ROUTES: Novel processing routes for effective sewage sludge management. An on-going EU project

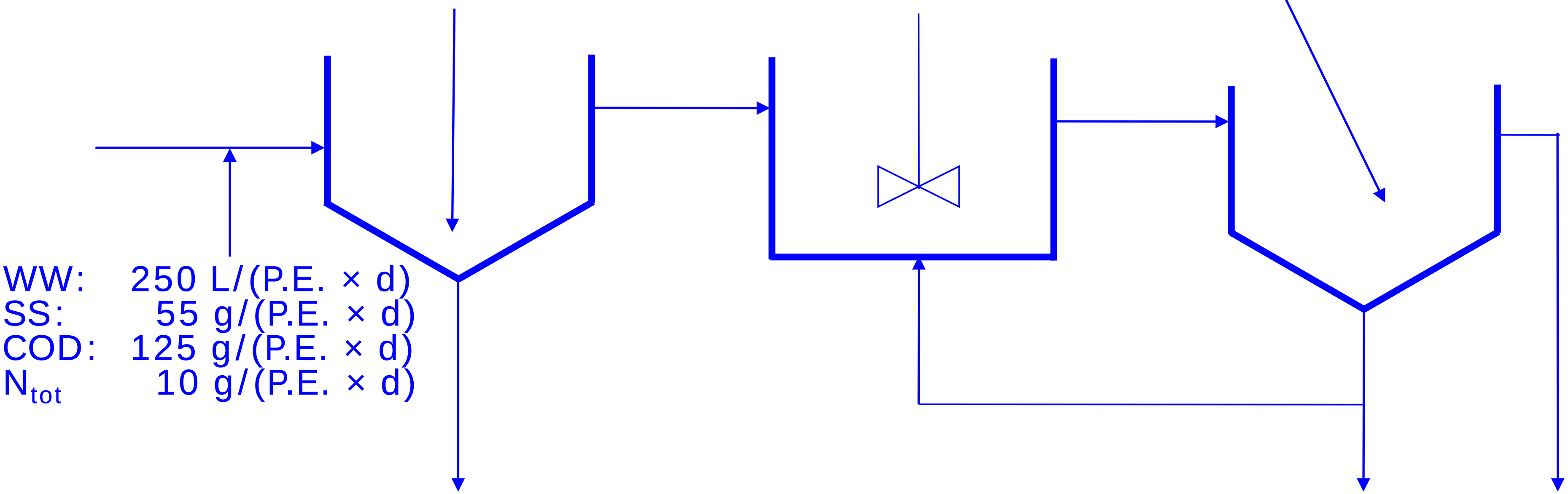
Giuseppe Mininni
CNR – Istituto di Ricerca Sulle Acque
Via Salaria, km 29,3
00015 Montelibretti (Roma)
mininni@irsa.cnr.it

Sewage sludge production

SS removal in primary settling tank: 60%
COD removal in primary settling tank: 30%
BOD_5 removal in primary settling tank: 35%
N removal in primary settling tank: 10%
P removal in primary settling tank: 10%

Secondary sludge production: 37,1 g/(P.E. × d)
Secondary sludge concentration: 1%
Secondary sludge production (volume): 3,71 L

Primary sludge production (weight): 46,7 g/(P.E. × d)
Primary sludge concentration: 2%
Primary sludge production (volume): 2,34 L

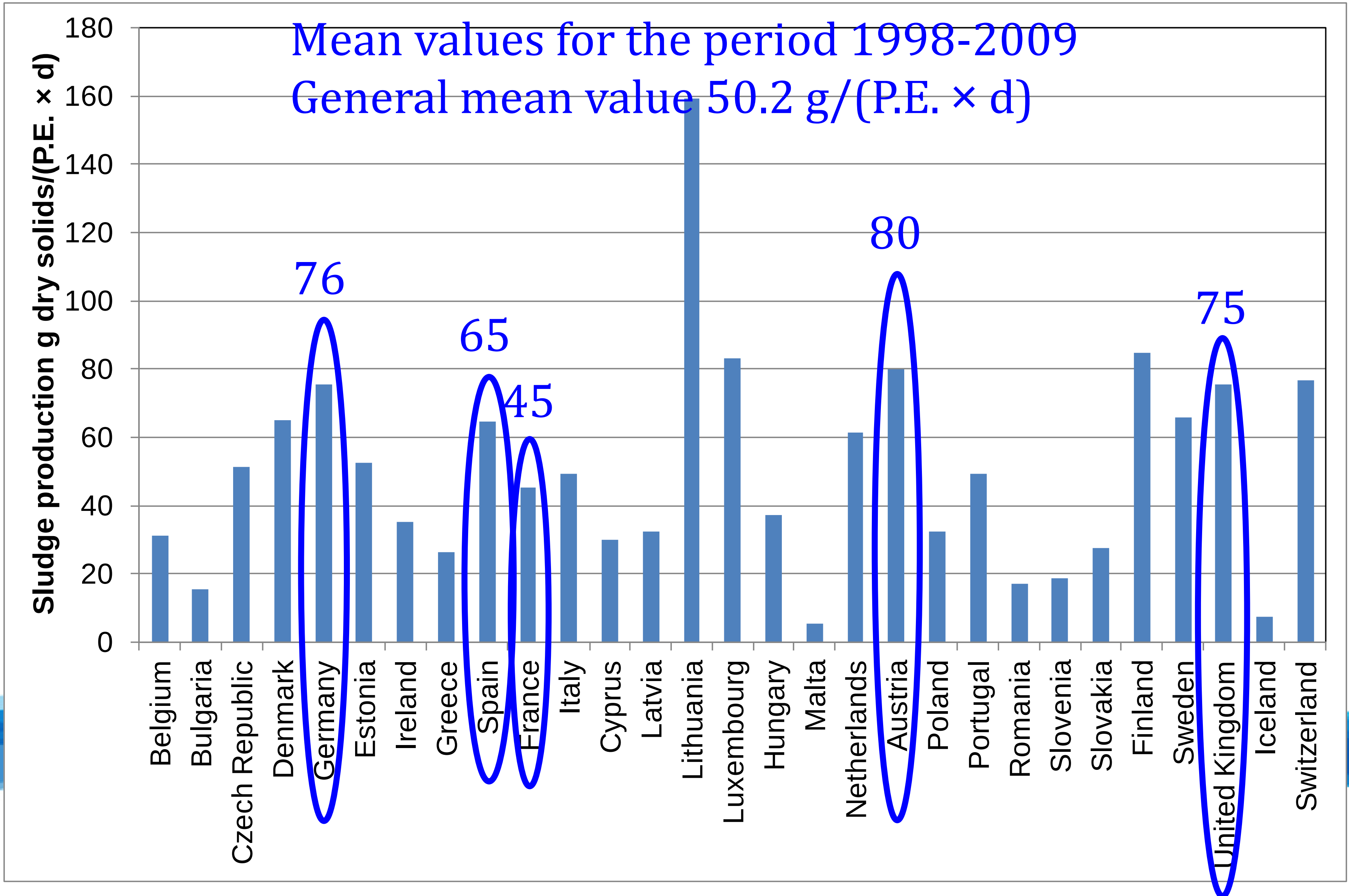


Total production

Volume: 2.34 + 3.71 = 6.05 L/(P.E. × d) i.e. 2.4% of WW

Solids: 46.7 + 37.1 = 83.8 g/(P.E.× d)

Data in Europe of per capita production [g/(P.E. × d)] (EC - Eurostat)



Impacts of the project

- Setting up of innovative technical solutions to be benchmarked with standard ones;
  - Reduction of sludge production;
- Supporting the related EU policies regarding the sludge utilization on land by assessing the interactions between sludge (at different level of treatment) and soil.

Objectives

- Develop new routes and innovative techniques in wastewater and sludge treatment for;
  - Production of sludge suitable for agricultural use;
  - Sludge minimization;
  - **Materials** and energy recovery;
  - Sludge disposal minimizing the emissions.
- Evaluation of effects on soil due to sludge utilization in agriculture;
- Assessment of economic and environmental sustainability of the innovative techniques.

