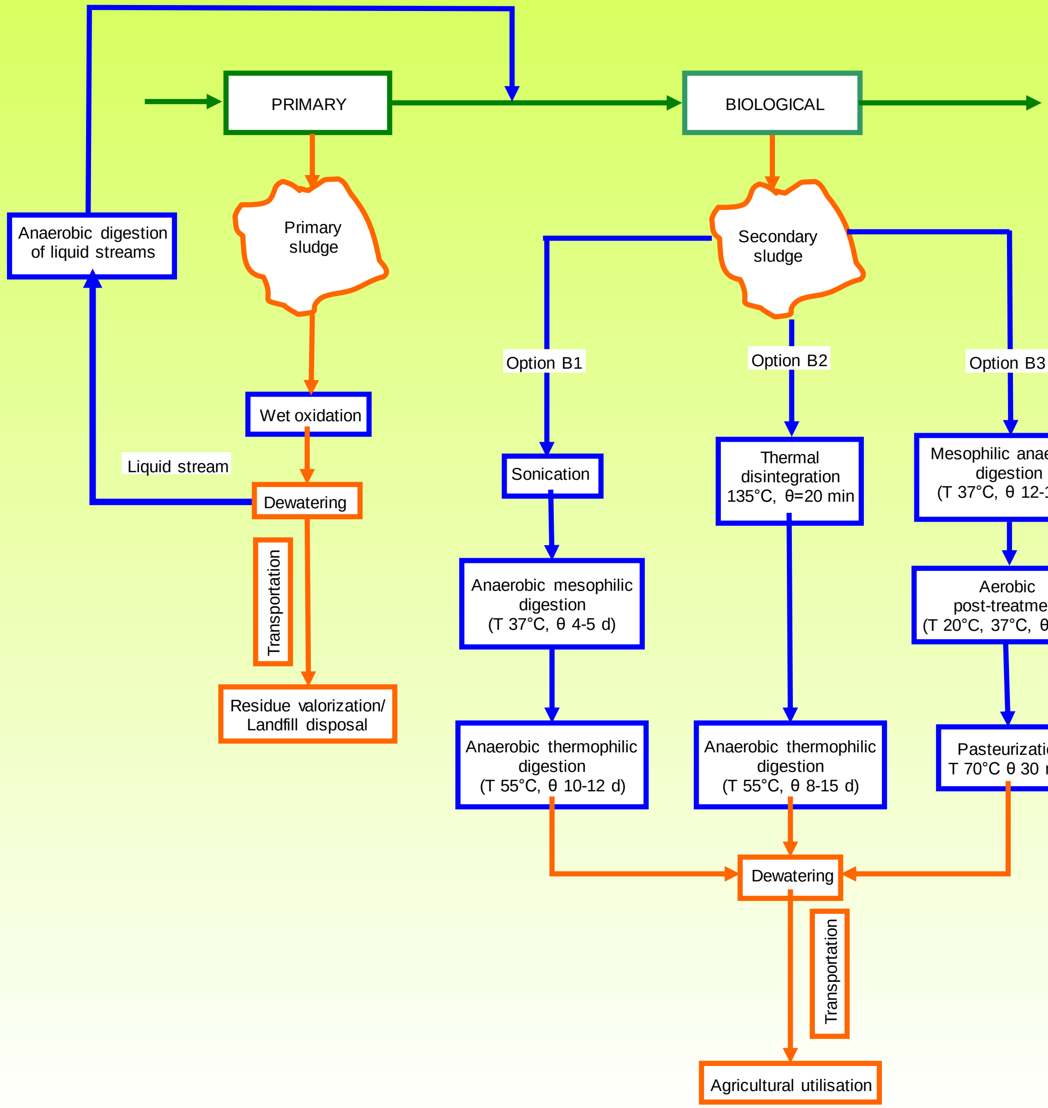
- The state of the art of chemical oxidation processes (ozonation, sonication, chlorination, hydrogen peroxide) does not allow to fully assess the ability of the above processes for organic micro-pollutants decontamination.
- Problems exist on the intermediate compounds formation.
- Some evidence exists on the higher concentrations of some non polar organic contaminants in primary than in secondary sludge.
- Separation of sludge processing between primary and secondary sludge might be the best solution.
- Nitrogen (5-6% of dry solids) and phosphours (2,5-3,0% of dry solids) concentration of secondary sludge are higher than in primary sludge (1,8-4% and 0.7-1,2%, respectively). Secondary sludge is therefore more clean. Moreover nutrient concentration render it much more suitable for agricultural use than in mixture with primary sludge.
- Primary sludge can be easily treated by gravity thickening, digestion and dewatering for the final disposal options.
- Secondary sludge should be intensively treated for assuring a good biological stability and pathogen removal.

Processes under investigation in the ROUTES FP-7 project

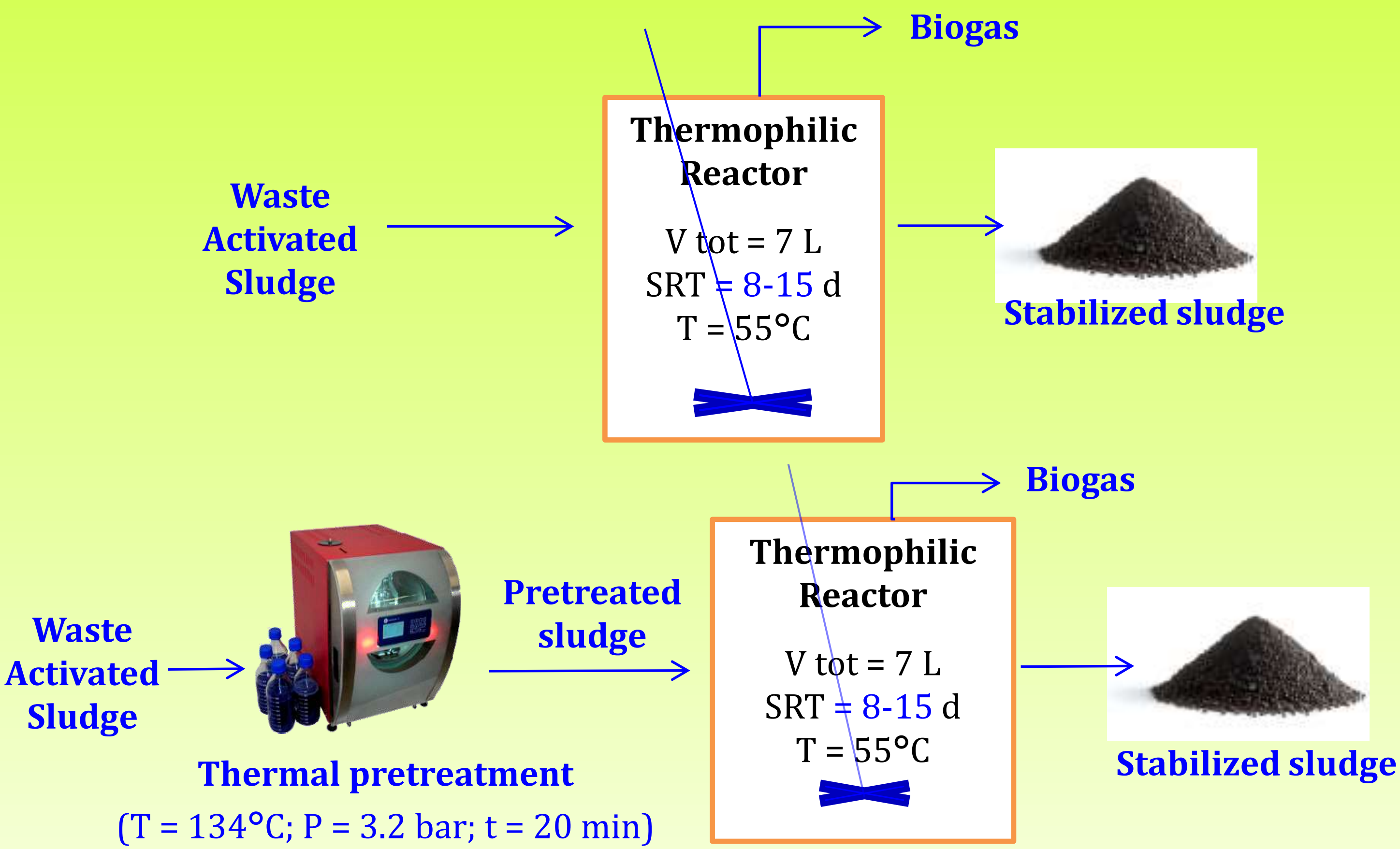
- Assessment of the efficiency of mechanical and thermal disintegration
- Optimization of semi-continuous anaerobic thermophilic digestion tests with or without integration of thermal hydrolysis or ultrasounds disintegration (VS reduction, biogas production, energy balance, dewaterability, ammonia content) at different HRTs.
- Optimization of semi-continuous anaerobic/aerobic digestion test followed by pasteurization (VS reduction, biogas production, energy balance, dewaterability, nitrogen content) at different HRTs.
- Great attention is now paid by the Commission to the problems of pathogens.

Sludge separation

Large WWTPs > 100,000 inhabitants
With primary sedimentation - With/Without nutrient removal - Low/High organic load - Medium pollution level
Problem: High sludge production at medium pollution level
Solution: Separation of primary and secondary sludge treatments.



TT process:
Thermal pretreatment + Thermophilic digestion



Test #1: OLR=1.0 kgVS $m^{-3}d^{-1}$
Test #2: OLR=1.7 kgVS $m^{-3}d^{-1}$
Test #3: OLR=3.7 kgVS $m^{-3}d^{-1}$

Parallel tests were carried out simultaneously, feeding untreated and pretreated sludge, at different loading rates.

