Spring 6-10-2014

Impact of enhanced stabilization treatments on sludge quality and methane recovery

Camilla Braguglia
Istituto di Ricerca sulle Acque

A. Gallipoli
Istituto di Ricerca sulle Acque

A. Gianico
Istituto di Ricerca sulle Acque

G. Mascolo
Istituto di Ricerca sulle Acque

G. Mininni
Istituto di Ricerca sulle Acque

Impact of enhanced stabilization treatments on sludge quality and methane recovery

Camilla M. Braguglia, A. Gallipoli,
A. Gianico, G. Mascolo, G. Mininni

Istituto di Ricerca sulle Acque
CNR - Consiglio Nazionale delle Ricerche

Wastewater and Biosolids Treatment and Reuse: Bridging Modeling and Experimental Studies, Otranto (LE), July 10th 2014

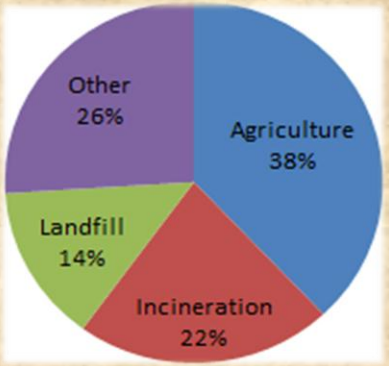
Estimates of annual sewage sludge production

Member State	2005 ($x10^3$ tonn DS / year)	2020 ($x10^3$ tonn DS / year)
Austria	266	280
Belgium	102	170
Denmark	140	140
Finland	147	155
France	910	1,600
Germany	2,059	2,000
Greece	126	260
Ireland	62	135
Italy	1,070	1,500
Luxembourg	8	10
Netherlands	550	560
Portugal	409	420
Spain	1,065	1,280
Sweden	210	250
United Kingdom	1,545	1,640
tot. EU15	**8,669**	**10,400**
Bulgaria	34	180
Cyprus	7	16
Czech Republic	221	264
Estonia	-	33
Hungary	128	200
Latvia	24	50
Lithuania	71	80
Malta	-	10
Poland	524	950
Romania	137	520
Slovakia	55	135
Slovenia	19	50
tot. EU12	**1,220**	**2,484**
tot. EU27	**9,889**	**12,884**

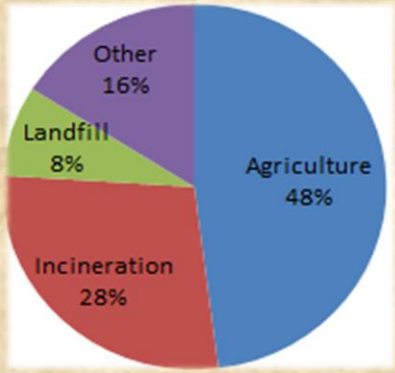
Expected sludge production increase considering a full implementation of the UWWT Directive across all of the 27 EU Member States by 2020
(EU15 should have complying with all the requirements in 2005..
..but was not the case!)

Sludge disposal routes - EU27

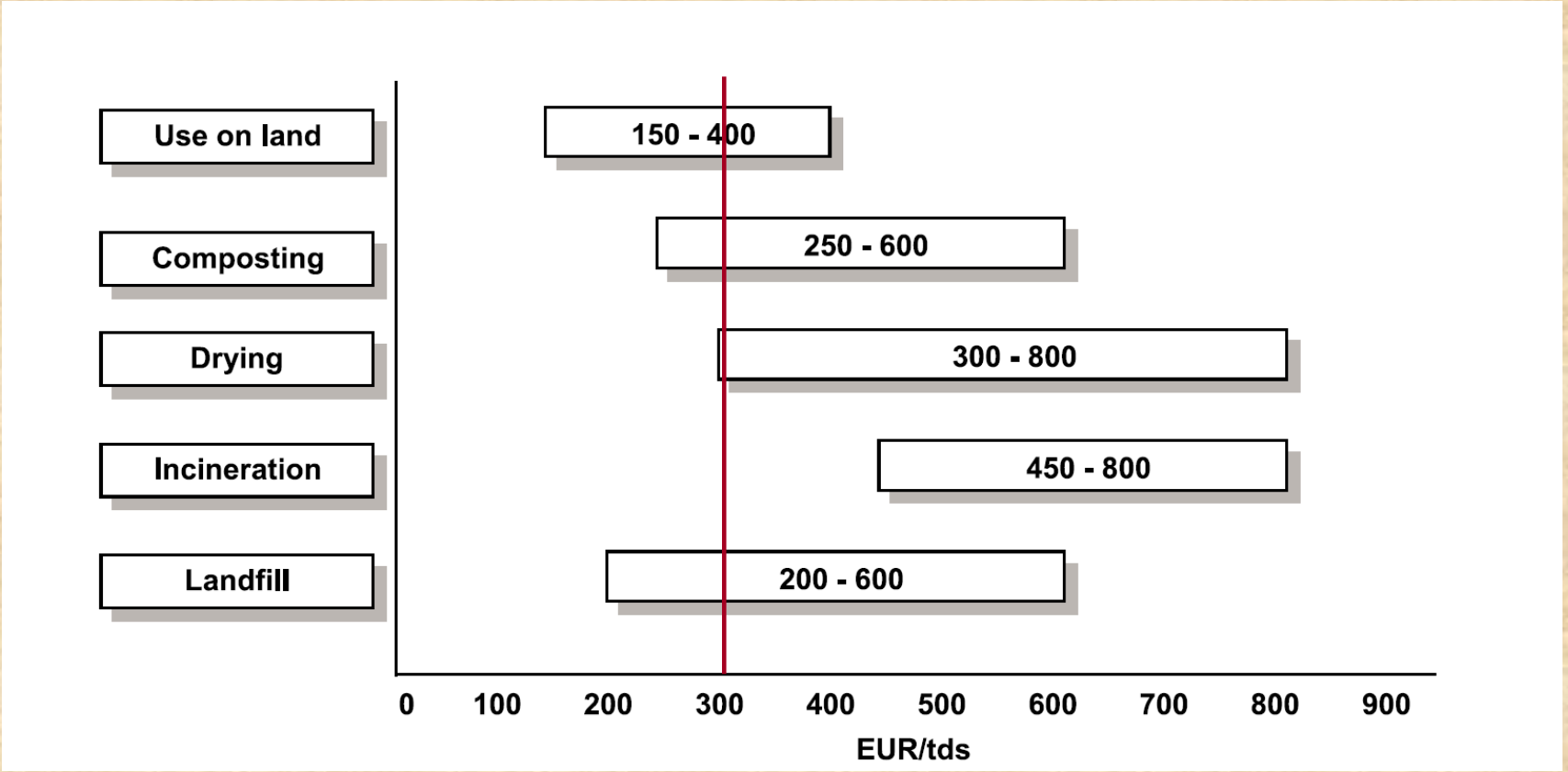
2005



2020



From "Study on the environmental, economic and social impacts of the use of sewage sludge on land" (DG ENV.G.4/ETU/2008/0076r)