UNIVERSITAT DE BARCELONA

INSTITUT DE L'AIGUA

Partners

IRSA CNR

INCA

UNIVERSITAS STUDIORUM BRIXIAE

eawag aquatic research

bfg Bundesanstalt für Gewässerkunde

ATH

UNIWERSYTET PRZYRODNICZY W LUBLINIE

UNIVERSITÉ DE REIMS CHAMPAGNE-ARDENNE

UNIVERSITAT DE BARCELONA

CHALMERS

3V GREEN EAGLE S.P.A.

vermicon solutions for microbiology

E·C·T Oekotoxikologie GmbH

ANOXKALDNES

ATEMIS

Mediterranea delle Acque

SAPIENZA UNIVERSITÀ DI ROMA

Agriculture and Agri-Food Canada

People

Costs and grants (10^3 €)

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	TOTAL
Total costs	747,1	923,3	672,8	1.196,3	683,1	424,2	243,2	4.890,0
	15,3 %	18,9 %	13,8 %	24,5 %	14,0 %	8,7 %	5,0 %	
Commission financial contribution	567,8	601,2	336,4	771,7	485,4	398,1	204,0	3.364,6
	16,9 %	17,9 %	10,0 %	22,9 %	14,4 %	11,8 %	6,1 %	

Structure

WP7 – Management and coordination (Cnr-Irsa)

WP6 – Dissemination (Mediterranea Acque)

WP1 - Preparation for utilisation (CNR-IRSA)
- Advanced stabilization and oxidation process
- Pathogen detection by standard methods
- Pathogen detection by new molecular tools

WP2 - Minimisation (Anoxkaldnes)
- Microbial electrolysis cells
- Biopolymers integrated process for MBR
- Use of sequencing batch biofilter granular reactor
- Anaerobic co-digestion with bio-wastes

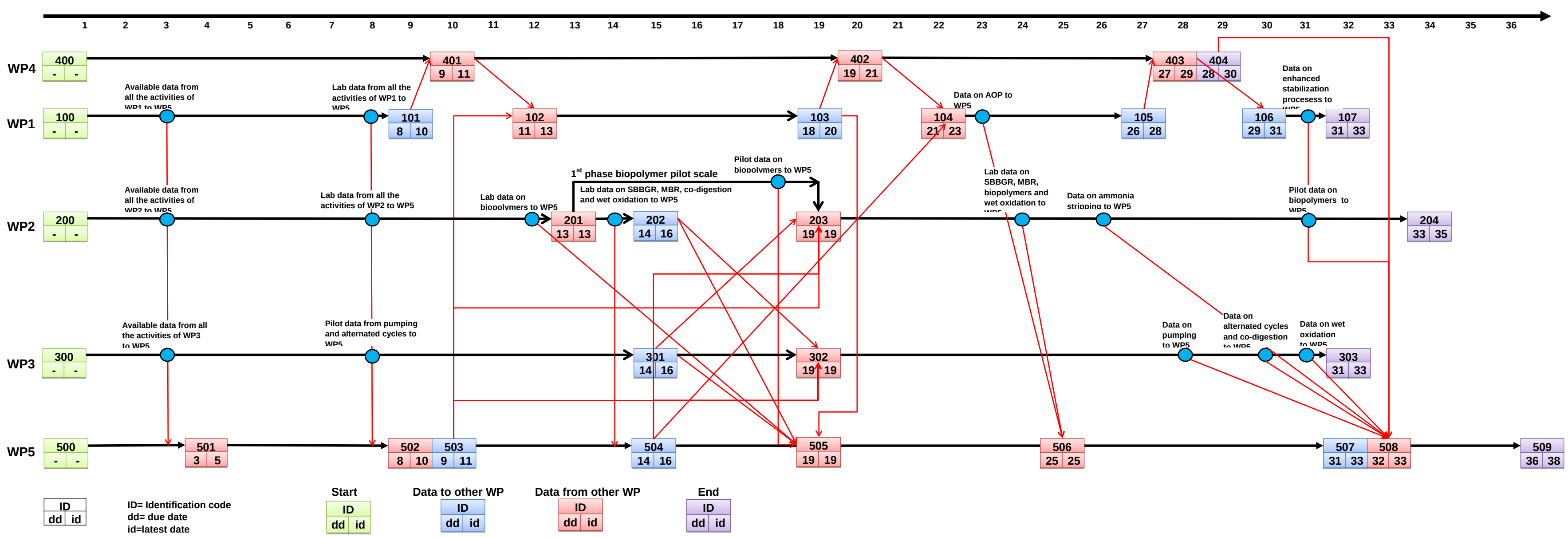
WP5 - LCA and LCC (UniChalmers)
- Benchmarking of techniques
- Data inventory
- Impact assessment

WP4 - Sludge-soil interaction (BFG)
- Organic micropollutants and metals and their fate in soil
- Bacterial re-growth during storage
- Ecotoxicological testing
- Assessment of sludge quality for agriculture reuse

WP3 - Practical aspects (INCA)
- Wet oxidation
- Rheological characterization and optimization of sludge pumping
- Full scale testing on sludge minimization by biological alternate cycles
- Recovering of $(NO_4)_2SO_4$ from ammonia stripping on a full scale plant

WP6 – Dissemination (Mediterranea Acque)

Overview of Pert (interconnections among WPs)



100 Start activity WP1

101 1st set of sludge sample produced to WP4

102 1st lab tests data acquisition; Adjustement of operating variables according to the 1st benchmarking

103 2nd set of sludge sample produced to WP4; data to WP5 for the 2nd benchmarking

104 2nd lab tests data acquisition; Adustrment of operating variables according to 1st LCA

105 3rd set of sludge sample produced to WP4

106 3rd lab tests data acquisition

107 End of WP1 activity

200 Start activity WP2

201 Adjustment of operating variables on biopolymer production (pilot scale) according to 1st bemchmarking

202 Data to WP5 for 2nd benchmarking

203 Adjustment of operating variables according to benchmarking and 1st LCA

204 End of WP2 activity

300 Start activity WP3

301 Data to WP5 for benchmarking; data on ammonia stripping to WP2

302 Adjustment of operating variables according to 1st benchmarking and 1st LCA; acquisition of data from WP2 on co-digestion and wet oxidation

303 Stop WP3 activity

400 Start activity WP4

401 1st sludge samples from WP1 (bacterial regrowth, metals, phytotoxicity org. micropollutants)

402 2nd sludge samples from WP1

403 3rd sludge samples from WP1

404 Full set of impact data to WP5; End of WP4 activity

500 Start activity WP5

501 Available data from WP1, WP2 and WP3 (1st acquisition)

502 Experimental data from WP1, WP2 and WP3 (2nd acquisition)

503 1st technological benchmarking, completed

504 1st environmental assessment of technological routes, completed

505 Start of 2nd benchmarking

506 Start of 2nd environmental assessment of AOP, SBBGR, SBR, biopolymer (bench scale), co-digestion (lab scale)

507 2nd benchmarking of technological routes (box 506), completed

508 Start of 2nd environmental assessment on enhanced stabilization, biopolymner (pilot scale), ammonia stripping, wet oxidation, pumping, alternated cycles, co-digestion (pilot sclale). Data from WP4 for LCIA

509 End of WP5 activity

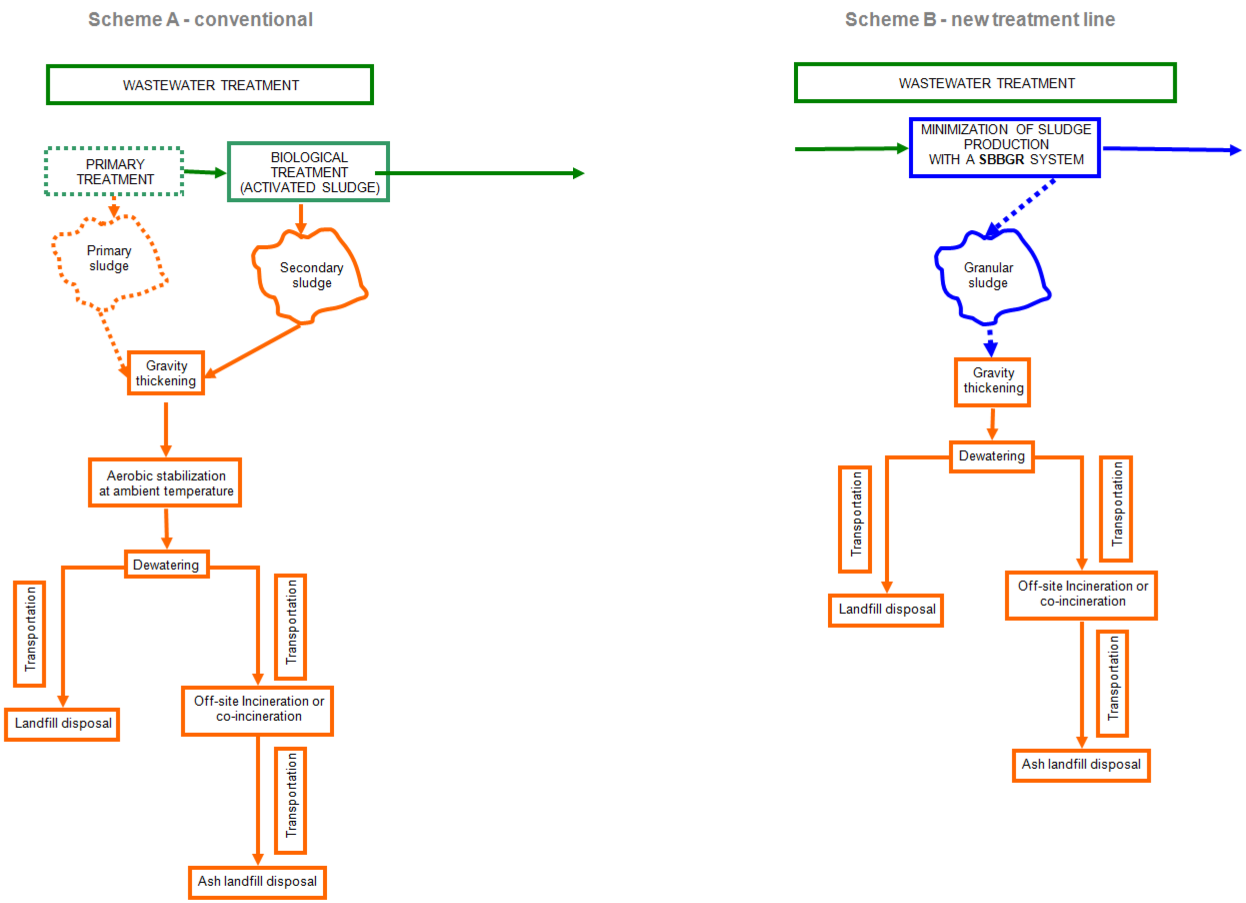
Examples of flow sheets – Small plants

Small WWTPs ≤ 20,000 inhabitants

With/Without primary sedimentation - Without nutrient removal - High organic load - High pollution level

Problem: High sludge production not suitable for agricultural use.