UMT process:
Ultrasonic pretreatment + Two-stage digestion (1st mesophilic and 2nd thermophilic)

Waste Activated Sludge

1° short Mesophilic digestion
V tot = 3-6 L
HRT = 3-5 d
T = 37°C

Biogas

2° Thermophilic digestion
V tot = 7 L
HRT = 10 d
T = 55°C

Biogas

Stabilized sludge

Waste Activated Sludge

Sonication
DD_{COD} = 3%
E_{spec}=0.5 kWh/kg TS

1° short Mesophilic digestion
V tot = 3-6 L
HRT = 3-5 d
~~T = 37°C~~

Biogas

2° Thermophilic digestion
V tot = 7 L
HRT = 10 d
~~T = 55°C~~

Biogas

Stabilized sludge

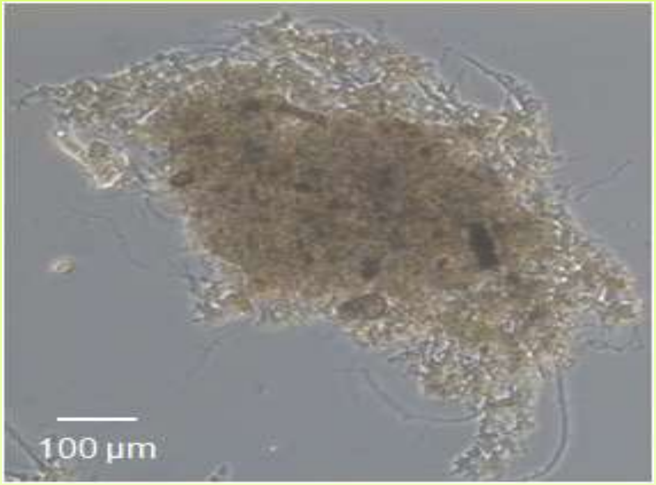
Test #1: OLR=1.7 kgVS $m^{-3}d^{-1}$
Test #2: OLR=3.1 kgVS $m^{-3}d^{-1}$

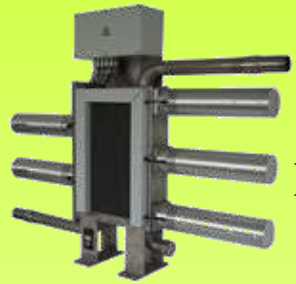
Parallel tests were carried out simultaneously, feeding untreated and pretreated sludge, at different loading rates.

Enhanced Stabilization Processes

Effect of pretreatments:

Untreated WAS floc





Sonication

N = 20 kHz; t = 2 min

DD_{COD} = 3–4 %

Specific energy ~ 0.5 kWh/kg TS

Small aggregates, dispersed cells

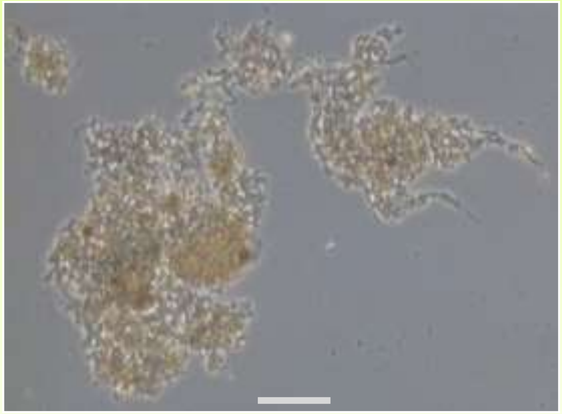
Thermal pretreatment

T = 134°C; P = 3.2 bar;

t = 20 min

DD_{COD} = 13%

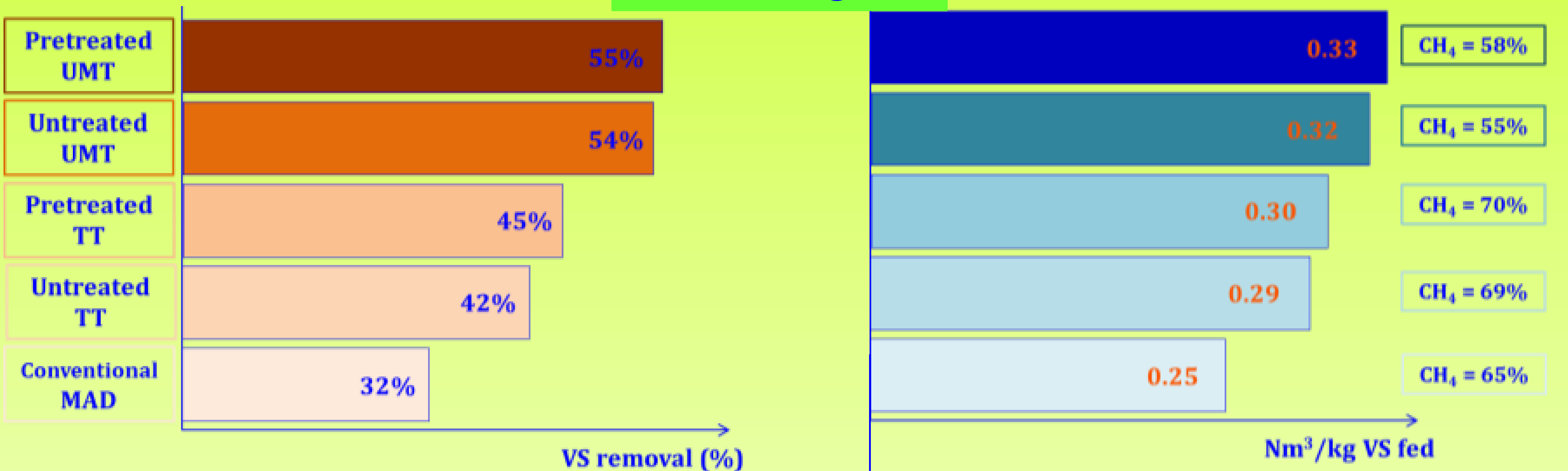
Specific energy ~ 5 kWh/kg TS



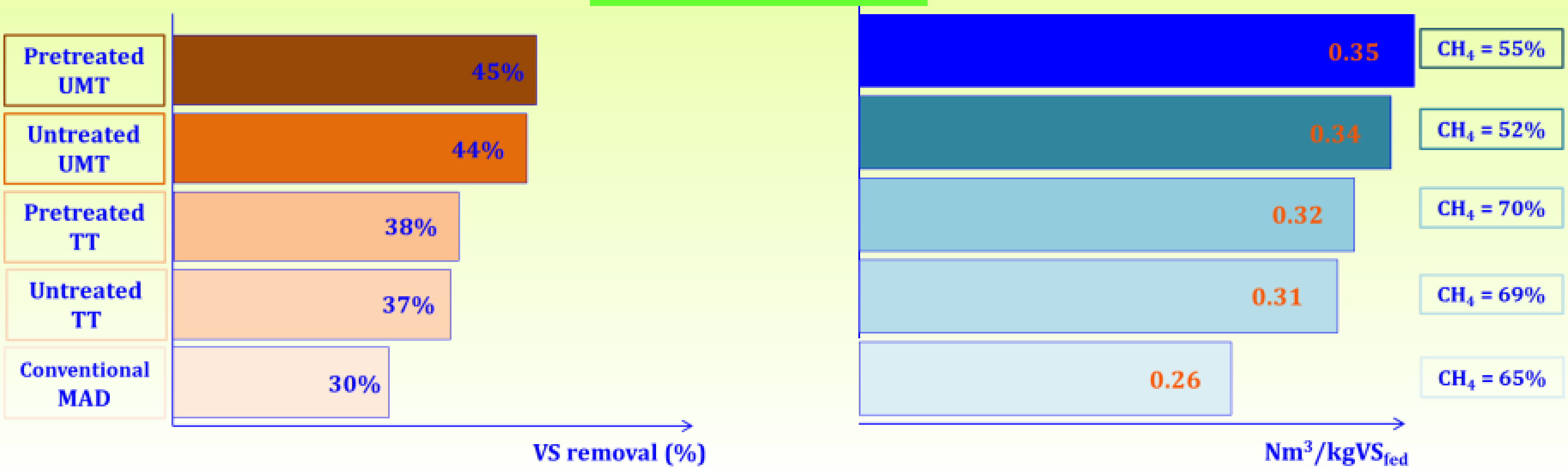
Floc destructuration, no small aggregates