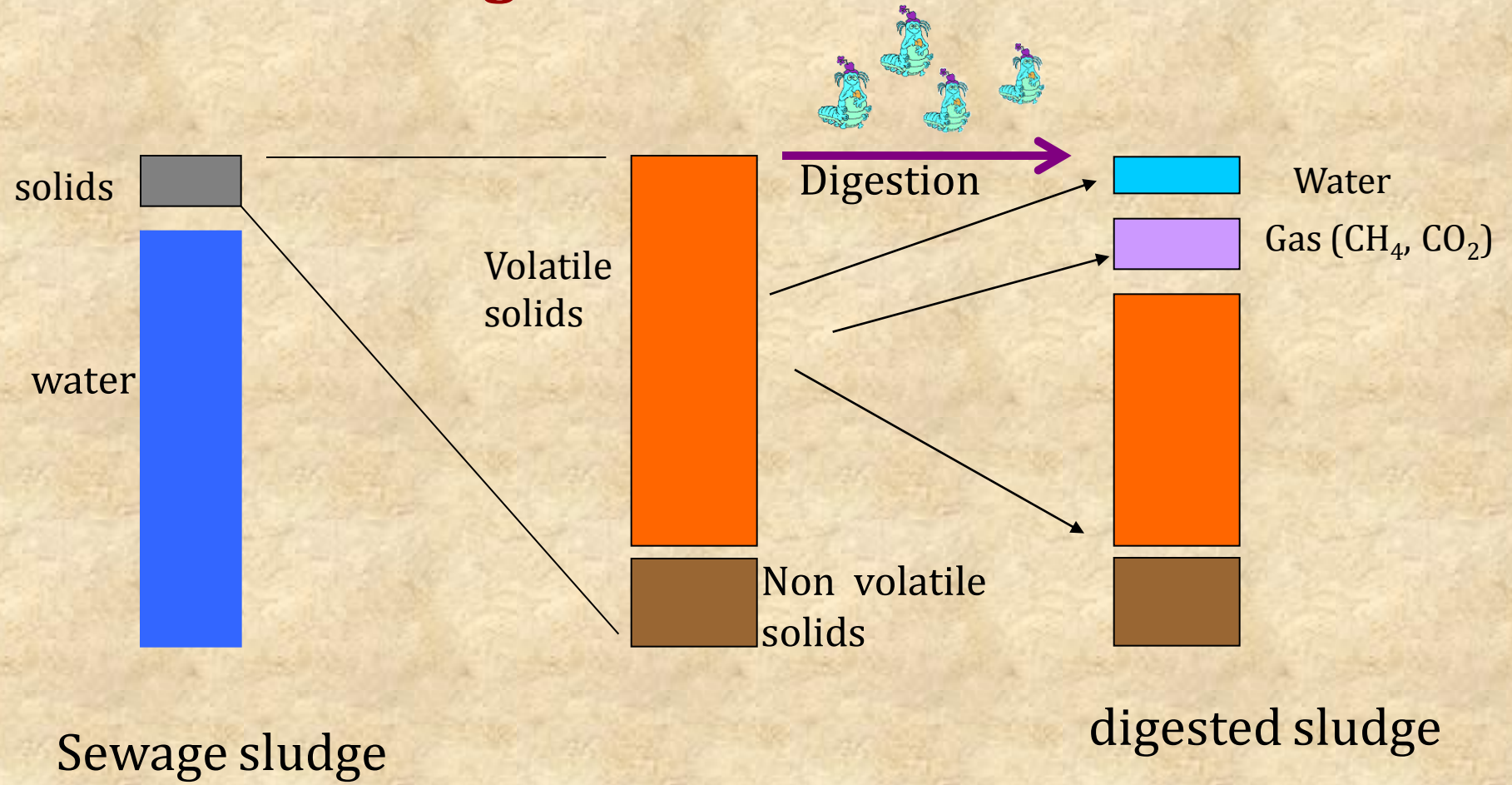
In Italy: average cost 300 Euro/tDM,
the annual cost for treatment and disposal is 450 million euro

75 times the annual Balotelli's salary

Overall trends (EU 27)

- Continued increased level of sewer connection and wastewater treatment ⇒ **increased production of sewage sludge**, which will need proper management;
- **Increased treatment of sludge before recycling to land through anaerobic digestion** and other biological treatments, like composting. The use of raw sludge will no longer be acceptable;
- **Potential increased restrictions on types of crops** being allowed to receive treated sludge;
- **Enhanced production and utilisation of biogas;**
- **Production of alcohols and other fuels** directly from sewage sludge using pyrolysis and gasification;
- Similar proportion of **treated sludge recycled to agriculture at around 40-50% by 2020**.
- **Phasing out sludge being sent to landfill due to EC restrictions** on organic waste going to landfill and increased dislike by the public of use of landfill disposal.
- **main alternative** to landspreading **is likely to continue to be incineration** (where land suitable for recycling is unavailable)
- Increased **attention to climate change** and mitigation of greenhouse gas emissions ⇒recognised additional benefits of sludge use on land
- Increased attention to **recovery of organic nutrients**, including those in sludge

Anaerobic digestion: volatile solids reduction



The volatile/total solids ratio and/or the percentage of volatile solids destroyed can be used as stability index:

VS/TS< 0.60 and **VS removal> 40%** are, generally,an indication of achieved stabilisation.

Enhanced anaerobic digestion: why?

to produce biosolids of exceptional quality for recycling

to provide following benefits of anaerobic digestion:

- Increased volatile solids reduction ;
- Reduced vector attraction potential in the product sludge;
- Improved biogas production rates and biogas quality;
- Minimization of amount of final product solids;
- Increased pathogen removal;
- Improved dewaterability of the product sludge;
- Diminished odor problems during and after processing;

A stable sludge will undergo no further change⇒ public perception and acceptability problems are likely to be avoided

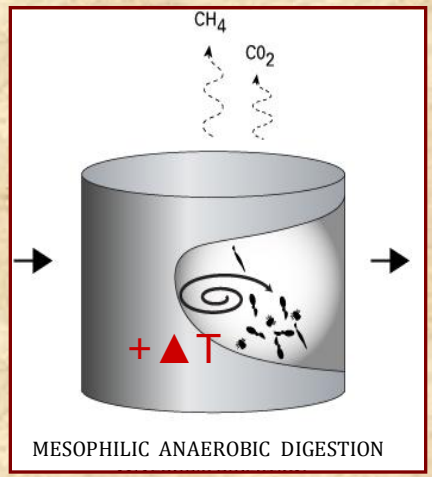
Enhanced anaerobic digestion: how?

1) Disintegration pre-treatment (Mechanical, thermal, chemical, etc)

2) Modification of the AD through temperature increase (from mesophilic conditions (35°C) to thermophilic conditions (55°C)

3) Post-treatment: a successive thermophilic stage acting as methane fermenter and hygienization step, or an aerobic stage to improve VS removal