Solution: Sludge reduction with compact treatment systems (applied in water line)



STORYLINE

In small conventional plants with high sludge production not suitable for agricultural use, we suggest a new treatment line based on the application of sequenching batch biofilter granular reactor (SBBGR) system in order to minimize sludge production.
Reductions of 80% and 50-60% are expected in comparison with conventional treatment with or without primary sedimentation, respectively.
Aerobic stabilization of granular sludge is not needed, as it is produced at a very prolonged sludge age.
In the new scheme, primary sedimentation is abandoned.

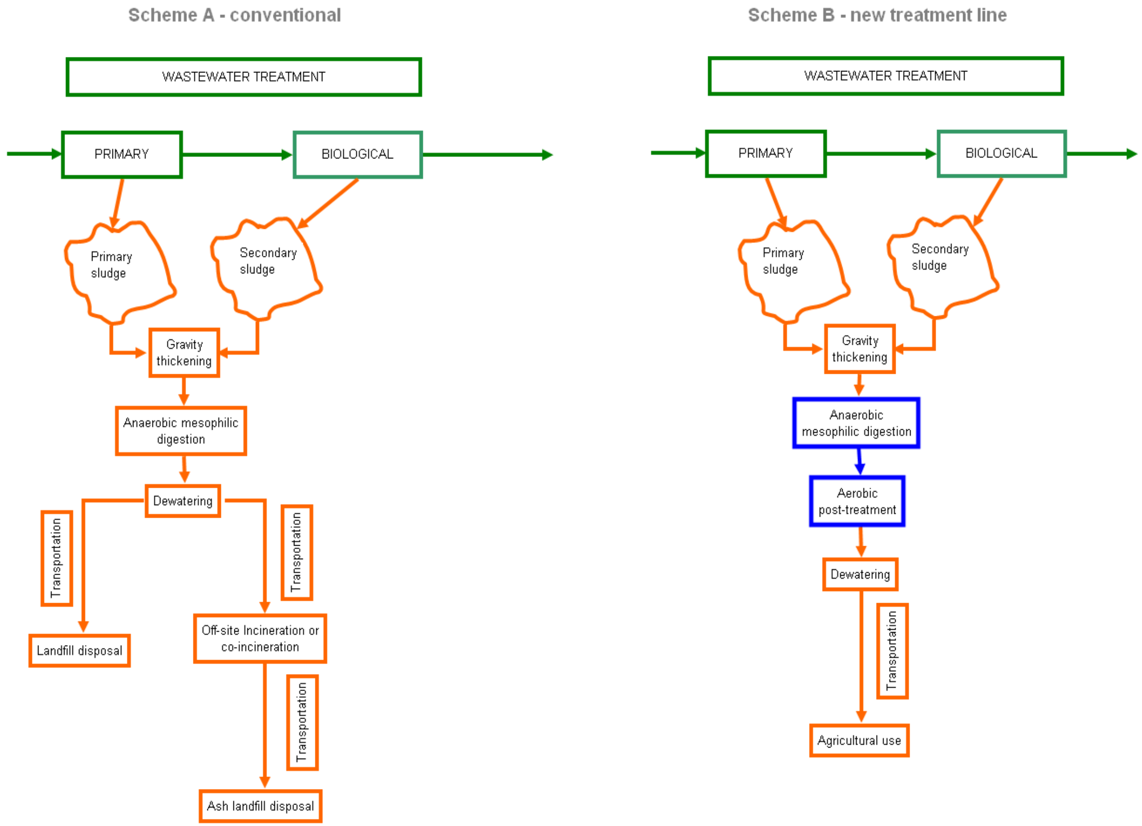
Examples of flow sheets – Medium plants

20,000 <Medium WWTPs ≤ 100,000 inhabitants

With primary sedimentation - With/Without nutrient removal - Low/High organic load - Low pollution level

Problem: Production of mixed sludge almost suitable for agricultural use but not well stabilized to be disposed

Solution: Adoption of a post-aerobic stabilization treatment on mixed digested sludge



STORYLINE

In medium size plants with primary sedimentation and with a low pollution level the production of a mixed sludge almost suitable for agricultural use is expected. However, in many cases sludge anaerobic digestion is not well conducted or the organic load is too high for the production of a well stabilized sludge. In these cases we suggest to combine anaerobic mesophilic digestion with an aerobic post-treatment, aimed to improve performance of the conventional mesophilic digestion and dewaterability with consequent reduction of polymer dosage and costs. The main goal is to produce a sludge suitable for agricultural use.
Emissions of N2O due to partial denitrification and subsequent air stripping will be taken into consideration for LCA.

Examples of flow sheets – Large plants

Option A1 (WO + BP): Wet oxidation of primary and secondary sludge after BP production. Use of liquid phase from wet oxidation for BP production.

Option A2 (WO): Wet oxidation of primary and secondary sludge. Treatment of liquid phase by mesophilic digestion.

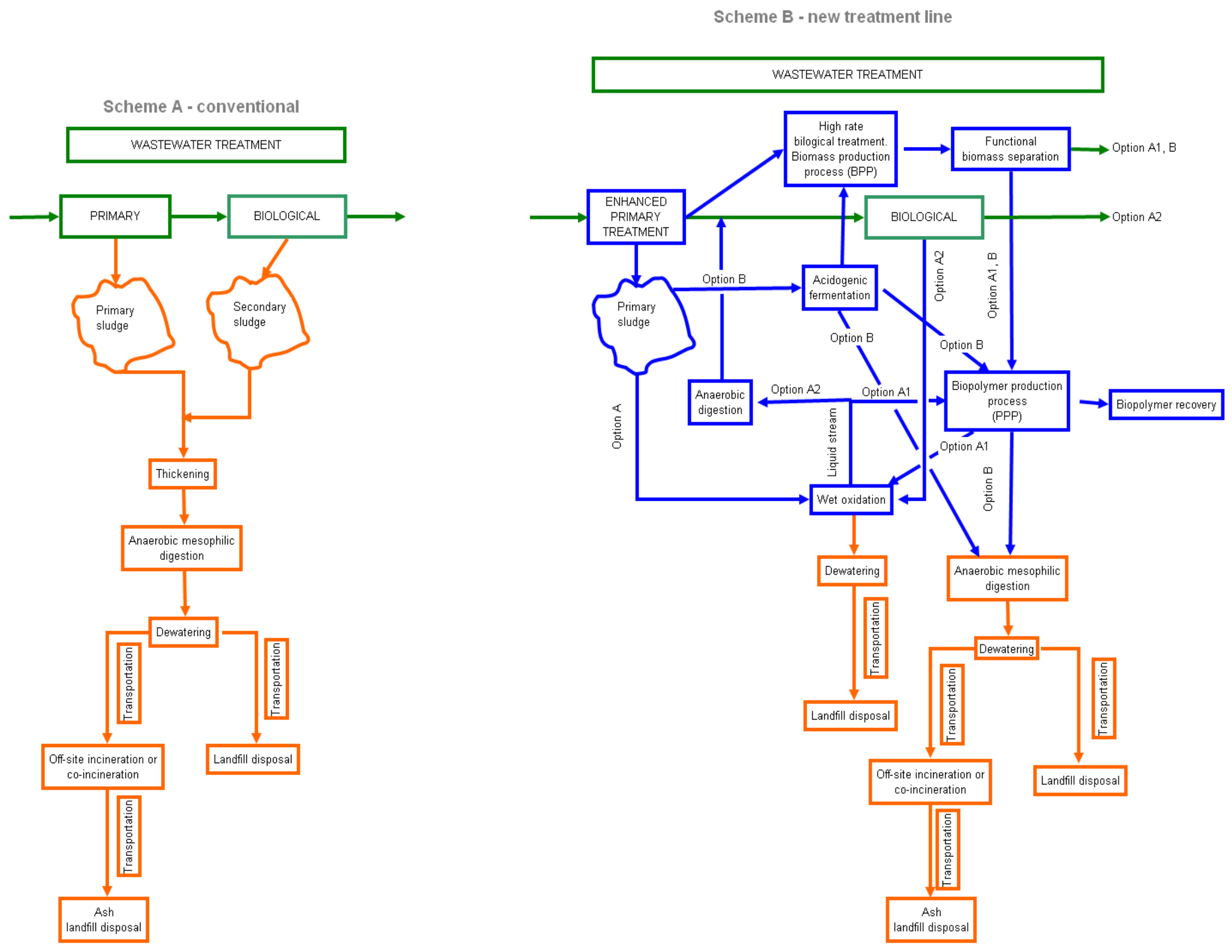
Option B (BP): biopolymer production using the fatty acids produced in primary sludge acidonogenic fermentation.