Results: VS removal and biogas production at low and high loading rate

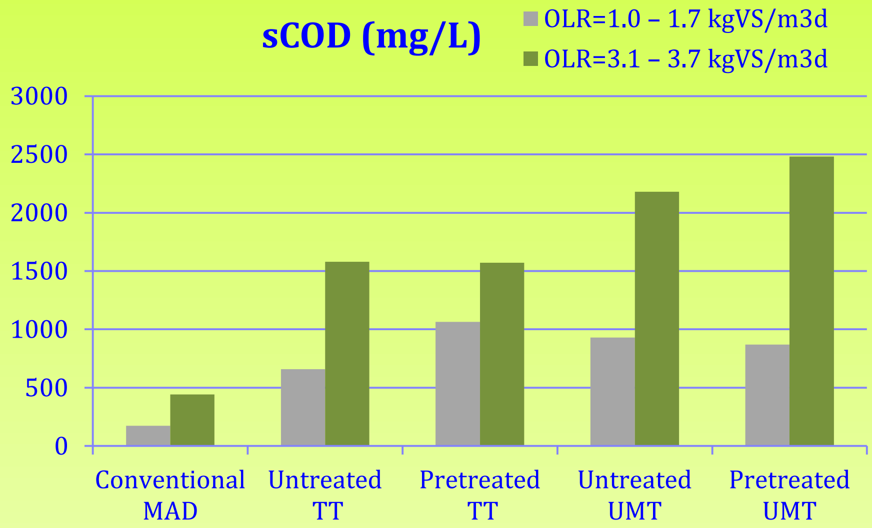
Low loading rate

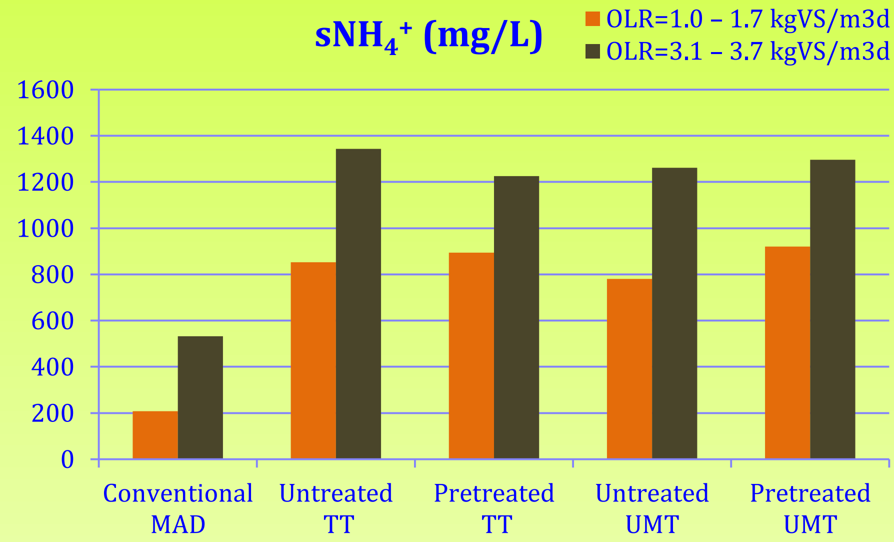


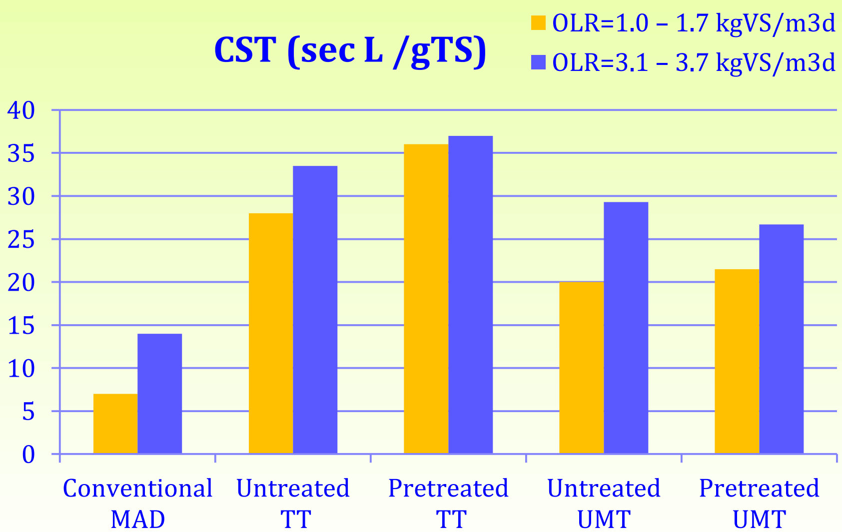
High loading rate



Supernatant characteristics and filterability



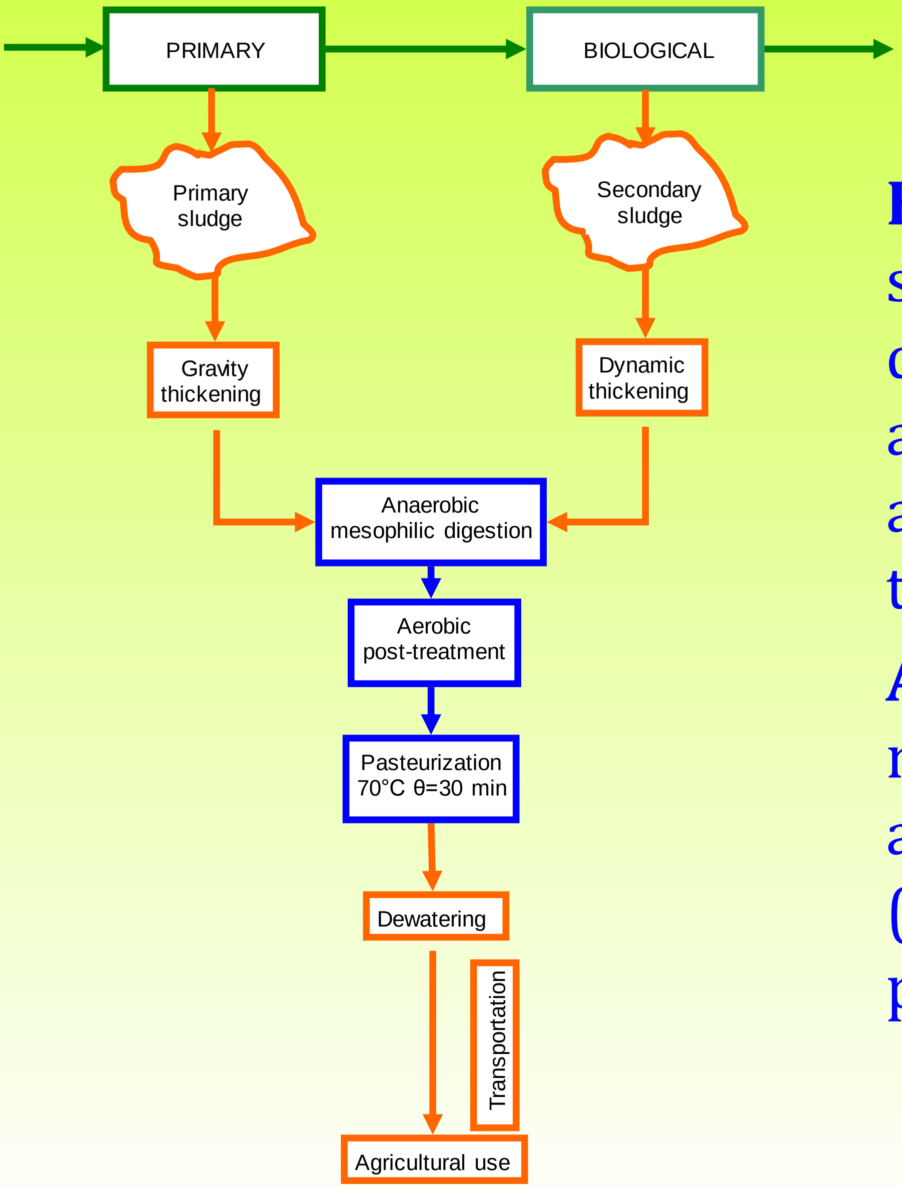




Enhanced processes caused an increase in soluble COD and ammonia in anaerobic supernatants, with respect to conventional MAD.

Enhanced processes caused also worse dewaterability of digested sludge.

Sequential anaerobic-aerobic digestion



Basic motivation: to improve stabilization performance with different reaction environments anaerobic and aerobic suitable for a more efficient biodegradation of the different VS sludge fractions.

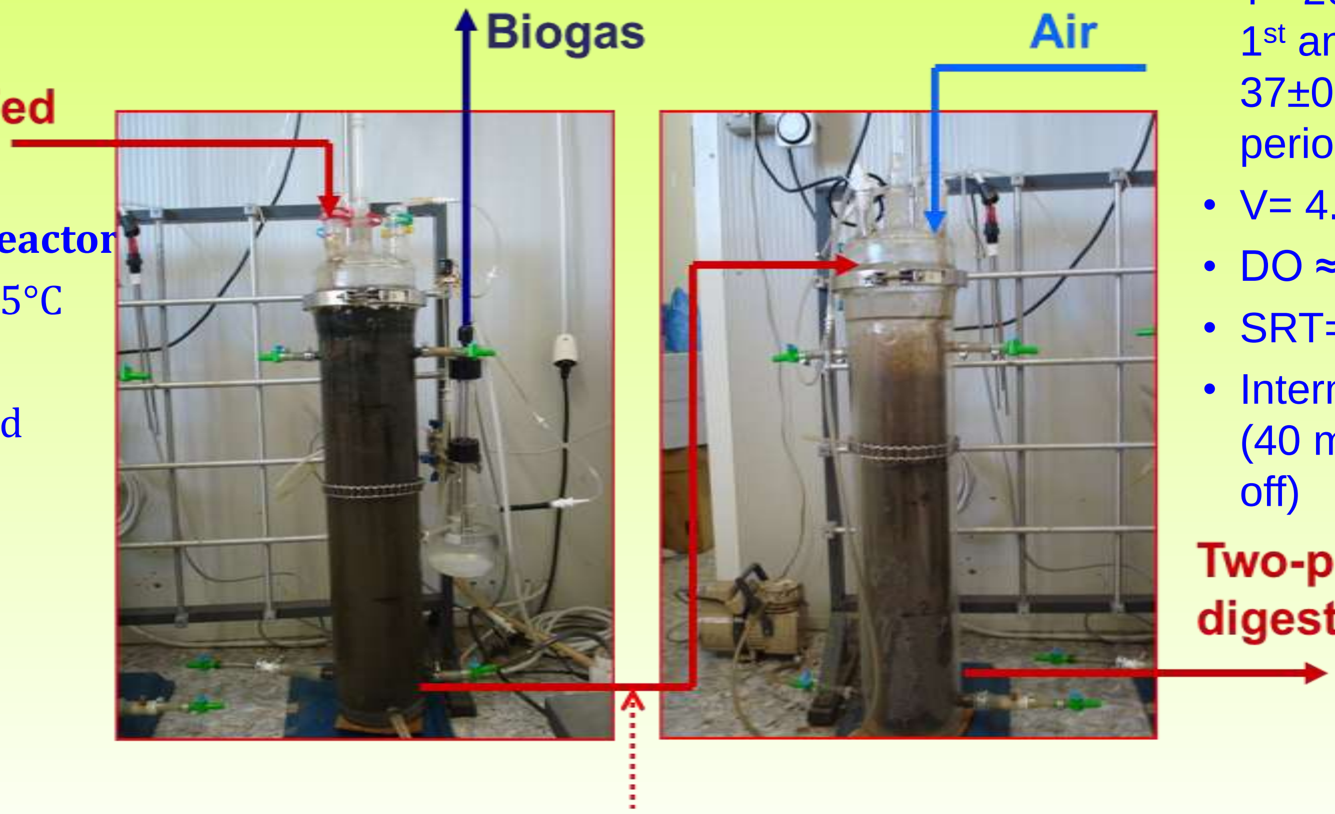
Additional achievements: nitrogen removal by intermittent aeration in the aerobic stage (nitrification - denitrification process)

Experimental apparatus

Reactors: 7.4 L cylindrical vessels operated in semi-continuous mode and fed daily

Anaerobic reactor

- T= 37±0.5°C
- V= 7 L
- SRT= 15 d

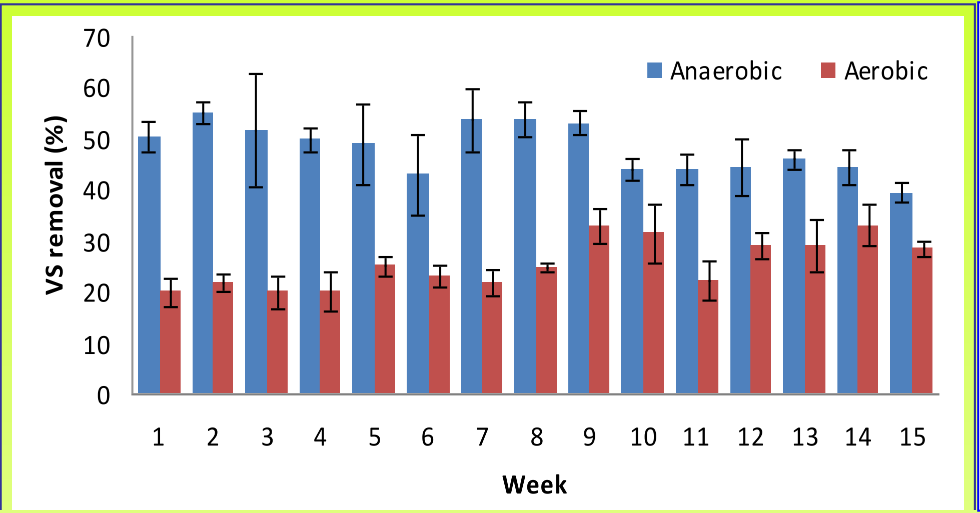


Aerobic reactor

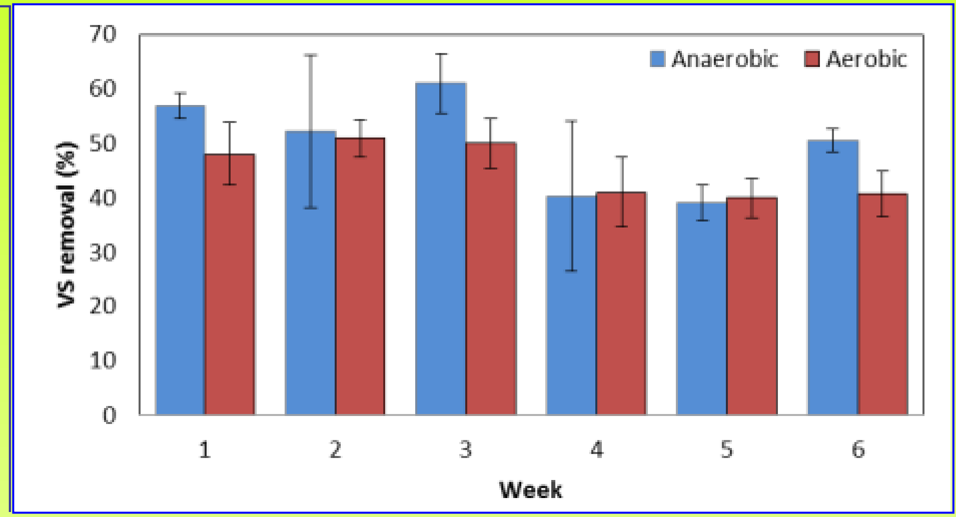
- T= 20±0.5°C in the 1st and 2nd period, 37±0.5°C in the 3rd period
- V= 4.5 L
- DO ≈ 3-5 mg/L
- SRT= 12 d
- Intermittent aeration (40 min on - 20 min off)