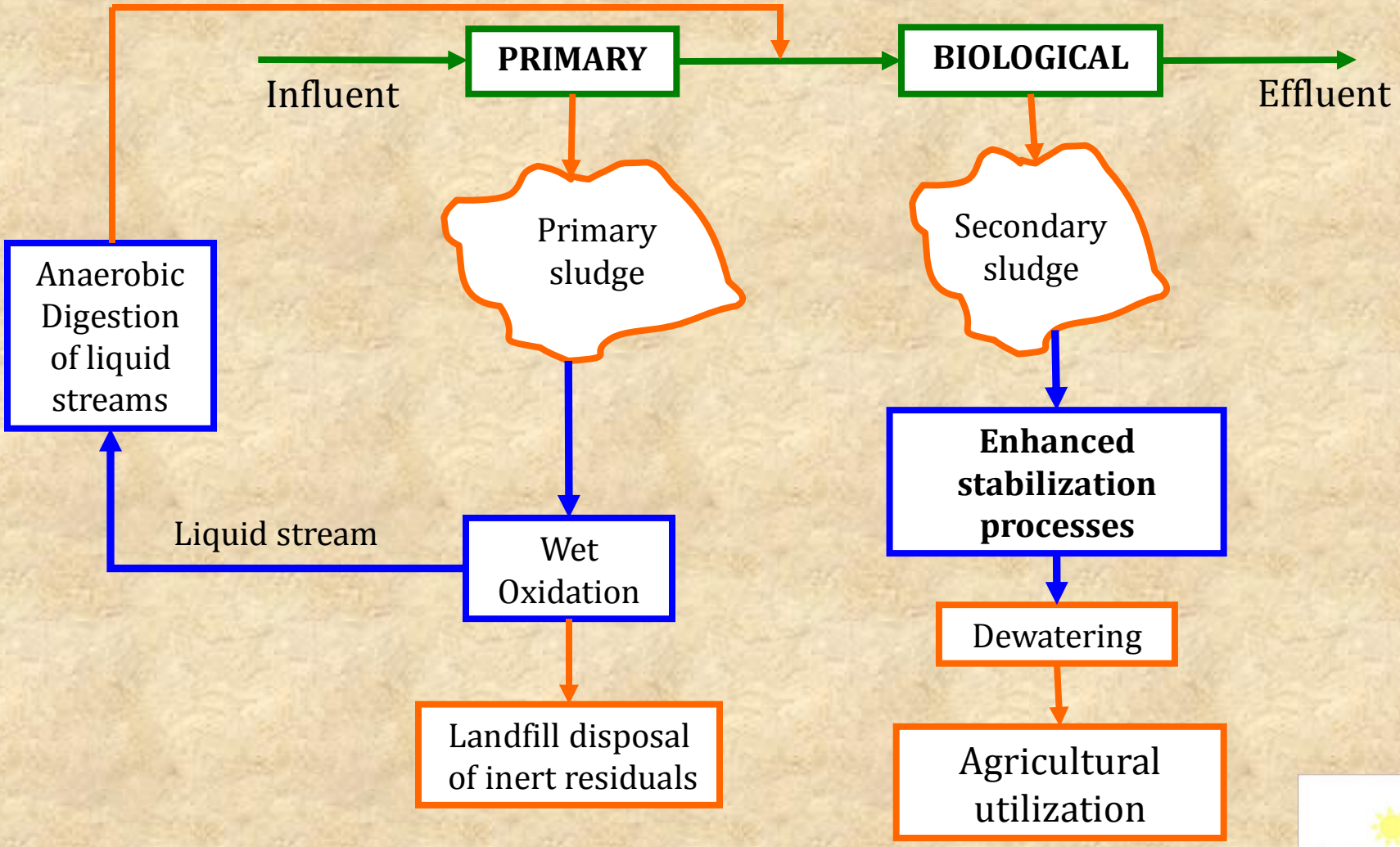
Sludge disintegration pre-treatments



Thermophilic post-treatment

“Sludge separation”

For large WWTPs with primary sedimentation:
high sludge production not suitable for agricultural use



THERMOPHILIC
DIGESTION

THERMAL
HYDROLYSIS/thermo AD

HYDRODYNAMIC/CHEMICAL PRETREATMENT

AEROBIC POST-TREATMENT

ENHANCED STABILIZATION PROCESSES

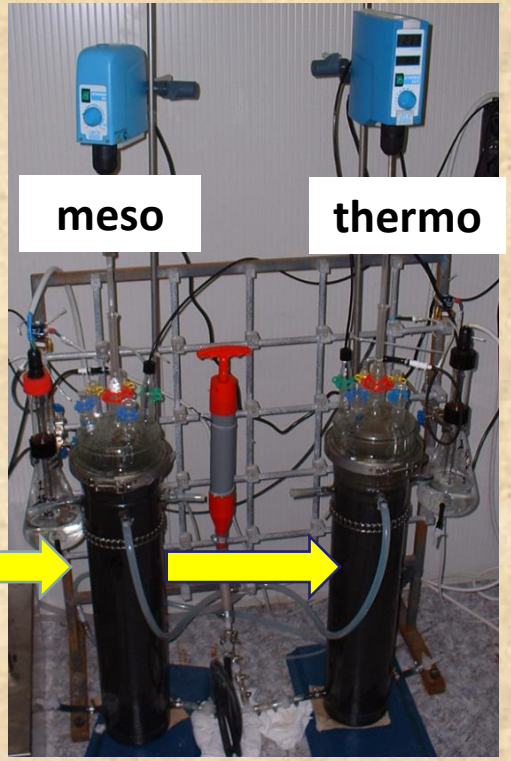
ULTRASOUND/meso-thermo AD

Meso/thermo AD

TWO PHASED MESOPHILIC/THERMOPHILIC AD - EXPERIMENTAL SETUP

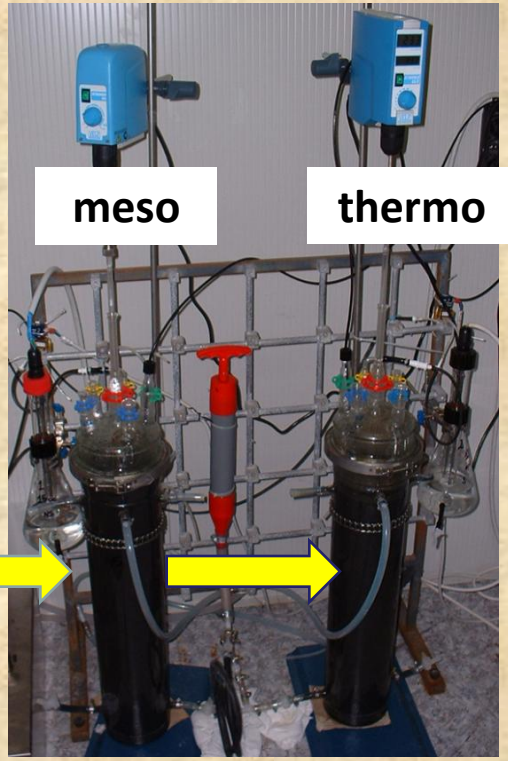
The aim is to separate microbial groups into two phases: hydrolytic and acidogenic/fermentative bacteria in mesophilic, and acetogenic /methanogenic microorganisms in thermophilic stage

UNTREATED SLUDGE



US pretreatment
20 kHz
2'
(300 W)

SONICATED SLUDGE



	1°stage	2°stage	1°stage	2°stage
T (°C)	37°C	55°C	37°C	55°C
OLR (g VS L^{-1} d^{-1})	3.6	1.2	10	3
HRT (d)	5	10	3	10
Test duration (d)	100		90	