Large WWTPs > 100,000 inhabitants

With primary sedimentation - Without nutrient removal - High organic load - High pollution level

Problem: High sludge production not suitable for agricultural use.

Solution: Disposal by wet oxidation. Reduction of sludge production and utilisation of liquid stream from wet oxidation for biopolymer production



STORYLINE

In large size plants with high sludge production not suitable for agricultural use,
we suggest diposing primary and secondary sludge by wet oxidation (options A1 and A2).
Liquid stream originating from wet oxidation, very reach in volatile fatty acids,
might be used as substrate for biopolymer production (option A1) or treated by anaerobic digestion (option A2).
We can suggest also sludge disposal by conventional process including anaerobic mesophilic digestion and
dewatering (option B) and biopolymer production utilising volatile fatty acids produced by acidogenic fermentation
of primary sludge and biomass produced by a high rate biological treatment (option B).

Main results of the activities on intensive stabilization processes

- ⇨ Thermal pretreatment positively affects the specific biogas production of thermophilic anaerobic digestion (gain up to 20%, increased by lowering the load).
- ⇨ Hydrodynamic disintegration and subsequent two steps (meso/thermophilic) anaerobic digestion can increase biogas production up to 45%. The biogas production in the first stage was faster in comparison to the second thermophilic step, for both untreated and treated sludge.
- ⇨ The sequential anaerobic/aerobic process showed a satisfactory performance with significant volatile solids removal in the post aerobic digestion stage (15% for secondary sludge and 46% for mixed sludge). A significant nitrogen removal in the aerobic stage operated with intermittent aeration was observed (79% nitrification☞46% N removed for secondary sludge, 95% nitrification ☞50% N removed for mixed sludge).

UNIVERSITAT DE BARCELONA

INSTITUT DE L'AIGUA

- Sonolysis efficiency is significantly influenced by input energy, solids content of sludge and ultrasound frequency. Removal rates up to 40% of native anionic surfactants have been obtained applying 200 kHz ultrasounds directly in secondary sludge, whereas at the "conventional" 20 kHz no degradation effect was evident.
- Ozonation was effective in removing brominated flame retardants (brominated diphenyl ethers) in both secondary and mixed-digested sludge. Ozone dosage of 0.06 g O_3/g TSS resulted in a removal percentage higher than 90%. Identification of degradation products as well as organic bromine mineralization is still in progress.

HYGIENIZATION ASSESSMENT BY PATHOGENS DETECTION AND QUANTIFICATION

⇨ Continuous hygienization assessment by means of *Ecoli*, *Clostridia spp.*, somatic bacteriophages and *Salmonella* screening in sludge samples taken from three different technologies under investigation:

a) thermophilic anaerobic sludge digestion (55°C),

b) thermophilic anaerobic sludge digestion (55°C) with thermal pre-treatment,

c) combined anaerobic/aerobic mesophilic digestion.

Data till now showed general good hygienization performances of all tested technologies with higher performances mainly associated to thermophilic treatments.

⇨ Somatic coliphages, enteroviruses have been also evaluated in untreated and treated samples deriving from the different technologies

a) A significant decrease of somatic coliphages (2 to 4 log units) was observed on the studied samples from the different treatments.

b) Untreated sludge samples present positive result for enteroviruses but all treated sludge samples were negative for enteroviruses.

Somatic coliphages are showing to be an appropriate viral indicator to measure the efficacy of reduction of viruses by the new process of sludge treatment. The concentration of enteroviruses is very low in untreated samples that are not useful to measure the efficiency of decreasing of viruses by any of the treatments.

UNIVERSITAT DE BARCELONA

INSTITUT DE L'AIGUA

Benchmarking

- reliability of the technology;
- complexity and integration with existing structures;
- flexibility/modularity of the innovative solutions compared to the traditional;
- residues (solids, liquids and gaseous) produced by the solutions;
- consumption of raw materials and reagents;
- **costs (e.g. costs of materials, reagents, personnel, disposal of residues, capital etc...).**
- consumption and net production of energy;
- impact of transportation;
- social and authorization aspects;

LCA – Impact categories

1. Global warming potential (carbon footprint) GWP
2. Acidification potential AP
3. Euthrophication potential EP
4. Ozone depletion potential ODP
5. Photochemical smog formation potential POCP

First benchmarking results for WP1 activities

Solution	Technical score[1] (gap)	Cost gap[1] €/[PE × y]
2.1 Mesophilic anaerobic digestion, aerobic post-treatment, agriculture vs. landfilling in the reference scheme	0.23	-5.40
2.1 Mesophilic anaerobic digestion, aerobic post-treatment, agriculture vs. off-site incineration in the reference scheme	-0.06	-5.40
3.2_1 W.O., sonolysis, anaerobic mesophilic + thermophilic digestion, landfilling of solid residue from W.O. and agriculture use of secondary sludge vs. landfilling in the reference scheme	0.32	-0.92
3.2_1 W.O., sonolysis, anaerobic mesophilic + thermophilic digestion, landfilling of solid residue from W.O. and agriculture use of secondary sludge vs. off-site incineration in the reference scheme	0.17	-0.92
3.2_2 W.O., ultrasounds, anaerobic mesophilic + thermophilic digestion, landfilling of solid residue from W.O. and agriculture use of secondary sludge vs. landfilling in the reference scheme	0.30	-0.39
3.2_2 W.O., ultrasounds, anaerobic mesophilic + thermophilic digestion, landfilling of solid residue from W.O. and agriculture use of secondary sludge vs. off-site incineration in the reference scheme	0.16	-0.39
3.2_3 W.O., thermal hydrolysis, anaerobic thermophilic digestion, landfilling of solid residue from W.O. and agriculture use of secondary sludge vs. landfilling in the reference scheme	0.34	-0.40
3.2_3 W.O., thermal hydrolysis, anaerobic thermophilic digestion, landfilling of solid residue from W.O. and agriculture use of secondary sludge vs. off-site incineration in the reference scheme	0.19	-0.40
3.2_4 W.O., ozonation, anaerobic mesophilic digestion, aerobic post-treatment, landfilling of solid residue from W.O. and agriculture use of secondary sludge vs. landfilling in the reference scheme	0.30	-2.39
3.2_4 W.O., ozonation, anaerobic mesophilic digestion, aerobic post-treatment, landfilling of solid residue from W.O. and agriculture use of secondary sludge vs. off-site incineration in the reference scheme	0.14	-2.39
3.3 Hydrodynamic cavitation anaerobic mesophilic + thermophilic digestion, agriculture vs. landfilling in the reference scheme	-0.01	-0.05
3.3 Hydrodynamic cavitation anaerobic mesophilic + thermophilic digestion, agriculture vs. off-site incineration in the reference scheme	-0.15	-0.05

First LCA results for scenario 3.2 (sludge separation)