Performances

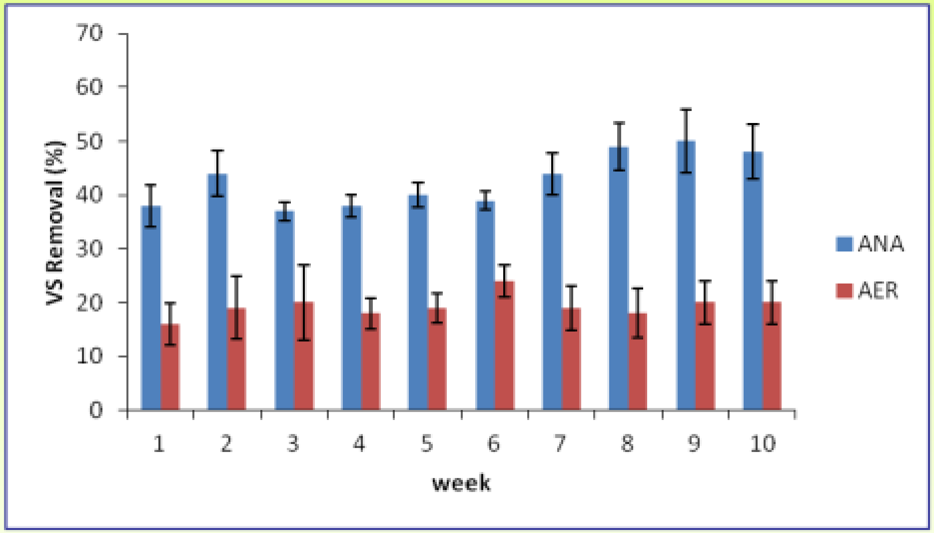
Mixed sludge	
SGP (Specific Biogas production) [Nm^3/(kg VS destroyed × d)]	0.82 ± 0.15
CH_4	67%
Nitrification efficiency	97 ± 1% (mixed sludge at 20°C)
Denitrification efficiency	70 ± 7% (mixed sludge at 20°C)
Secondary sludge	
SGP (Specific Biogas production) [Nm^3/(kg VS destroyed × d)]	0.78 ± 0.24 1st series 0,81 ± 0.25 2nd series
CH_4	65-68%
Nitrification efficiency	90 ± 6% (20°C 1st series); 86 ± 6% (20°C 2nd series); 65 ± 10% (37°C 3rd series)
Denitrification efficiency	62 ± 11% (20°C 1st series), 66 ± 12% (20°C 2nd series); 75 ± 8% (37°C 3rd series)



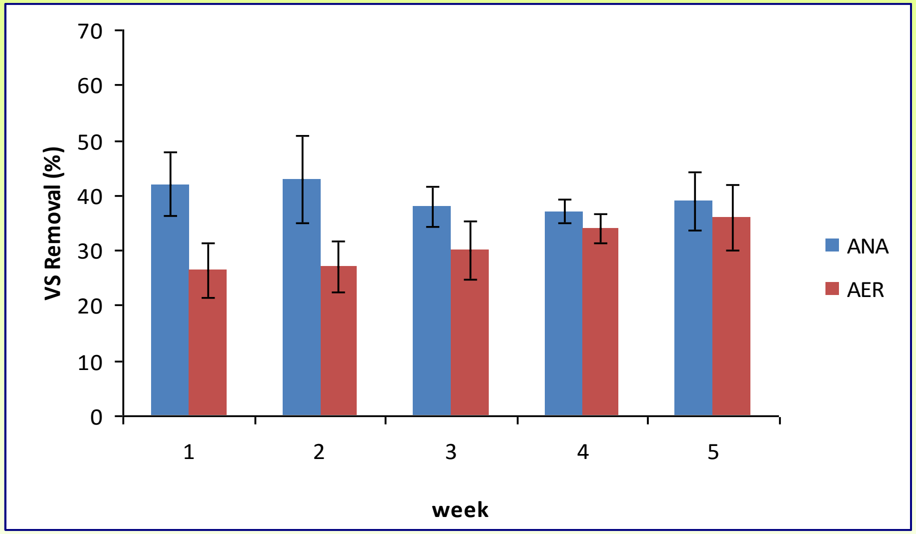
Secondary sludge: 1st series
(cumulative 40+25% - Total 55%)



Mixed sludge
(cumulative 50+45% - Total 72,5%)

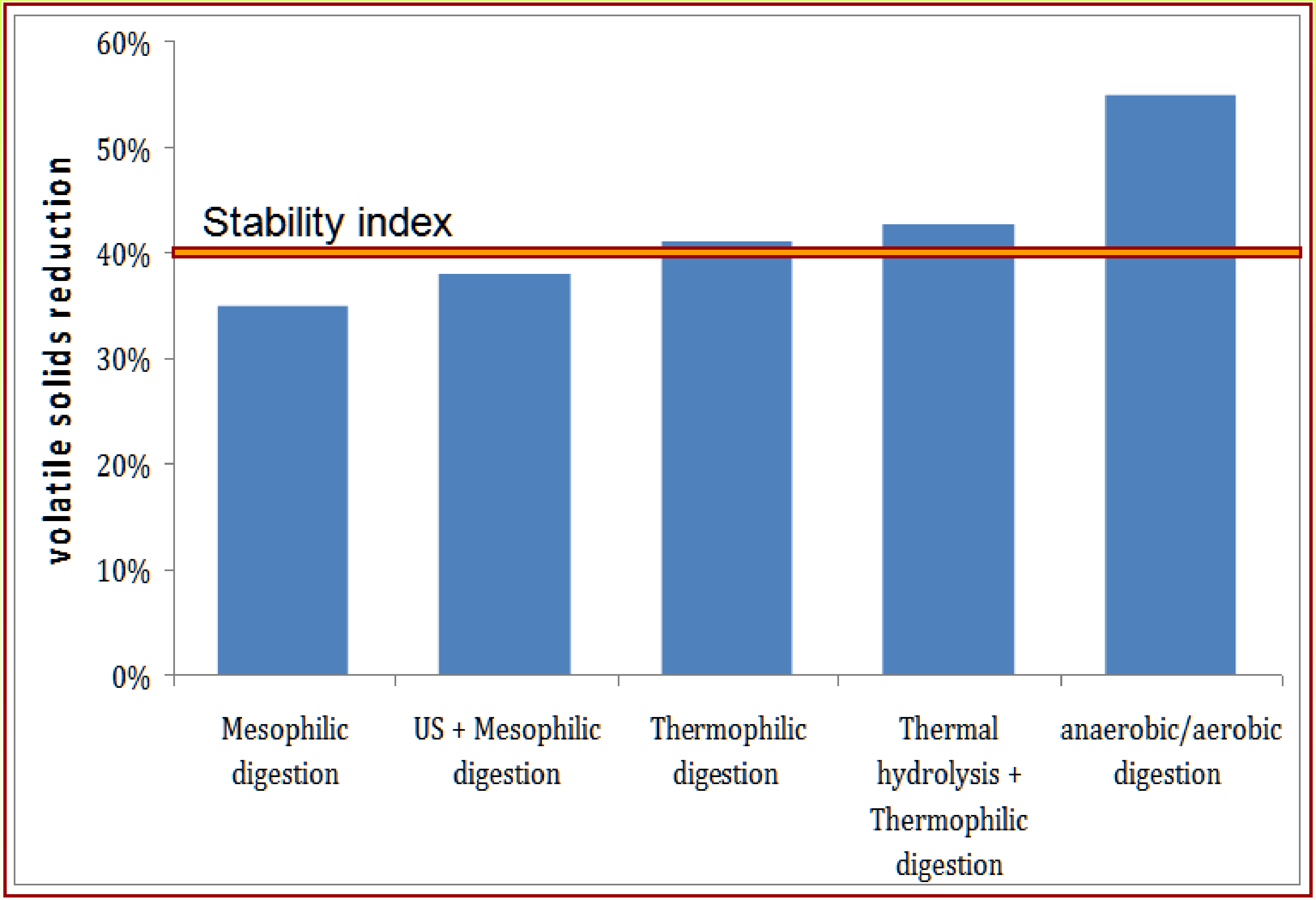


Secondary sludge: 2nd series
(cumulative 43+20% - Total 54,4%)



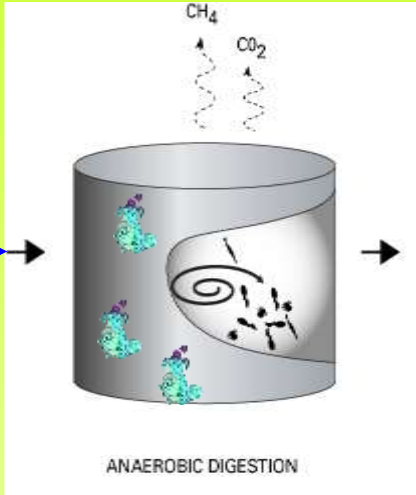
Secondary sludge: 3rd series (37°C)
(cumulative 40+33% - Total 60%)

Some results on VS reduction



Pollutants fate during anaerobic digestion

Pollutant load (feed)



Expected concentration in the digested sample:

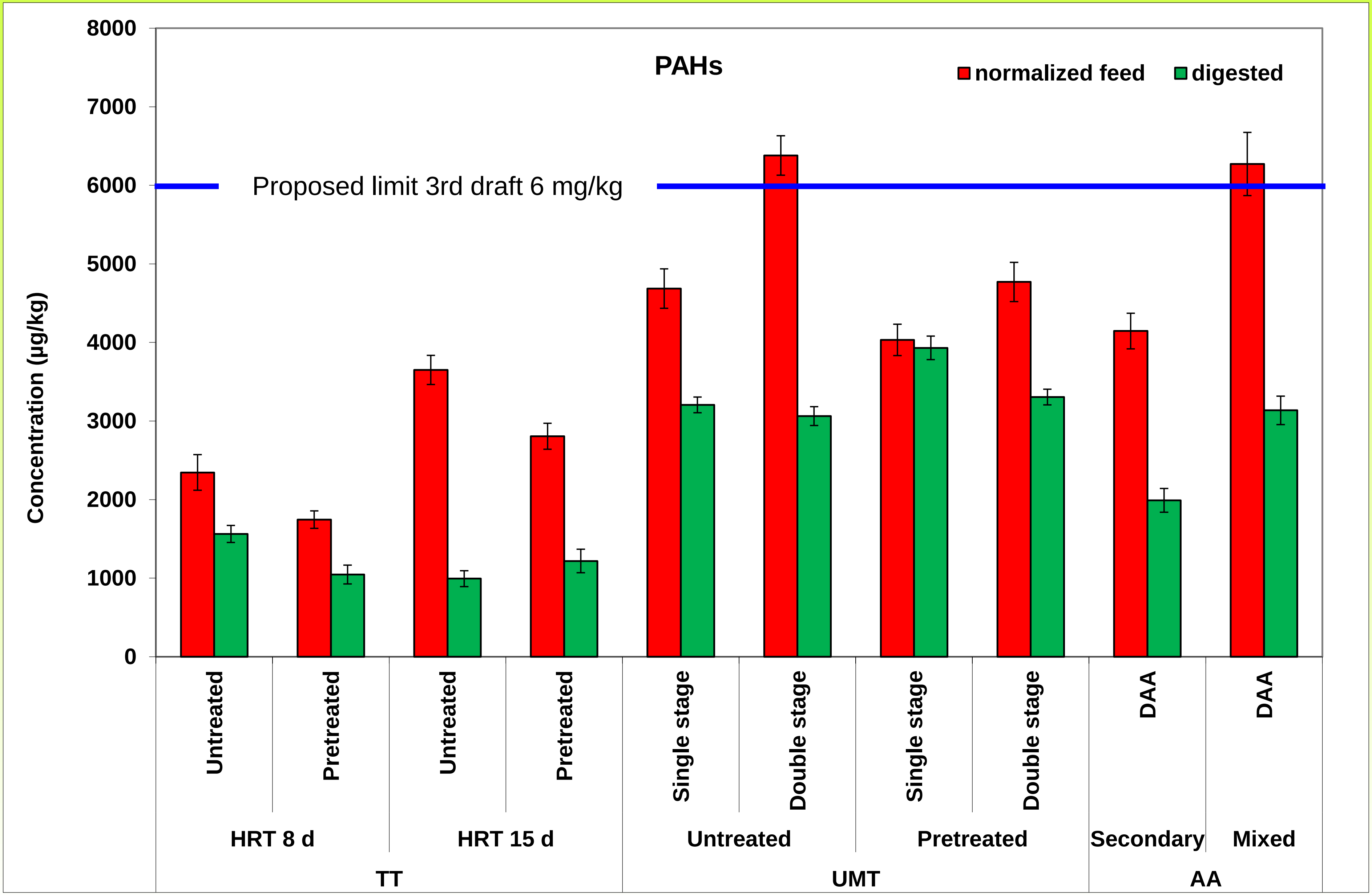
normalized feed concentration (NF) with respect to the original mass

Mass reduction due to anaerobic process

Theoretical accumulation of pollutant

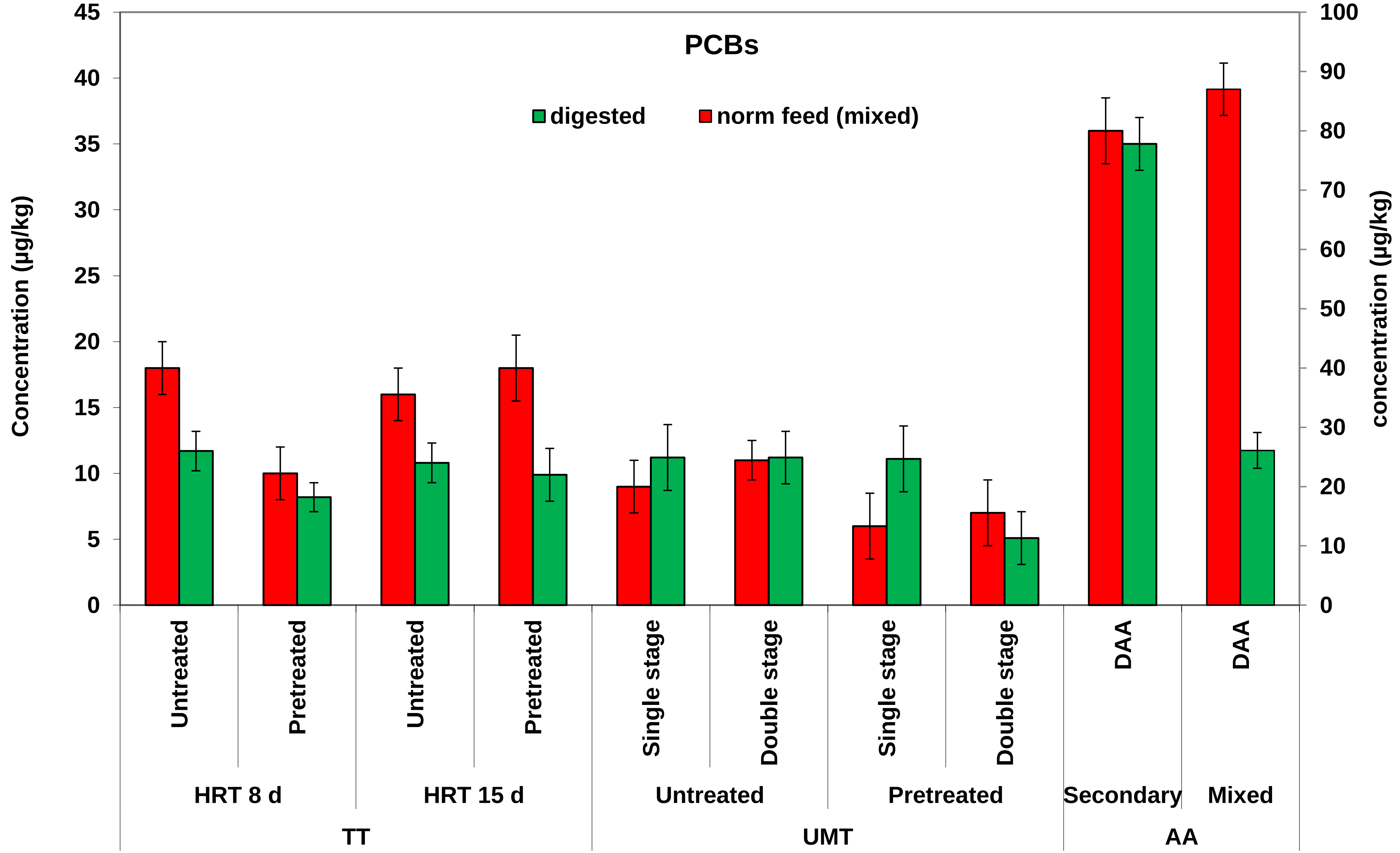
Organic micropollutant (mg/kg dm)	**Feed sludge concentration (mg/kg dm)**	**Literature range (mg/kg dm)**
EOX	4.7 – 12	
Non-ionic surfactants	1 –4	22-650
Anionic surfactants	115 – 630	400-700
PAHs	1.7 – 3.6	1-3
PCBs	0.011 – 0.022	0.003-0-7
Phthalates	25 – 86	0.2-150