THERMOPHILIC DIGESTION

THERMAL HYDROLYSIS/thermo AD

HYDRODYNAMIC/CHEMICAL PRETREATMENT

AEROBIC POST-TREATMENT

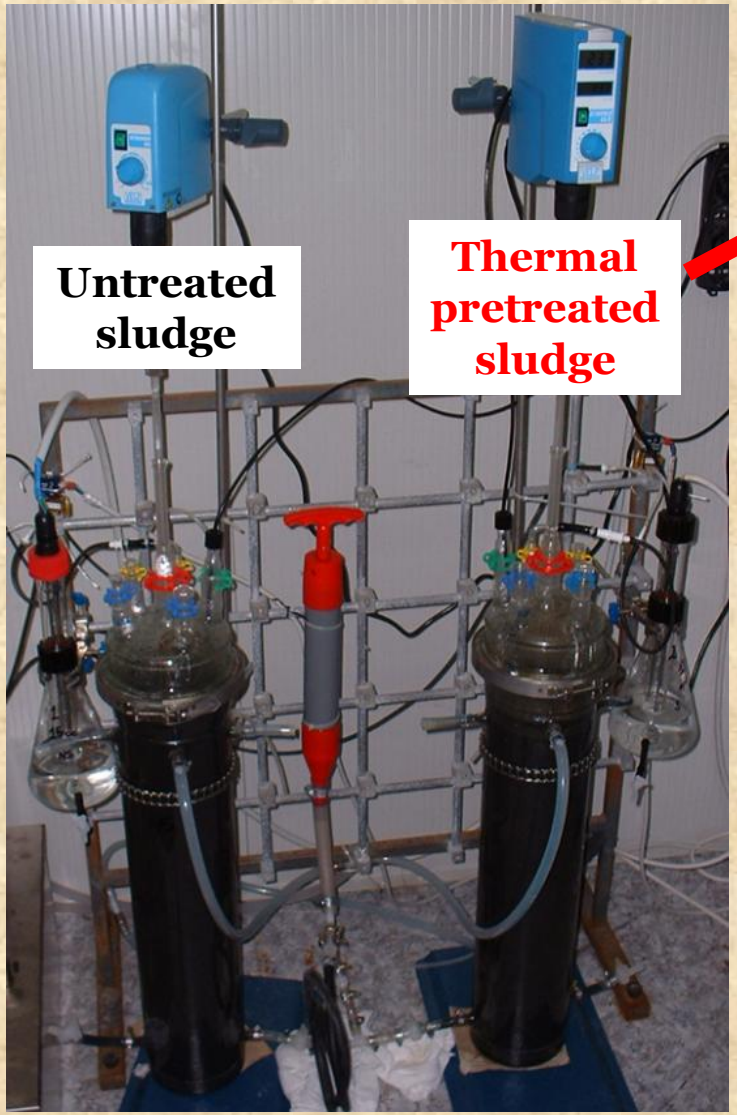
ENHANCED STABILIZATION PROCESSES

ULTRASOUND/meso-thermo AD

Meso/thermo AD

THERMOPHILIC AD - EXPERIMENTAL SETUP

Both jacketed reactors (7 L) were completely mixed and maintained at the constant temperature of 55° C. Reactors were fed every day.



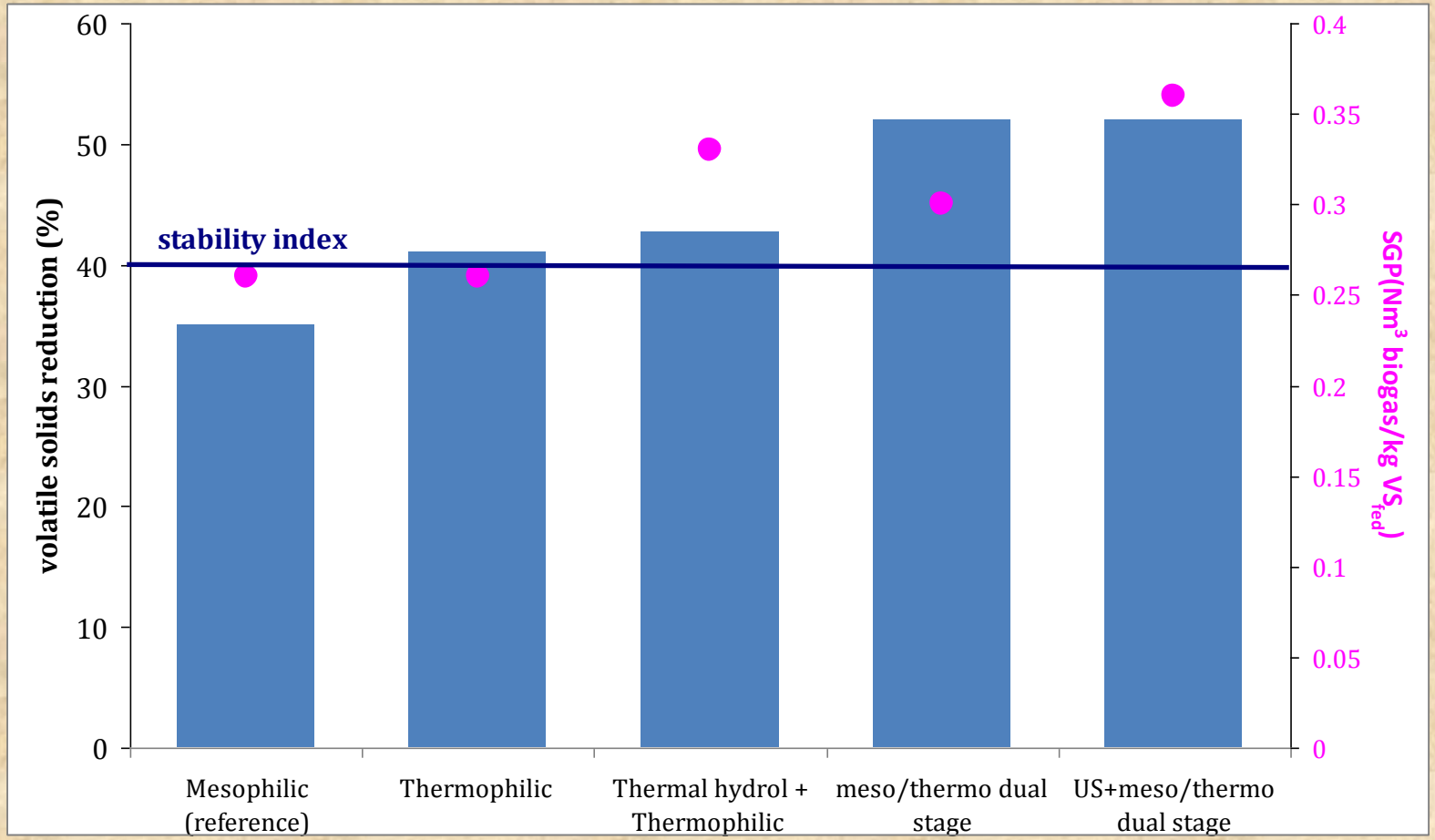
Thermal pretreatment

135° C
2.5 bar
20'

Digestion time of 250 days divided in three phases :

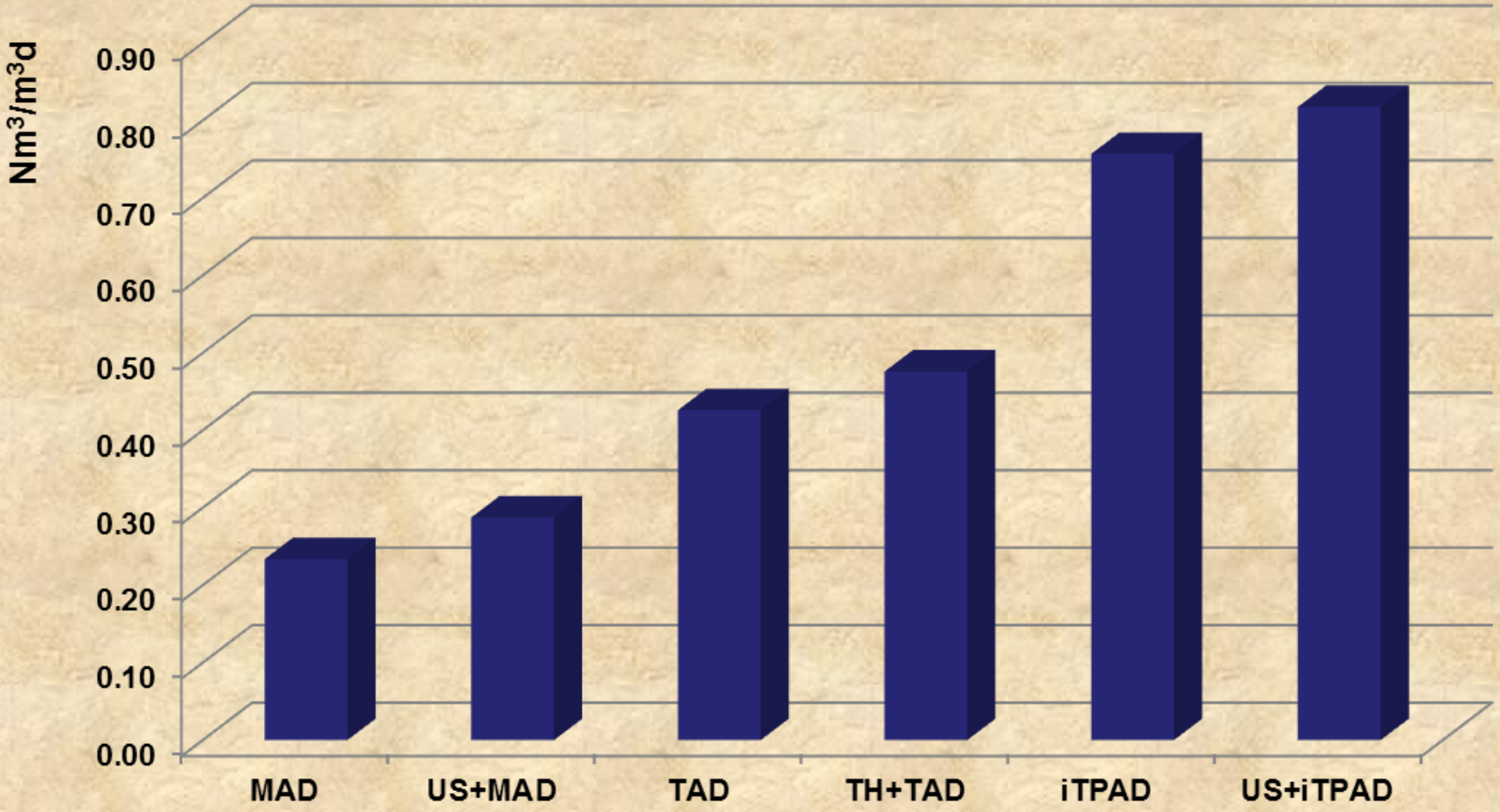
Test	1	2
OLR (g VS L^{-1} d^{-1})	1.7	1
HRT (d)	8	15
Digestion time (d)	102	103