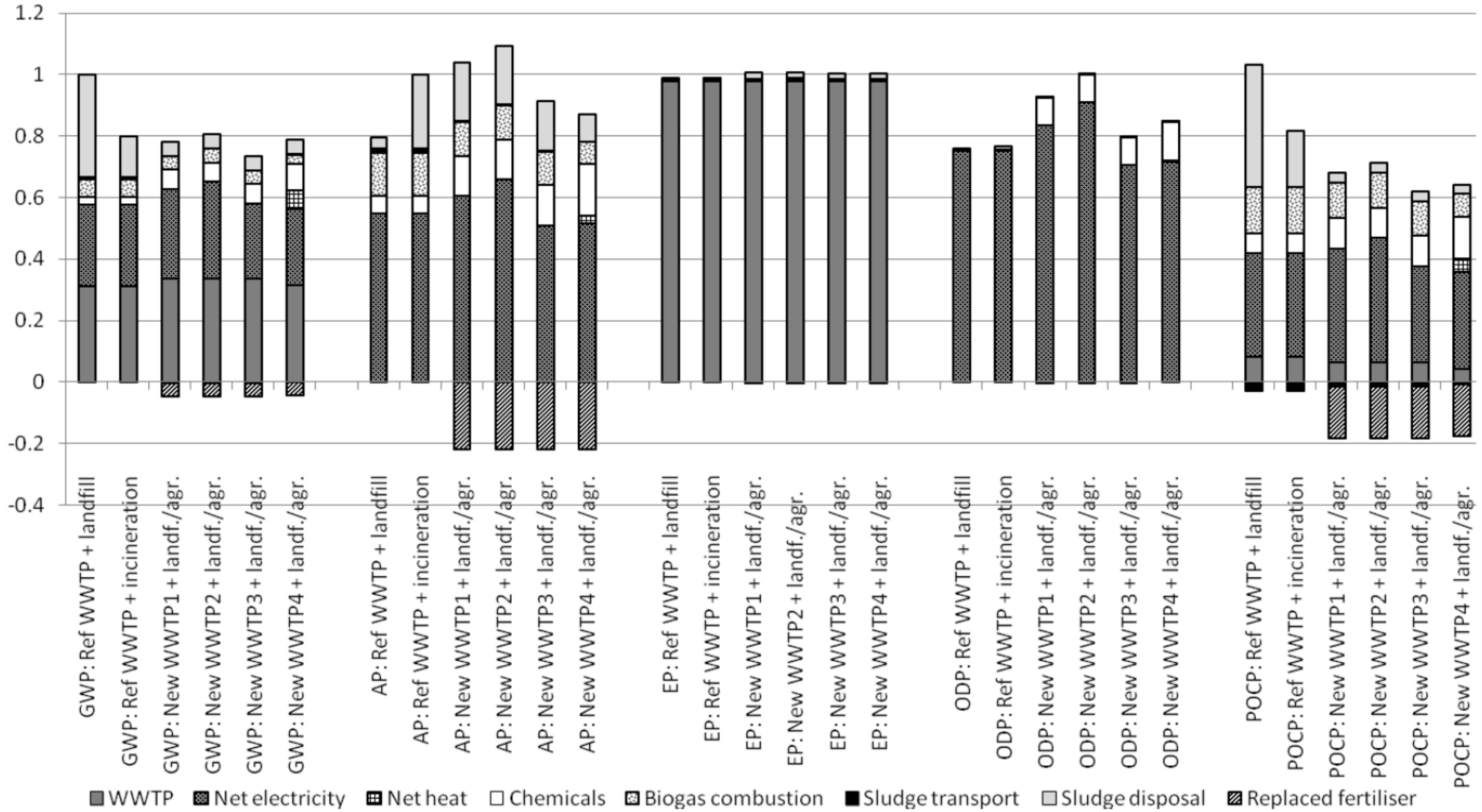


Figure 34 LCIA results for scenario 3.2, normalised against the largest result for each impact category

New 1: 200 kHz ultrasounds before MAD+TAD New 3: thermal hydrolysis before TAD
New 2: 20 kHz ultrasounds before MAD+TAD New 4: ozone before MAD+Aerobic

WP2 Tasks

2.1 Sludge production minimization by SBBGR

2.2 Optimization of integrated side-streams bioprocesses for sludge reduction in MBR

2.3 Sludge production minimization by microbial electrolytic cells

2.4 Production of biopolymers from primary sludge and side-streams from wet oxidation (bench-scale)

2.5 Pilot scale production of biopolymers from primary sludge and side-streams from wet oxidation

2.6 Downstream processing of biopolymer-rich biomass for recovery of polymer (pilot-scale)

2.7 Anaerobic co-digestion of WAS and bio-waste

2.8 $(NH_4)_2SO_4$ recovery from ammonia stripping

2.9 Experimental set up of experiments on wet oxidation

2.10 Kinetic studies and process scale up of wet oxidation at pilot scale

WP3 Tasks

3.1 Full-scale tests of wet oxidation with different types of sludge and assessment of the residues

3.2 Rheology analysis and optimization of sludge pumping at actual scale

3.3 Production of $(NH_4)_2SO_4$ from ammonia stripping

3.4 Full scale testing of sludge minimization by biological alternated cycles

3.5 Anaerobic co-digestion of waste activated sludge (WAS) with bio-waste

WP4 Tasks

4.1 Bacterial re-growth during storage
4.2 Fate of heavy metals in sludge amended soil
4.3 Effects of emerging organic micropollutants in soil
4.4 Ecotoxicological testing
4.5 Phyto—toxicity tests
4.6 Fate of emerging organic micropollutants in soil
4.7 Lysimeter field studies
4.8 Emerging organic micropollutants monitoring of sludge samples provided by WP1
4.9 Conventional organic micropollutants monitoring of sludge samples provided by WP1
4.10 Monitoring of sludge treated fiield sites

WP5 Tasks

- 5.1 Technological benchmarking of new technological trains against conventional WWTPs
- 5.2 Environmental sustainability analysis of proposed WWT scenarios via LCA
- 5.3 Updating of the Technological benchmarking
- 5.4 Integration of the activities with impact assessment (LCIA, final LCA, LCC)

WP6 Tasks

- 6.1 Results dissemination (Dissemination plan, documents, creation of a board of end users, workshops, website, catalogue)
- 6.2 Organization of training courses fro microbial procedures
- 6.3 Commission environmental policy
- 6.4 Technological uptake
- 6.5 Publications

WP7 Tasks

7.1 PROJECT MANAGEMENT (Consortium agreement, contractual and financial management, collection of the ERP from the beneficiaries, scheduling and organization of the meetings, overall monitoring of the work plan, decision making procedure, receipt of payments from the Commission and distribution to the consortium, mediation between consortium and European Commission, reporting)

An advisory board was created since the preparation of the project. Currently the following scientists and managers are included:

Prof. John Novak (Virginia State University);

Prof. Helmut Kroiss (Vienna Univesity of Technology);

Dr. David Newman (International Solid Waste Association).

Deliverables already submitted

Delivery N.	Deliverable title	Lead Beneficiary
D2.1	Midterm report on anaerobic co-digestion of WAS and biowaste	INCA
D2.2	Midterm report of wet oxidation of primary and mixed sludge	UniBrescia
D3.1	Midterm report on $(NH_4)_2SO_4$ recovery from ammonia stripping	ATEMIS
D3.2	Midterm report on sludge pumping	Mediterranea
D5.1	Technological benchmarking of new technological trains against conventional WWTPs	UniBrescia
D5.2	Environmental sustainability analysis of proposed WWT scenarios via LCA	UniChalmers
D5.6	Addendum to the Deliverable D5.1 . Confidential information on techniques including biopolymer production	UniBrescia
D5.7	Addendum to Deliverable D5.2	UniChalmers
D6.1	Dissemination Plan	CNR-IRSA, Mediterranea
D6.2	Project website	Mediterranea
D6.3	Report on the training course for microbial procedures	UniBarcelona
D6.4	1st package of dissemination material	CNR-IRSA
D7.1	Consortium agreement	CNR-IRSA

Deliverables to be submitted by the end of October

Delivery N.	Deliverable title	Lead Beneficiary
D1.1	Midterm report on new molecular tools for pathogen detection	Vermicon
D1.2	Midterm report of AOP and enhanced stabilization processes	CNR-IRSA
D2.3	Midterm report on sludge minimization by different techniques	CNR-IRSA
D2.4	Midterm report on biopolymer production from primary sludge or liquid side-streams from WO	UNIROMA1
D2.5	Midterm report of sludge production minimization by microbial electrolytic cells	UNIROMA1
D4.1	Midterm report on heavy metal speciation in sludge and soil	URCA
D4.2	Midterm report on fate and effects of organic micropollutants in soil	BFG
D6.5	1st end user conference proceedings	CNR-IRSA
D7.2	1st activity and management report to the Commission	CNR-IRSA

Conclusions

- ROUTES is a quite complicated project including many different activities to set up and to develop new treatment techniques at lab, pilot and full scale with the aim to (a) produce a more stabilized sludge, (b) reduce its production, (c) recover valuable materials with potential commercial value and (d) dispose not recoverable sludge by intrinsic secure treatment.
- Each new developed technique is included in a flow sheet (the unique exception is MEC) to be compared with a reference one to assess its applicability on full scale plants regarding feasibility, reliability, costs and environmental benefits or impacts.
- There is no a unique solution for solving the sludge problems. Each geographical situations and plant size would require a specific analysis to assess the best options which mainly depend on sludge quality, public attitudes and availability of disposal sites. Whenever possible sludge utilization should be the 1st option for its management.

1st conclusions from the LCA

- Currently the new techniques were evaluated considering conservative criteria.