Polycyclic aromatic hydrocarbons

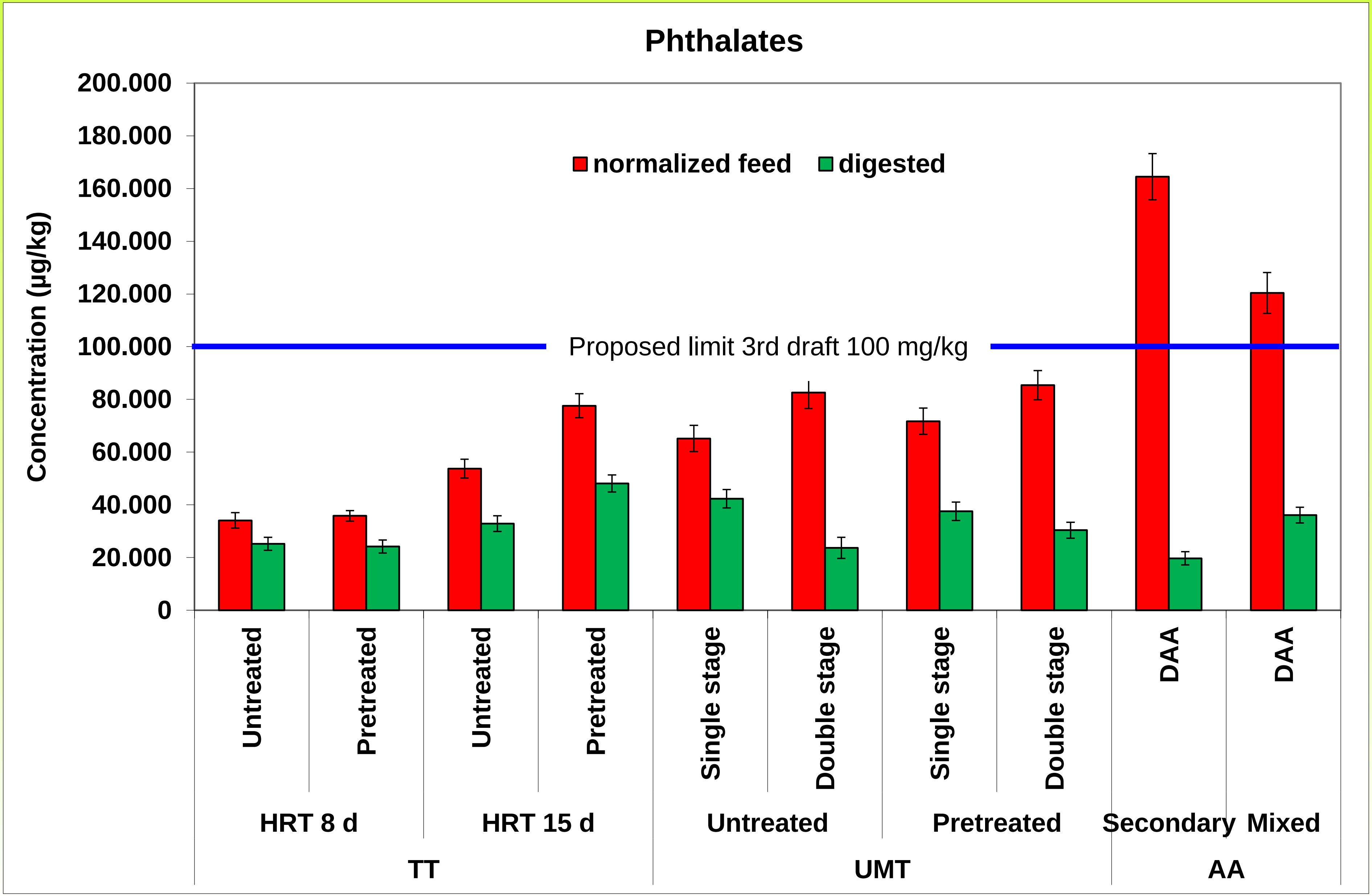


Polychlorinated biphenyls

Proposed limit 3rd draft 800 μg/kg

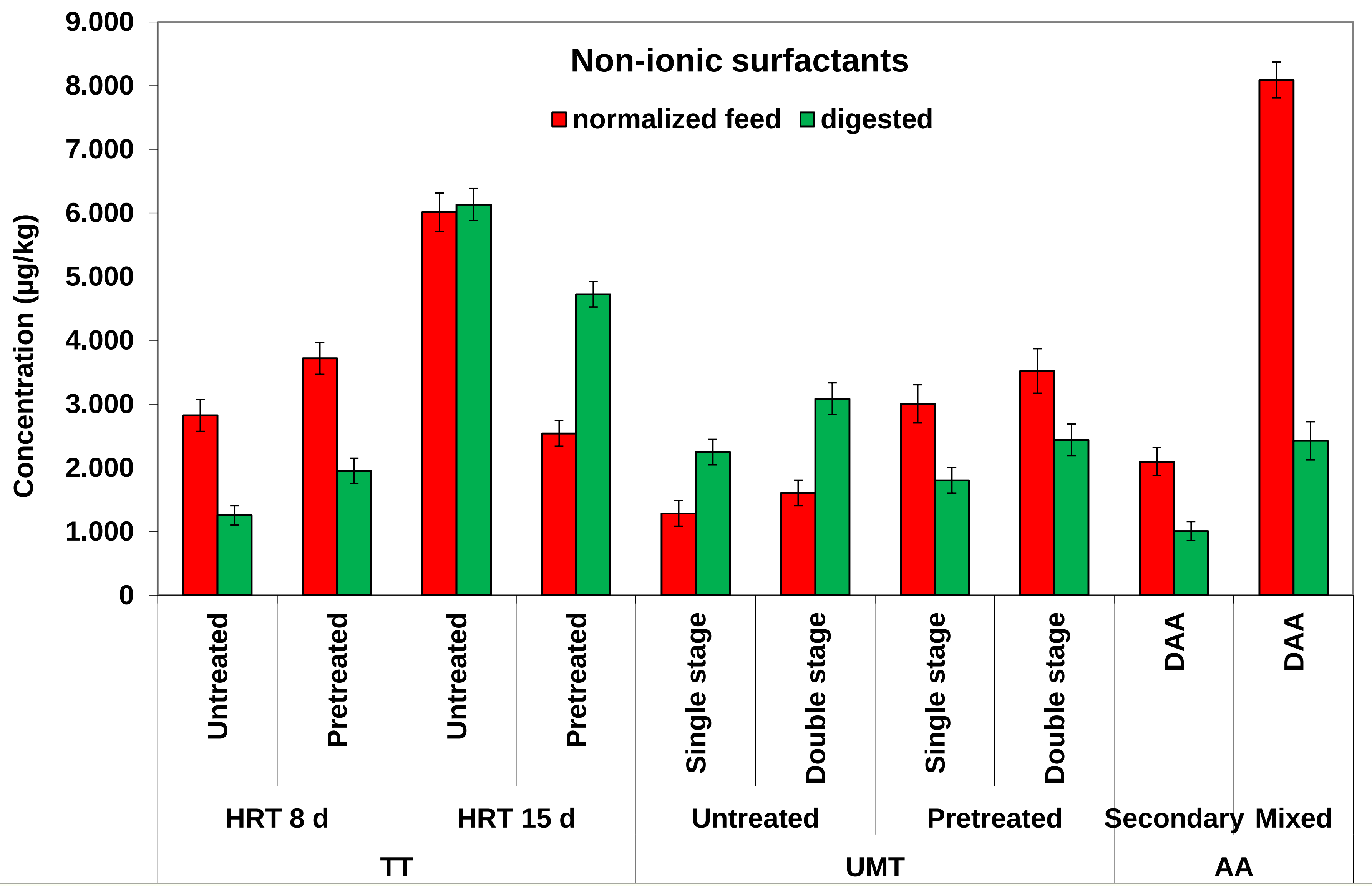


Phthalates

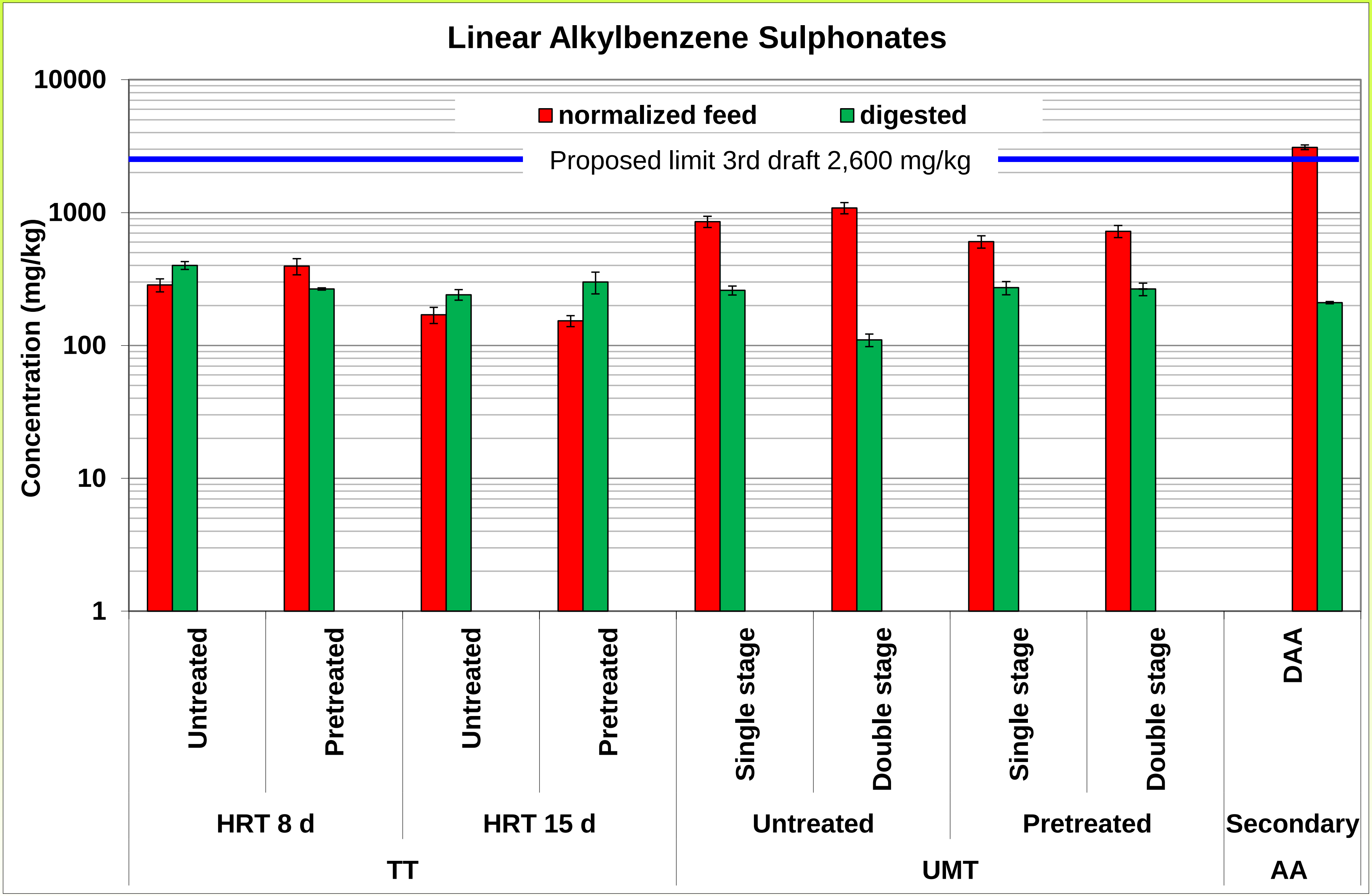


Phthalates
Concentration (µg/kg)
200.000
180.000
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0
normalized feed
digested
Proposed limit 3rd draft 100 mg/kg
Untreated
Pretreated
Untreated
Pretreated
Single stage
Double stage
Single stage
Double stage
DAA
DAA
HRT 8 d
HRT 15 d
Untreated
Pretreated
Secondary
Mixed
TT
UMT
AA

Non-ionic surfactants



Anionic surfactants



Emerging compounds under investigation in the ROUTES project

- UV-filter
- musk fragrances
- brominated flame retardants (BFR),
- quaternary ammonium compounds (QAC)

Some results on pathogen removal

Adopted criteria in ROUTES

1) 2 log removal *E. coli*

2) Absence of *Salmonella* in 50 g /WW (CEE2000)

2) *E. coli* < 500 CFU g dry weight (CEE2000)

3) SOMCPH < 10^3 – 10^4 PFU/g dry weight;

4) Spores of *Clostridium perfringens* (?).

CLASS A BIOSOLIDS STANDARDS (USEPA)

- ⇨ *Salmonella* less than 3 MPN/4 g dry weight
- ⇨ *Faecal coliforms less than 1.000 MPN/g dry weight;*
- ⇨ *Enteric viruses 1 PFU/4 g dry weight*;
- ⇨ Helminth viable eggs less 1/4 g dry weight

C. perfringens is a good indicator in AD?

OBSERVATIONS

- ⇨ No removal or a *slight* increase of *C.perfringens* was observed between the feed sludge and the digested sludge.
- ⇨ A net increase up to 4 log unit was observed between the thermal pretreated feed and the thermophillic digested sludge.
- ⇨ *C. perfringens* in pure culture cannot grow and replicate at 50-55°C.

Odours

- Often odours are not linked to the biological stabilization.
- Generally odours can be controlled by chemical processes using high dosages of alkali or lime. Neutralization is after needed by adding acid like sulphuric acid.
- Finally sludge is quite rich of gypsum.