secondary sludge digestion
OLR 1-3 kg VS/m^3.d



- 30 % more gas is feasible, with pretreatment integration
- stability degree achievable only by means of enhanced processes
- Double stage guarantee high organics reduction, less putrescibility, less odours

Methane production rate



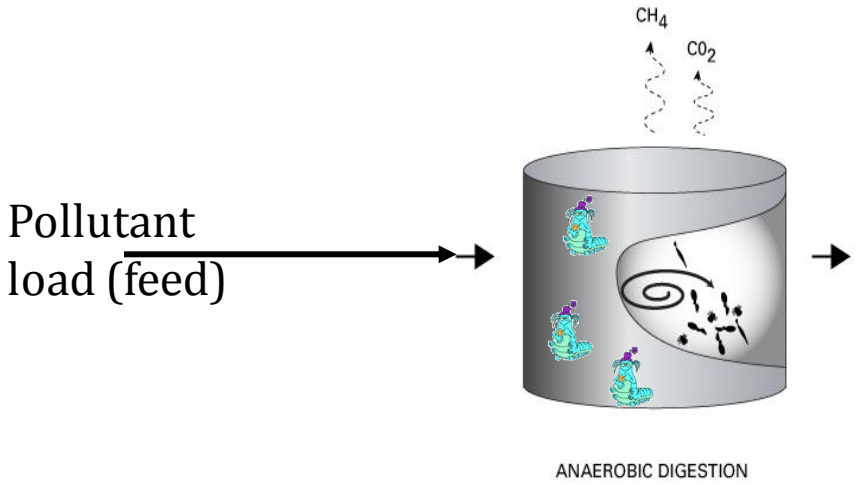
Digestate characteristics

	Soluble N-NH_4 (mg/L)	Soluble COD (mg/L)	Capillary suction time CST (sec gTS/L)
Conventional Mesophilic AD	350-500	200-440	7-14
Thermophilic AD	770-1300	650-1600	25-34
Thermal hydrolysis + TAD	750-1200	1000-1600	35-39
Meso/thermophilic dual stage	750-1200	1000-2200	20-29
US+meso/thermo dual stage	900-1300	900-2200	21-27

✓Decreased dewaterability, due to released biopolymers (… high soluble COD and ammonia).

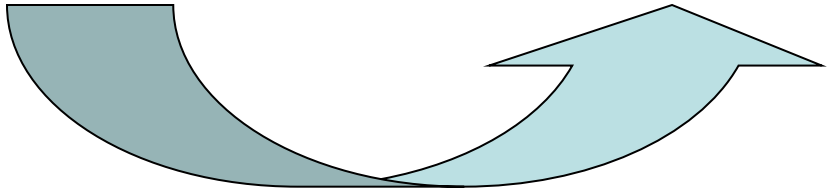
✓Solids degradation decreased dewatering ability of "enhanced digested" sludge

Pollutants fate during anaerobic digestion



Mass reduction due to anaerobic process

Theoretical accumulation of pollutant



expected concentration in the digested sample:

normalized feed concentration with respect to the residual mass

Organic micropollutant (mg/kg)	Feed sludge concentration	Literature range
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

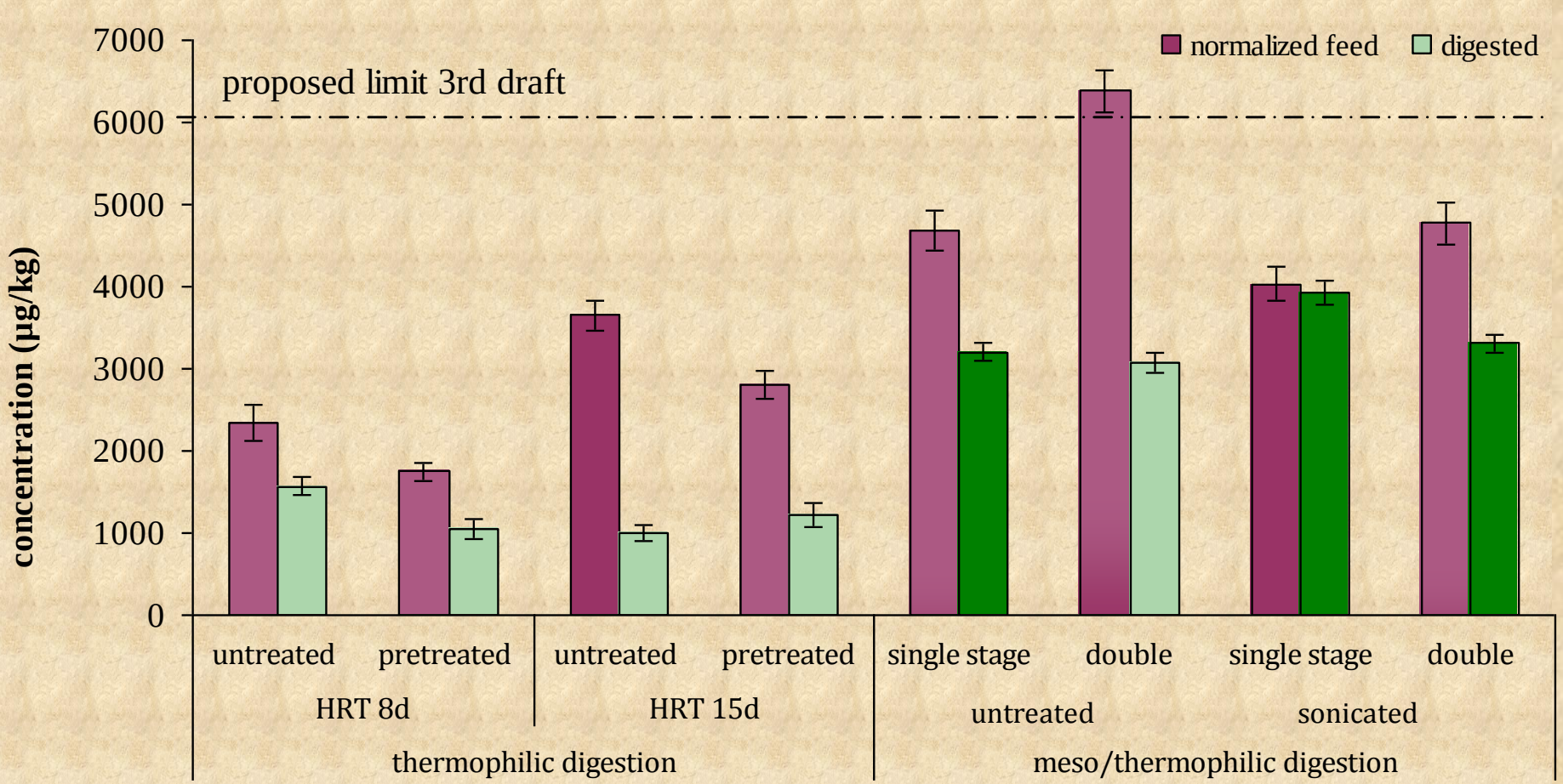
Evaluation of pollutants removal

- the normalized feed (NF) concentration represents the theoretical pollutant concentration in the digested sample if no degradation and volatilization of the pollutant occurred.
- The pollutant concentration in the digested sample (D) represents the real concentration found after the treatment