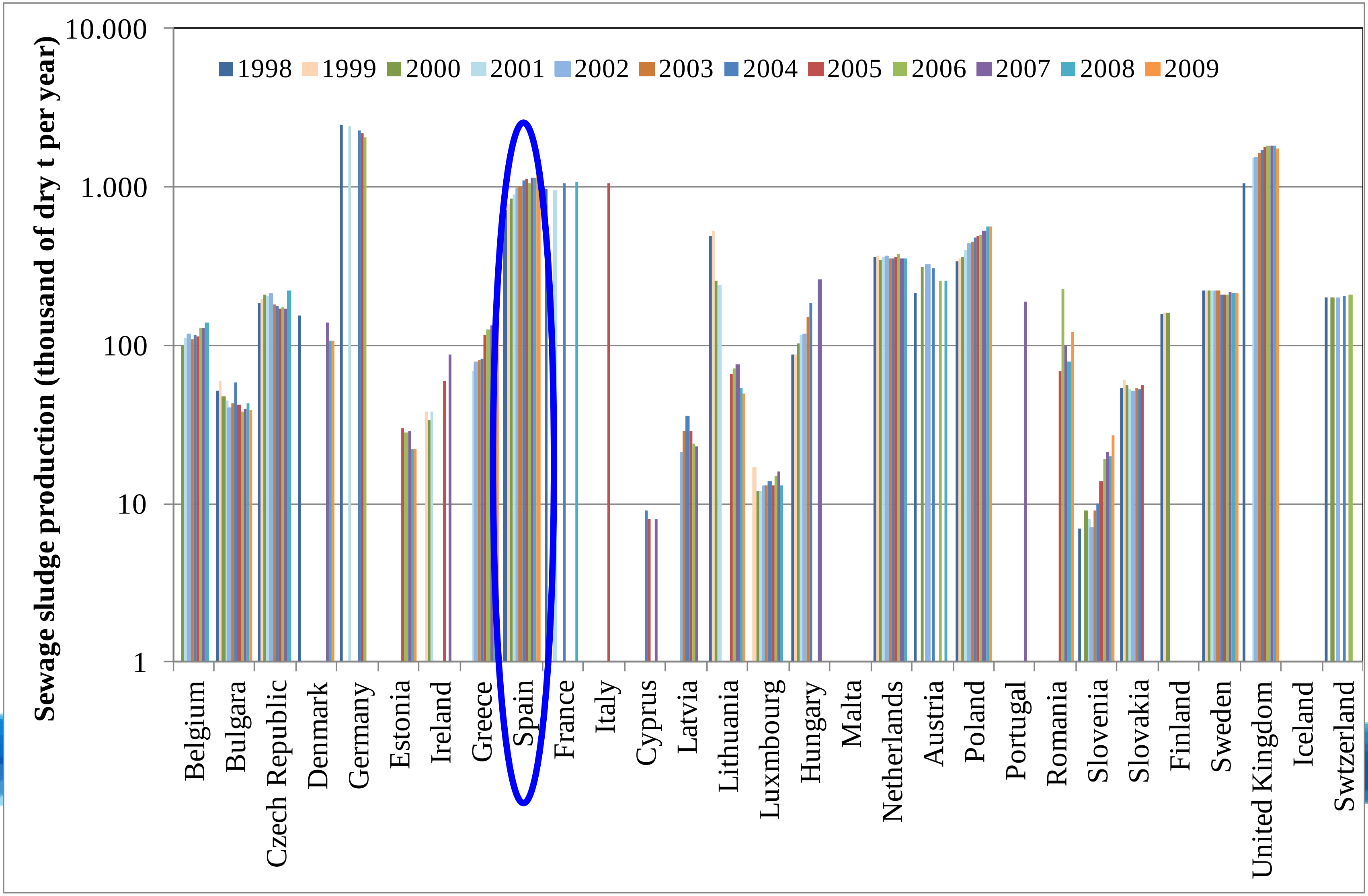
  - For small WWTPs overall worse LCIA results for the innovative scenarios [illegible]
  - For medium size WWTP the results showed an overall advantage for the [illegible]
  - Wet oxidation seems to be convenient considering GWP/CED/EP/ODP [illegible]
  - Scenarios with PHA production appear convenient considering [illegible] (the [illegible] aim to optimize the sludge generation in the [illegible]) [illegible] option with PHA production using VFA produced from primary sludge derived [illegible] decreased environmental impact from the sludge disposal does not compensate for the larger electricity consumption in the innovative scenarios. [illegible] truck transports does not balance the impact from the electricity needed for sludge pumping.
  - From case study with primary separation three of five impact categories show better result for the innovative scenario. The innovative scenarios are assumed to produce sludge suitable for agricultural use while in the reference one sewage sludge has to be disposed either in landfill or by on-site or off-site incineration.

General conclusions on LCA

LCA is for the coordinator

a big headache and a nightmare!

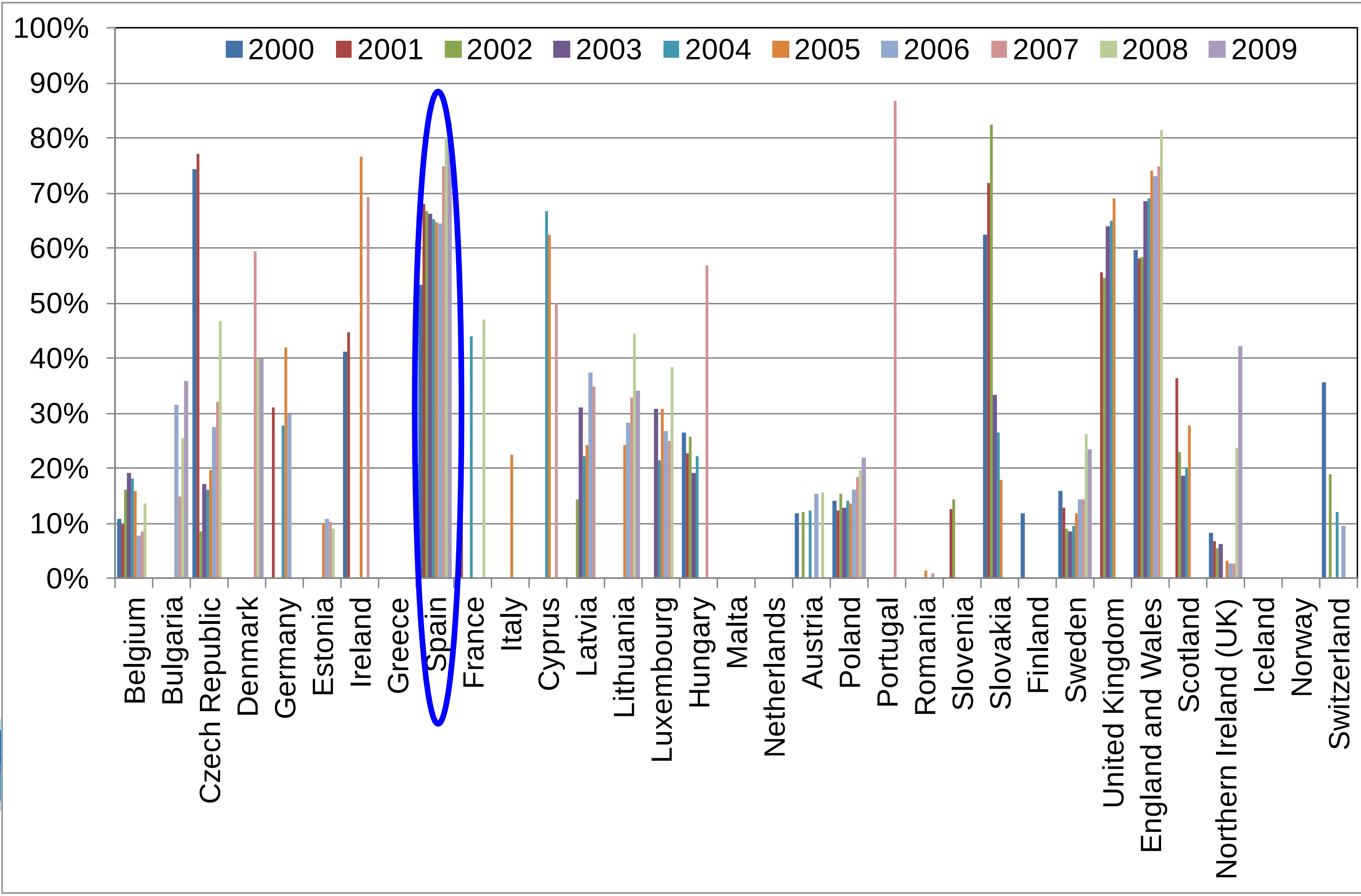
Sewage sludge production in Europe (OECD-Eurostat)



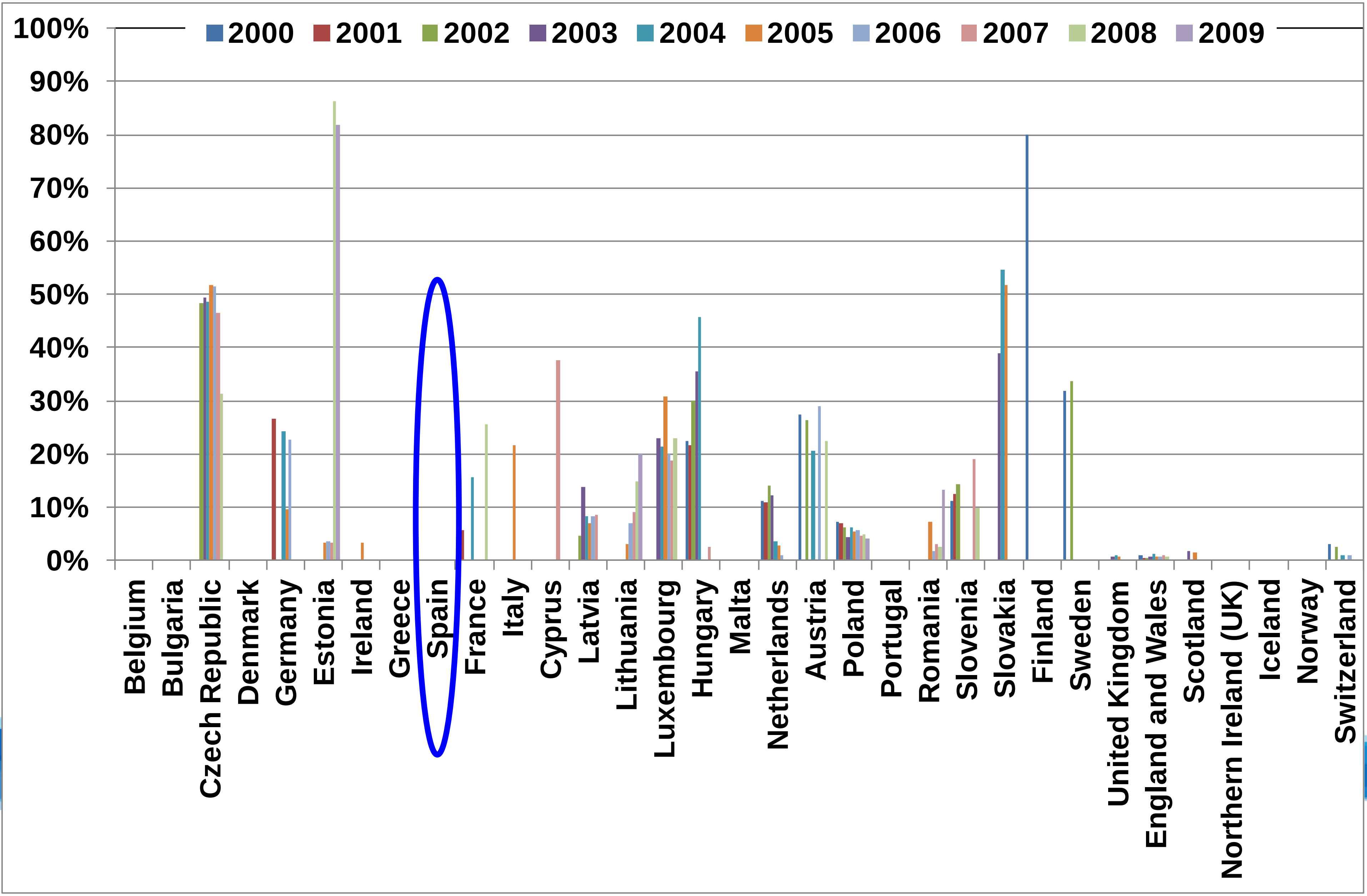
Total sewage sludge production in Europe