Reduction of microbial indicators in the enhanced stabilization processes

		TH	SON	TAD	MAD	AA	UMT	UMT son
E. coli	Log removal	3.2 - 5.3	NR	2.9 - 5.3	1.2	2.4	3.5 - 5.3	3.5 - 5.3
	(positive treated samples/total samples)	(1/9)	(4/4)	(0/8)	(7/7)	(4/7)	(0/4)	(0/4)
SOMCPH	Log removal	3.9 - 5.2	NR	2.2	0.9	2.0	2.3	2.4
	(positive treated samples/total samples)	(2/9)	(4/4)	(4/5)	(6/6)	(6/6)	(4/4)	(4/4)
SPORES	Log removal Average±dev.st	2.5 - 5.1	NR[c]	NR	NR	NR	NR	NR
	(positive treated samples/total samples)	(0/9)	(4/4)	(8/8)	(7/7)	(7/7)	(4/4)	(4/4)
Salmonella	Log removal	0.9 - 2.3	NR	0.9 - 1.3	0.9 - 2.0	0.9 - 2.1	0.8 - 2.1	0.8 - 2.1
	(positive treated samples/total samples)	(0/2)	(1/1)	(0/1)	(0/1)	(0/1)	(0/1)	(0/1)

Adopted standards

E. Coli 2 log removal

E. Coli less than 500 CFU/g dm

SOMCPH less than 10^4 PFU/g dm

Salmonella absent in 50 g wet weight

Compliance to the proposed microbial indicators limits and removal requirements

	E. Coli 2 log units removal[a]	*E. Coli* <500 CFU/g dm[a]	*Salmonella* <1/50 g ww[a]	*SOMCPH* <10^4 PFU/g dm[a]
Th	100% (9)	89% (9)	100% (4)	100% (9)
Son	0% (4)	0% (4)	0% (4)	0% (4)
MAD	0% (7)	0% (7)	100% (3)	0% (9)
AA	100% (7)	43% (7)	100% (3)	33% (6)
TAD	100 % (8)	100 (8)	100% (3)	20% (5)
UMT[b]	100% (8)	100% (8)	100% (2)	25% (8)

a: percentage of samples (total samples); b: UMT and UMT–son are reported together

Conclusions on pathogens

- ⇨ Pathogens, Enteroviruses and *Salmonella* were never found in the final treated samples.
- ⇨ Bacterial indicators *Salmonella* and *E. coli* limit were easily achieved when thermal digestion is carried out.
- ⇨ Only thermal pre-treatments is able to achieve all the limits, including SOMCPH.
- ⇨ Bacterial indicators are easily removed to undetectable level
- ⇨ SOMCPH are the best indicators of viruses for assessing performance of the intensive as well of the conventional stabilization treatments

Enumeration of *Salmonella*

Time (d)	Sample 1 (thermophilic)	Sample 2 (mesophilic)	Sample 3 (thermophilic)	Sample 4 (compost)	Sample 5 (mesophilic)
0	>0,48	>0,48	0,48	<0,018	>0,48
5	>0,48	>0,48	0,046	<0,018	>0,48
20	0,046	0,48	<0,018	<0,018	>0,48
40	0,046	0,046	<0,018	<0,018	0,48
30	<0,018	0,046	<0,018	<0,018	0,019

Comments

Data show that only compost (sample #4) is always compliant with the hygienic requirements set up by the 3rd draft of April 2000, i.e. *E. coli* lower than 500 CFU/g dm and *Salmonella* absent in 50 g of final product (wet weight). Thermophilic digested sludge (samples #1 and #3) sometimes is complying, while mesophilic digested sludge is always not complying.

Eco-toxicity assessment

Selected terrestrial biotests were:

a) The test for inhibition of enzyme activity in the soil bacterium *Arthrobacter globiformis*

The endpoint of the *A. globiformis* test is the inhibition of dehydrogenase, a key enzyme of many organisms. A dilution series with five dilutions (between 0.1 % and up to 50% sludge added to the substrate quarz sand) was tested to estimate the median effect concentration (EC_{50} in g sludge dry weight/kg quartz sand dry weight). The maximum tested sludge concentration was 250 g sludge kg^{-1} substrate (in two cases 500 g sludge kg-1 substrate).

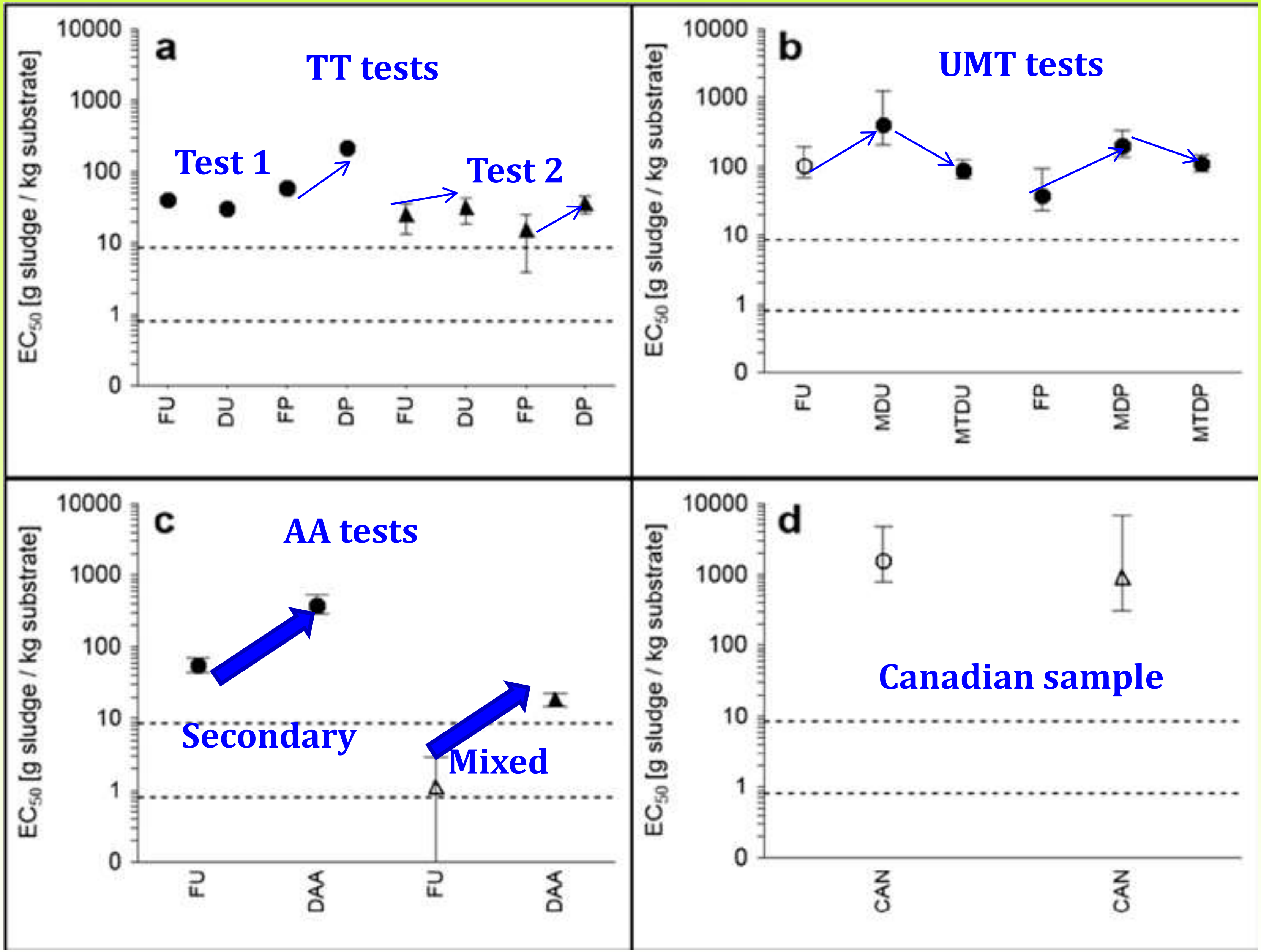
b) The test for avoidance behaviour of the earthworm *Eisenia fetida*.

Due to the limited amount of available sludge it was not possible to test a full range of dosages suitable to derive an EC_{50} estimate for avoidance, but only to conduct tests at very few different dosages. Sludge samples were applied at maximum with 25 g dry sludge kg^{-1} soil dm in the test.

Eco-toxicity assessment

- The ecotoxicological results were compared to the application rates of sludge to agricultural land in order to determine the resulting safety margin.
- Both the usual application rate in Europe, i.e. 2 t ha^{-1} (EC 2010), and the maximum allowed application rate in Ontario, Canada, i.e. 22 t ha^{-1} (OR 2009) are here considered.
- Assuming a ploughing depth of 20 cm and a soil bulk density of 1.3 g cm^{-3}, these application rates result in 0.8 g sludge kg^{-1} soil (Europe) and 8.5 g sludge kg^{-1} soil (Ontario).

Results by the *Arthrobacter globiformis*



General comments

- The *A. globiformis* toxicity of sludge samples is quantifiable and can be used for comparing the efficiency of various sludge treatment processes.
- The earthworm avoidance test requires a rather large volume of sludge sample and could therefore only be performed at a single dosage, which did not allow quantifying the toxicity toward earthworms.
- The earthworm avoidance test measures the response of a key soil organism at an integrative organismal level, which allows a more straightforward extrapolation to the field.
- The final digested sludge samples exhibited toxicity to the soil bacterium *A. globiformis* at concentrations that were always higher than the usual application rate of sludge to soil in Europe and the maximum allowed application rate in Ontario. In the avoidance tests, a safety margin of factor 30 was generally achieved for the final digested samples.
- The thermophilic digestion process achieved among the three processes the least toxicity reduction (at least when operated at low organic load), while the double stage AA process appeared as the most effective process as it could greatly reduce the considerable toxicity of the mixed sludge.
- The toxicity exerted by the Canadian biosolids was very low in both terrestrial tests. Interestingly, a similar safety margin (about factor 100) was obtained for the biosolids with regard to the maximum allowed application rate of Ontario as for the European sludge with regard to the European application rate.

Conclusions
Effects on ecotoxicity

- Only AA showed a clear reduction of ecotoxicity;
- UMT process displayed a reduction of ecotoxicity only after the 1st mesophilic step of digestion. Ecotoxicity increased after the 2nd thermophilic step.
- The toxicity exerted by the Canadian biosolids was considerably lower than that of the European samples even after enhanced stabilization processes. The toxicity of sludge seems to be more related to the source than to the treatment, with "source" meaning the origin (and thereby contamination) of the wastewater from which the sludge was produced. This was confirmed by some tests on mixed sludge (AA process) which was much more ecotoxic than secondary sludge.
- The stability of the sludge, as measured by the VS/TS ratio, significantly correlated with the toxicity to *A. globiformis* in 18 samples: the more stable the sludge the lower the toxicity was. Ammonium released from the less stabilized sludge may cause the toxicity in *A. globiformis*.
- Concentrations of only three of the measured individual pollutants (carbamazepine, triclocarban and napthalene) exhibited significant correlations with toxicity to *A. globiformis*.