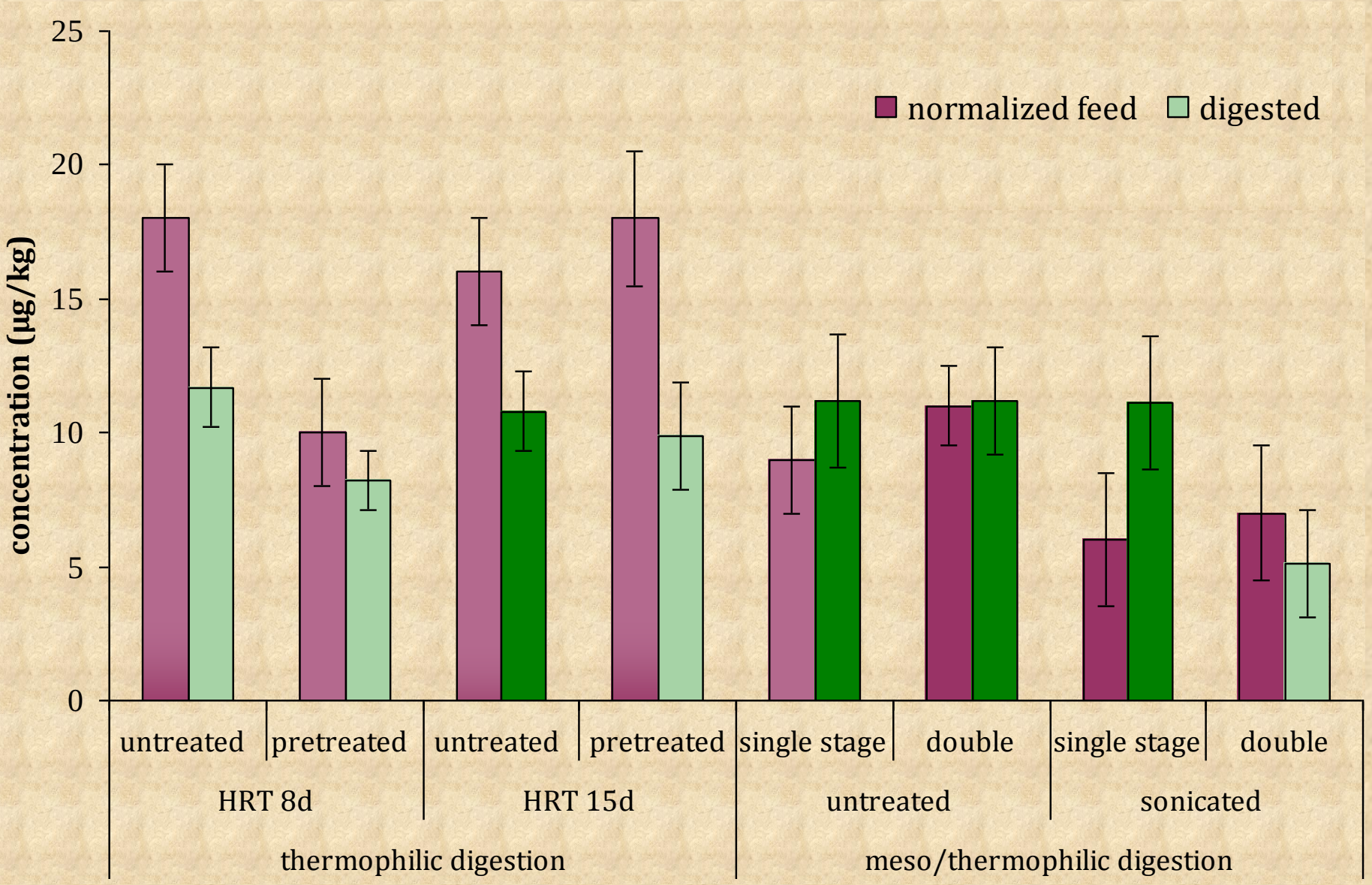
D=nF	NO removal
D<nF	removal
D>nF	desorption