- Considering a total population of about 500 millions and a per capita daily production of 50.24 g/d the estimated total sewage sludge production amounts to about 9.1 millions dry t/year.
- After conventional treatment (thickening, biological stabilization, dewatering) sewage sludge has to be transported to the final destinations (agricultural land, landfill sites, off-site incinerators, off-site utilisation in industrial plants, like power plants or cement kilns) unless it is on-site thermal treated (about 2.4 millions dry t/year).
- A total of about 33.5 millions t/year has to be transported to final destinations considering that the medium cake concentration after dewatering is about 20%.

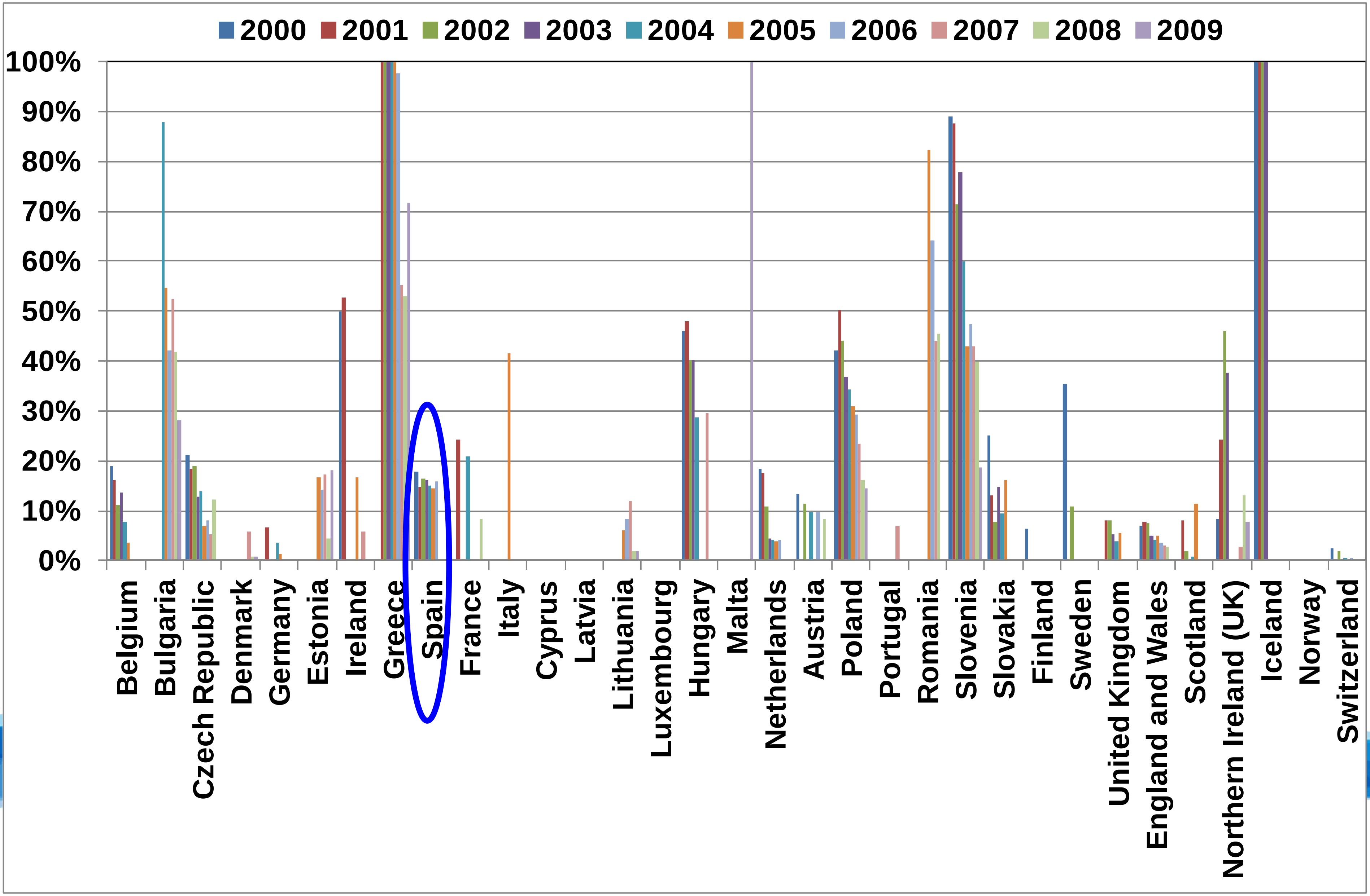
Sludge use in agriculture in different countries



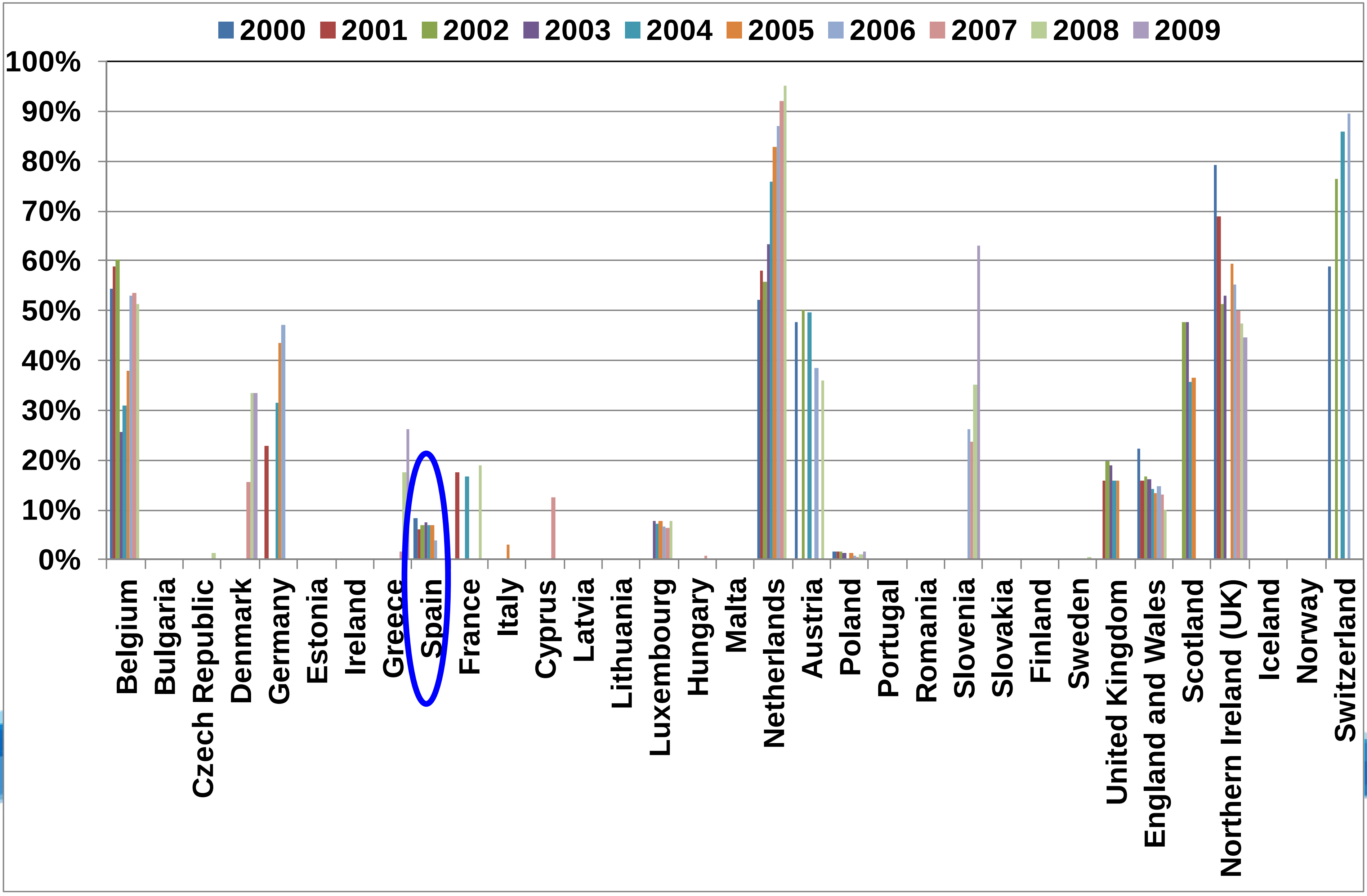
Sludge composting in different European countries