Correlation coefficients between toxicity to *A. globiformis* (EC_{50}) and characteristics of sludge samples

	R
Stability index VS/TS	**-0.61**
Carbamazepine	**-0.56**
Triclocarban	**-0.57**
Naphthalene	**-0.54**
Soluble COD	-0.16
Soluble N-NH_4	0.32
Sum of PAHs	0.13
Sum of PCBs	-0.13
Sum of phthalates	-0.38
Sum of QACs	-0.02
Sum of pharmaceuticals	-0.34
Sum of biocides and fungicides	-0.31
EOX	-0.20

Processo Cambi

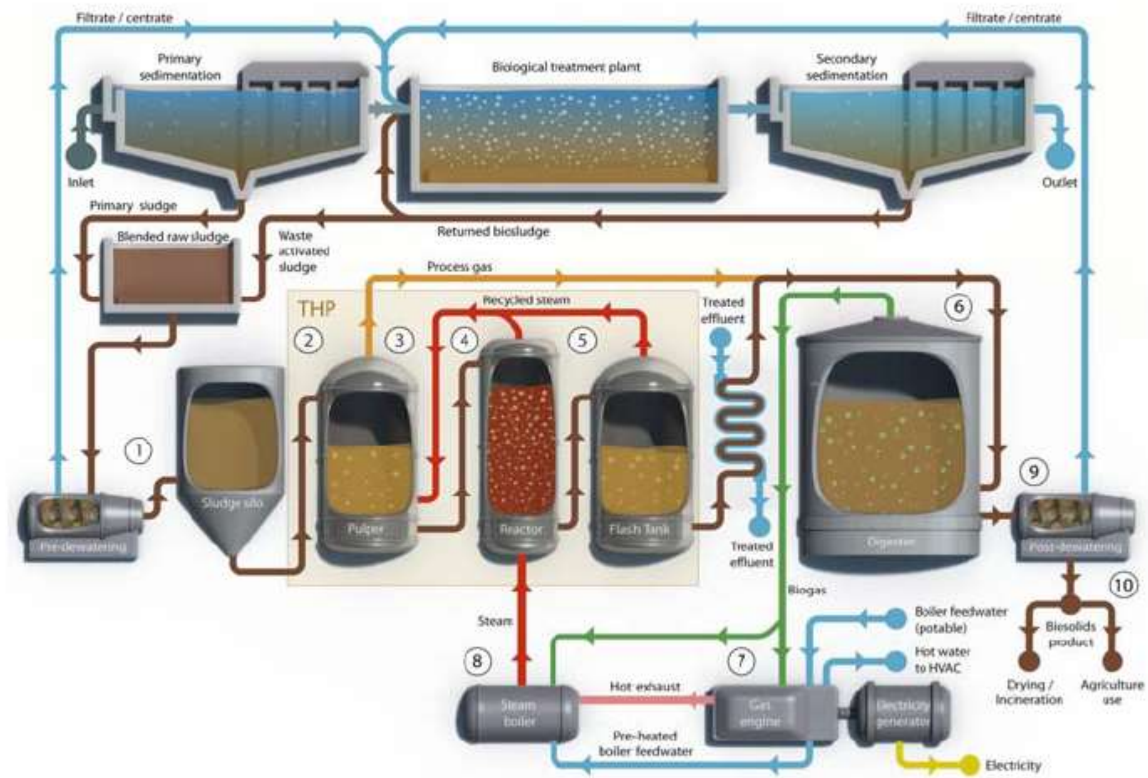
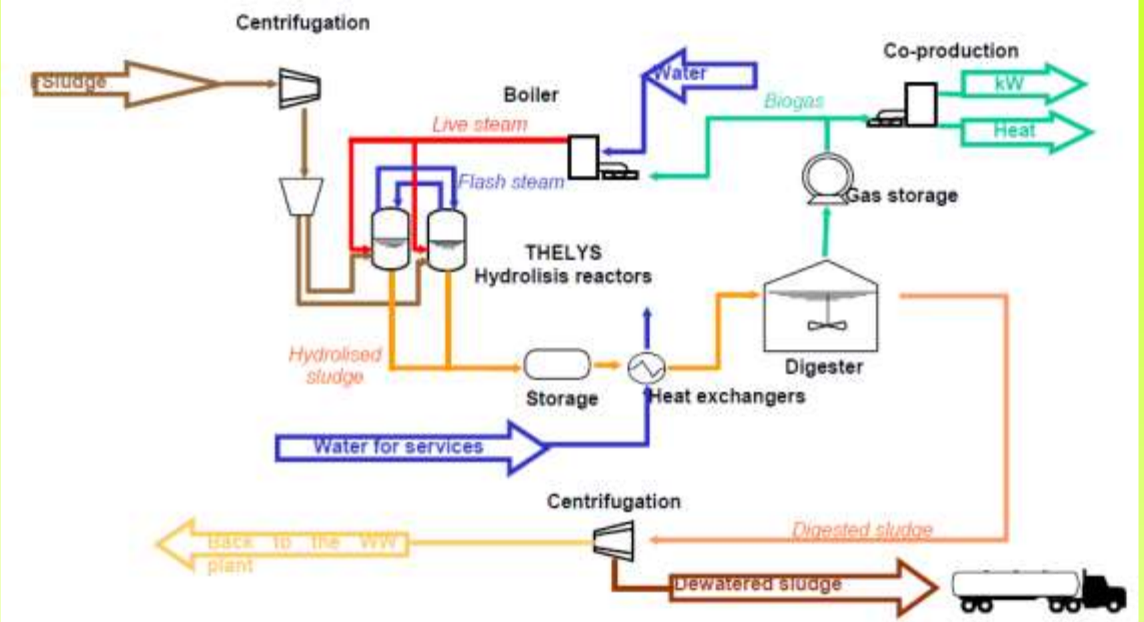


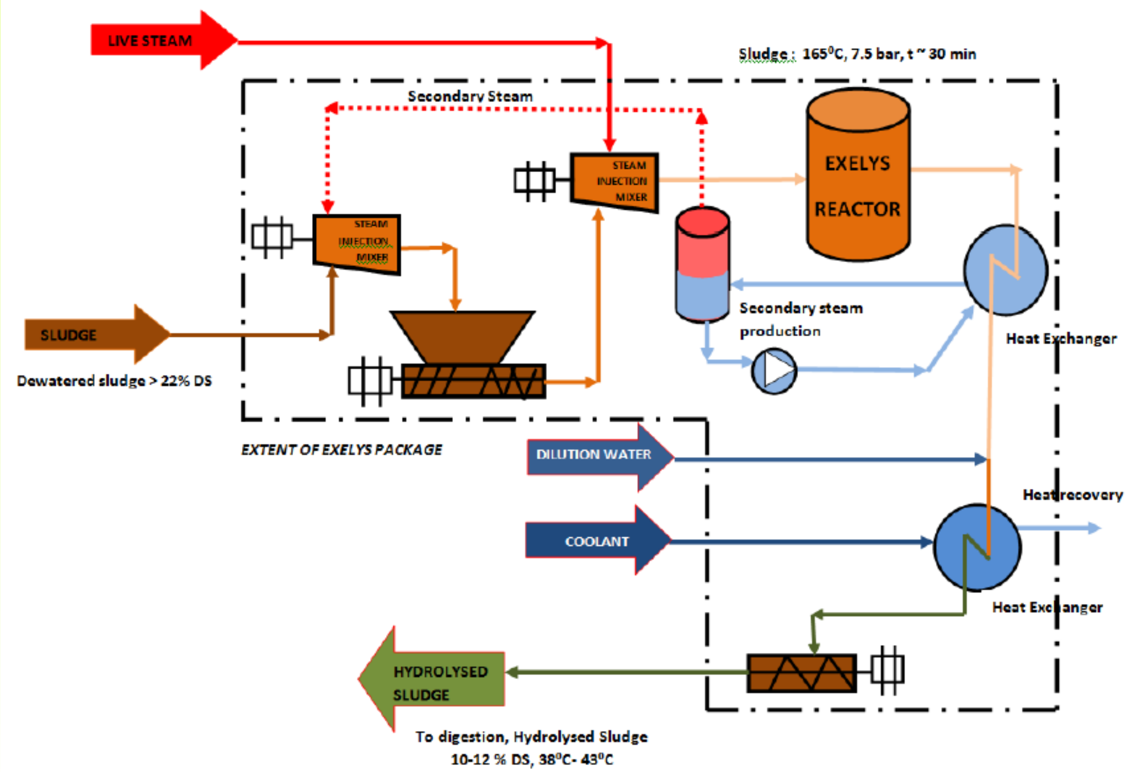
Figure 5.4 Flow sheet of the Cambi process

a. Primary and secondary sludge is mixed and dewatered in centrifuges to approx. 16% dry solids.
b. The dewatered sludge is led to a storage silo and then fed into the pulper (2).
c. In the pulper the sludge is pre-heated by injecting recycled steam from the reactors and the flash tank. The sludge is mixed by circulation pumps. All process gases are compressed and injected into the sludge pipe to the digester(s), thereby avoiding odour.
d. Pre-heated sludge is pumped into the reactor(s) (4) where thermal hydrolysis at high pressure and temperature takes place at approximately 165ºC for 30 minutes. Then a pressure release valve at the top of the reactor is opened gradually and the pressure is reduced.
e. After thermal hydrolysis, sludge is passed in to the flash tank (5), where the pressure and temperature of the hydrolysed sludge are decreased to approximately 105ºC by flashing steam back to the pulper. The sludge is cooled to the required digestion temperature.
f. The THP process is followed by anaerobic digestion (6), converting the organic matter (*volatile solids*) to biogas, mainly consisting of approximately 65% methane (CH_4) and 35% carbon dioxide (CO_2).
g. The biogas is utilised in a gas engine (7) with generator producing electricity.
h. Steam is produced in a waste-heat boiler (8) using exhaust gas from the gas engine. A small part of the produced biogas is fired directly in the steam boiler. Engine jacket cooling water preheats boiler feed water.
i. The digested sludge is dewatered with to a biosolids product in a centrifuge or belt-press to 30 – 34% .
j. The resulting cake/biosolids is applied directly on agricultural land or dried and used as fuel or fertilizer.

Processo Biothelys (Veolia)



Processo Exelys (Veolia)



Presentation by Andrew Gilbert (SludgeTech, 2015)

Acknowledgement

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THANKS FOR YOUR PATIENCE

ANY CURIOSITY?

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