LAS, PCB, PAH, DEHP, NP/NPE *removal have been investigated for the enhanced AD*

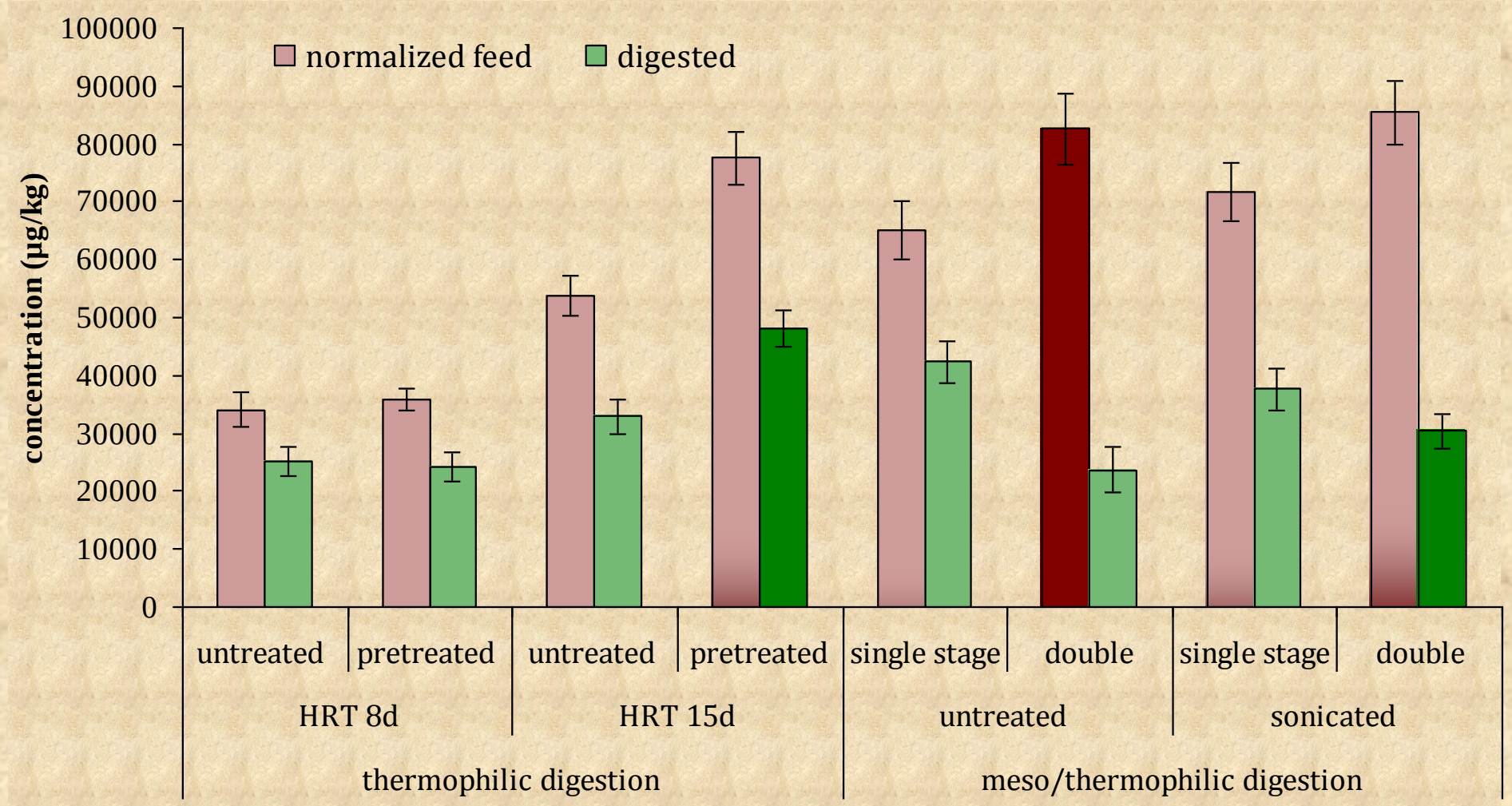
Polycyclic aromatic hydrocarbons



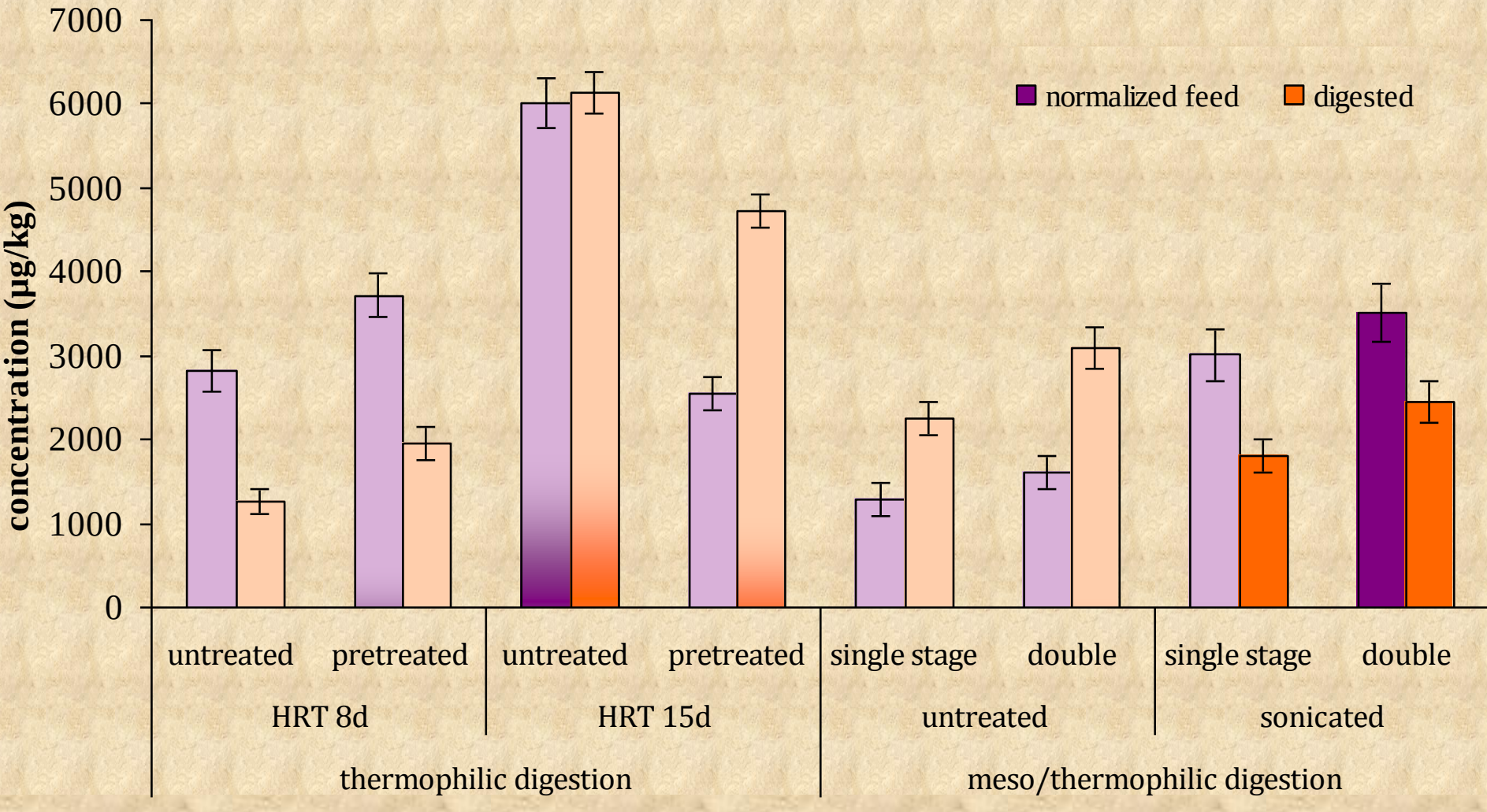
Polychlorinated biphenyls



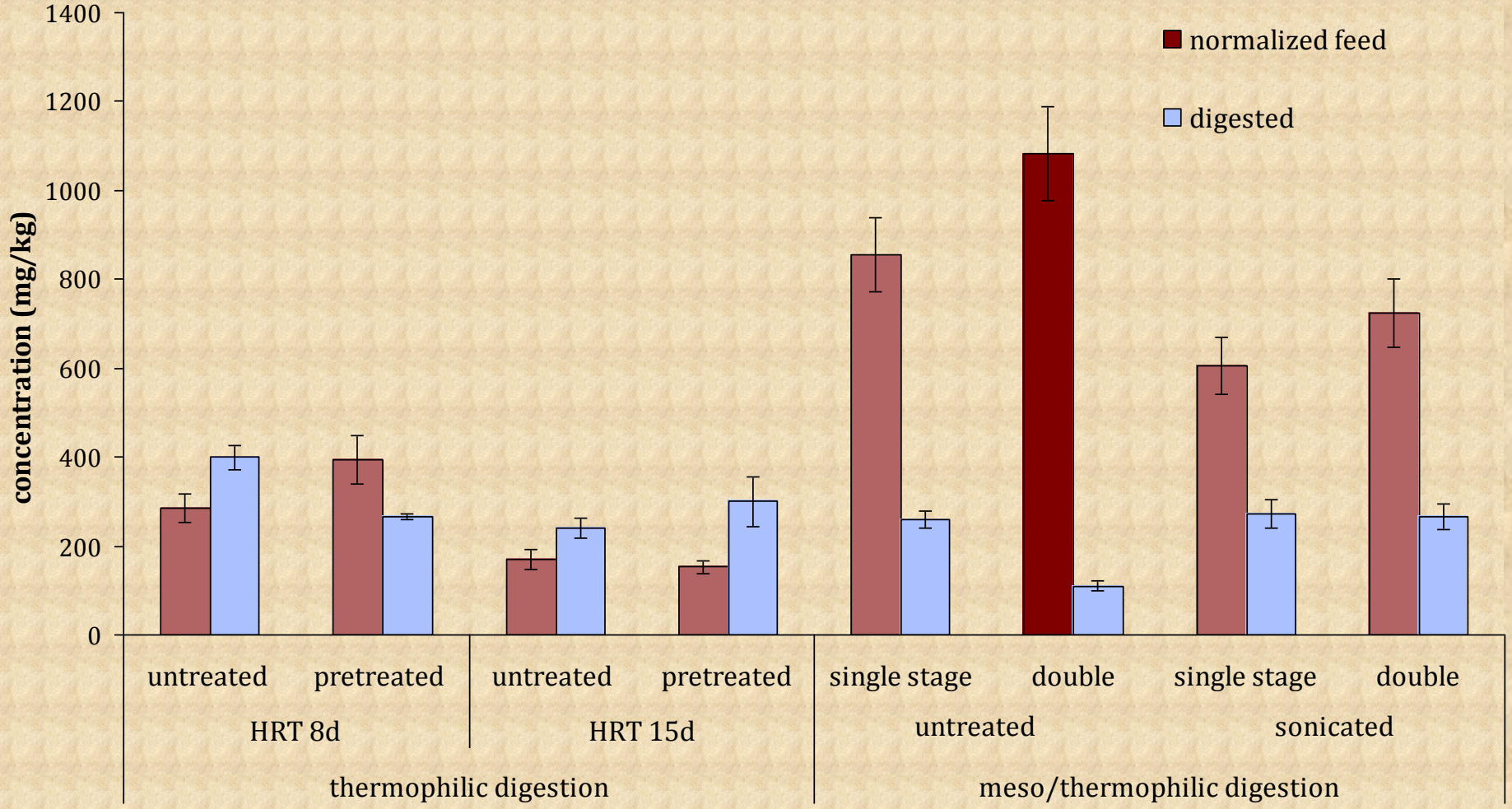
Phthalates


normalized feed
digested
concentration (µg/kg)
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
untreated
pretreated
untreated
pretreated
single stage
double
single stage
double
HRT 8d
HRT 15d
untreated
sonicated
thermophilic digestion
meso/thermophilic digestion

Non ionic surfactants



Anionic surfactants



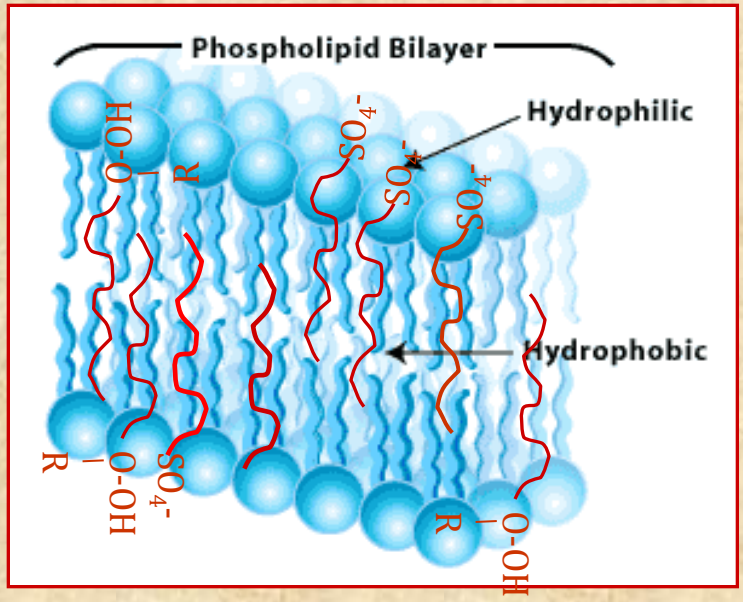
why desorption??

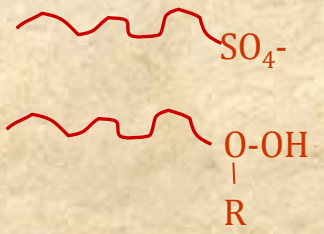
the sludge disintegration (by sonication, or by digestion) by modifying the sludge structure could enhance the surfactants diffusion rate from the non-extractable to the extractable part.

The CEN/TS 16189 method is not accurate for surfactants extraction from sludge? How to assess the total recovery of pollutants from sludge?

It is misleading consider that the "recovery of the analyte is about equal to that of the internal standard".

Spiking does not represent the reality because added compounds are firstly extracted in already contaminated sludges, while "aged" compounds, which are strongly linked to the matrix, require more time, more energy to be available and thus extracted.



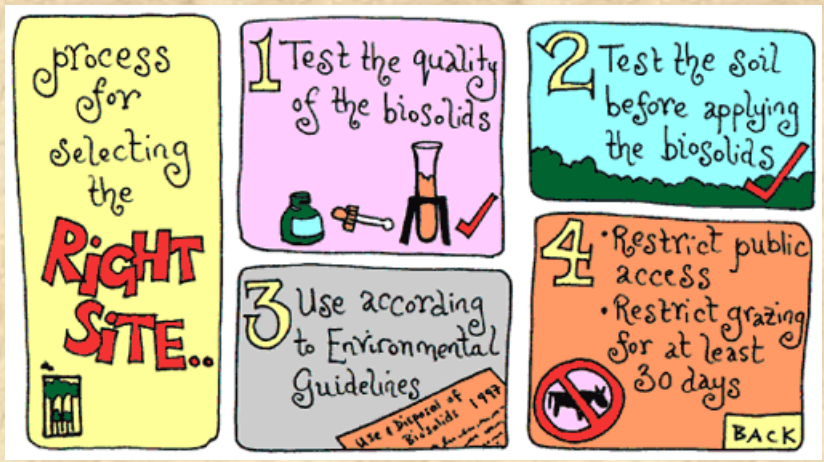


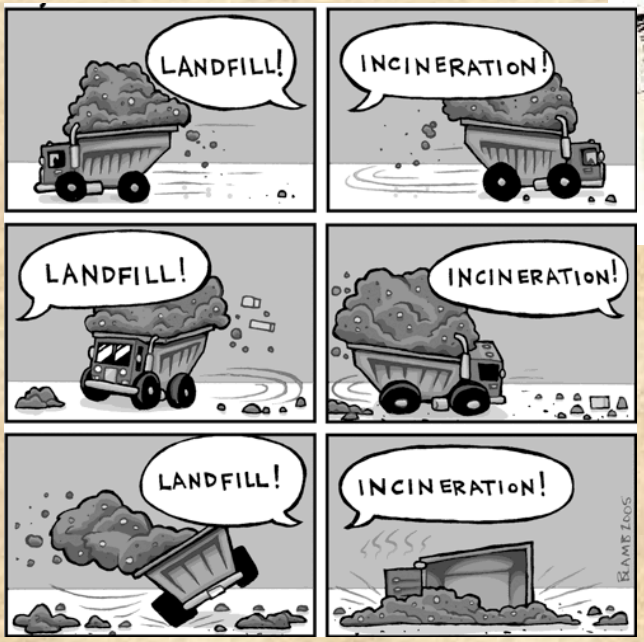
surfactants

Take home message

- Single stage thermophilic digestion affected negatively supernatant quality and sludge dewaterability
- Innovative dual stage meso/thermo achieved high organics reduction, which guarantee less odors, while digestate filterability was not dramatically impaired.
- The Enhanced stabilization processes did not give same results for the investigated conventional organic pollutants; however, the dual stage integrated with ultrasounds had evident benefits for removing pollutants
- If the economy is based only on cost/ benefit from biogas, the gain is marginal. Considering beneficial side-effects (less sludge, residual heat use, hygienization, pollutants removal) the pre-treatment could be the appropriate "enhancer"
- The "enhancement" of stabilization process implies by itself an inprovement of the digestion process and consequently a) more disintegrated sludge, b) more colloidal fine particles, c) more soluble COD $\Rightarrow\Rightarrow$ optimization (load, HRT) of the final step (methanogenesis) is requested in order to improve the transformation of these compounds avoiding digestate worsening!
- The appropriate technology to be implemented on a given WWTP should be evaluated according to plant's needs considering various goals of the plants upgrade (class A biosolids, more energy, etc).

Sludge treatment and disposal accounts for half the expenses, and 90 % the troubles in a WWTP





Thank you for your attention

braguglia@irsa.cnr.it