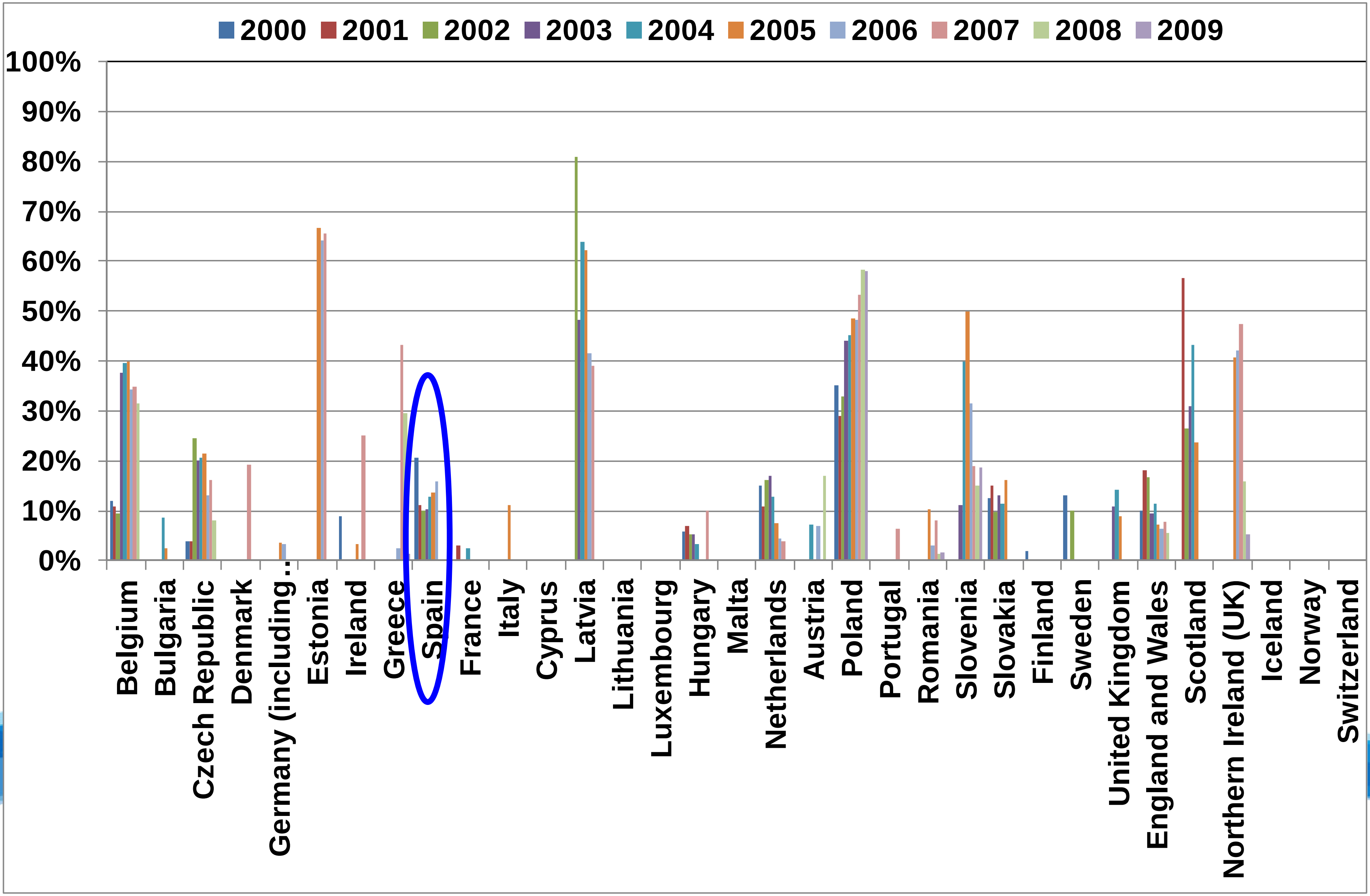
Sludge disposal in landfill in different countries



Sludge disposal by incineration in different countries



Sludge disposal by other solutions in different countries



	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Directive 86/278/EEC	20-40	-	1,000-1,750	16-25	300-400	750-1,200	2,500-4,000
Austria							
Lower Austria	2	50	300	2	25	100	1500
Upper Austria	10	500	500	10	100	400	2000
Burgenland	10	500	500	10	100	500	2000
Voralberg	4	300	500	4	100	150	1800
Steiermark	10	500	500	10	100	500	2000
Carinthia	2.5	100	300	2.5	80	150	1800
Belgium (Flanders)	6	250	375	5	100	300	900
Belgium (Walloon)	10	500	600	10	100	500	2000
Bulgaria	30	500	1600	16	350	800	3000
Cyprus	20-40	-	1,000-1,750	16-25	300-400	750-1,200	2,500-4,000
Czech republic	5	200	500	4	100	200	2500
Denmark	0.8	100	1000	0.8	30	120	4000
Estonia	15	1200	800	16	400	900	2900
Finland	3	300	600	2	100	150	1500
France	20	1000	1000	10	200	800	3000
Germany (1)	10	900	800	8	200	900	2500
Germany (2)	2	80	600	1.4	60	100	1500
Greece	20-40	500	1,000-1,750	16-25	300-400	750-1,200	2,500-4,000
Hungary	10	1,000	1000	10	200	750	2500
Ireland	20		1000	16	300	750	2500
Italy	20		1000	10	300	750	2500
Latvia	20	2000	1000	16	300	750	2500
Luxembourg	20-40	1,000-1,750	1,000-1,750	16-25	300-400	750-1,200	2,500-4,000
Malta	5	800	800	5	200	500	2000
Netherlands	1.25	75	75	0.75	30	100	300
Poland	10	500	800	5	100	500	2500
Portugal	20	1000	1000	16	300	750	2500
Romania	10	500	500	5	100	300	2000
Slovakia	10	1000	1000	10	300	750	2500
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	750-1,200	2,500-4,000
Sweden	2	100	600	2.5	50	100	800
United Kingdom	PTE regulated through limits in soil						
Range	0.5-40	50-2,000	75-1,750	0.2-25	30-400	40-1,200	100-4,000

(1) Regulatory limits as presented in the German 1992 Sewage Sludge Ordinance (BMU, 2002)
(2) Proposed new limits (BMU, 2007)

Other elements only restricted in some countries or regions

	Arsenic	Molybdenum	Cobalt
Lower Austria			10
Steiermark	20	20	100
Belgium (Flanders)	150		
Denmark	25		
Netherlands	15		
Czech republic	30		
Hungary	75	20	50
Slovakia	20		

Standards for maximum concentrations of organic contaminants in sewage sludge

	(AOX)	(DEHP)	(LAS)	(NP/NPE)	(PAH)	(PCB)	(PCDD/F)	others
Directive 86/278/EEC	-	-	-	-	-	-	-	
EC (2000)a)	500	100	2600	50	6b	0.8c	100	
EC (2003)a)			5000	450	6b	0.8c	100	
Austria								
Lower Austria	500	-	-	-	-	0.2 d)	100	
Upper Austria	500					0.2 d)	100	
Vorarlberg	-					0.2 d)	100	
Carinthia	500				6	1	50	
Denmark (2002)		50	1300	10	3b			
France					Fluoranthene: 4 Benzo(b)fluoranthene: 2.5 Benzo(a)pyrene: 1.5	0.8c)		
Germany (BMU 2002)	500					0.2 e)	100	
Germany (BMU 2007) f)	400				Benzo(a)pyrene: 1	0.1 e)	30	MBT+OBT:0.6 Tonalid:15 Glalaxolide:10
Sweden	-	-	-	50	3b)	0.4c)	-	
Czech Republic	500					0.6		

a) proposed but withdrawn
b) sum of 9 congeners: acenapthene, fluorene, phenanthrene, fluoranthene, pyrene, benzo(b+j+k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, indeno(1,2,3-c,d)pyrene
c) sum of 7 congeners: PCB 28, 52, 101, 118, 138, 153, 180
d) sum of 6 congeners:PCB28,52,101,138,153,180
e) Per congener
f) Proposed new limits in Germany (BMU 2007)

Standards for maximum concentrations of pathogens in sewage sludge (Millieu, WRc and RPA, 2010 – citing SEDE and Andersen, 2002 and Alabaster and LeBlanc, 2008)

	Salmonella	Other pathogens
Denmark a)	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	Sludge cannot be used in agriculture if it contains salmonella	

a) applies to advanced treated sludge only

UNIVERSITAT DE BARCELONA

INSTITUT DE L'AIGUA

Thanks for your attention and for your patience