Estonian sludge management strategy and possibilities for phosphorus recovery

Taavo Tenno

OÜ aqua consult Baltic

University of Tartu

Gdansk, 12.06.2018

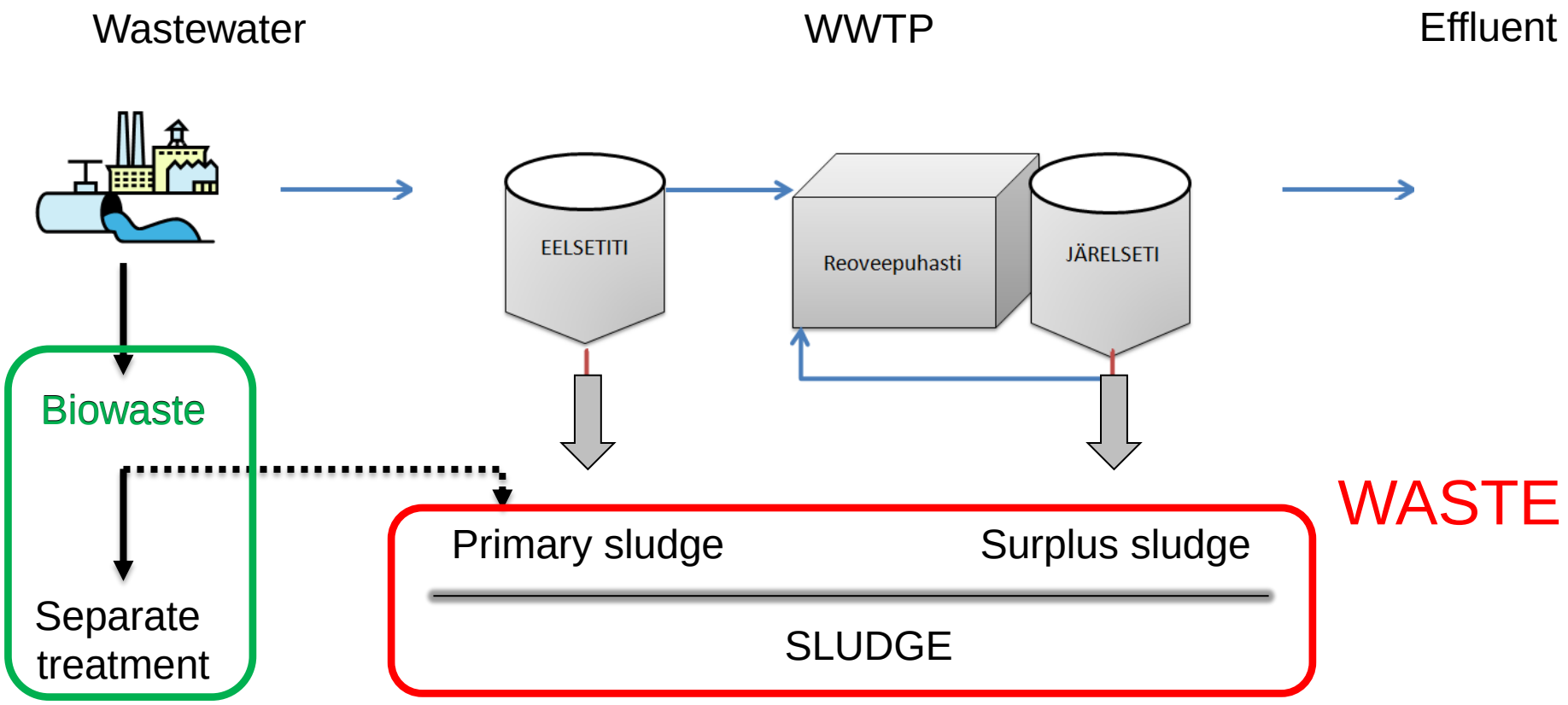
Overview

- Definition of sludge and how to distinguish “good sludge” from “bad sludge”?
- Legislation and how Estonian sludge corresponds to the legislation?
- What is done with the sludge in Estonia?
- What should be done with the sludge?
- P – reuse in agriculture, greenery and recultivation.
- Possibilities for P – recycling.


NORWAY
SWEDEN
Oslo
Stavanger
Turku
Helsinki
Åland Islands
Gulf of Finland
St. Petersburg
Stockholm
Tallinn
Hiiumaa
ESTONIA
RUSSIA
Skagerrak
Kattegat
Saaremaa
Gulf of Riga
Gotland
Baltic Sea
DENMARK
Öland
Riga
LATVIA
Copenhagen
Malmö
Funen
Zealand
Bornholm
LITHUANIA
Kiel
Rügen
Kaliningrad (RUSSIA)
Vilnius
Gdansk
Minsk
NORTH
GERMANY
POLAND
BELARUS


NORWAY
Oslo
Stavanger
SWEDEN
Stockholm
Åland Islands
Turku
Helsinki
Popul. 5,5 M
- 16 per sq. km
Gulf of Finland
St. Petersburg
Tallinn
Hiiumaa
ESTONIA
Popul. 1,3 M
- 28 per sq. km
Saaremaa
Gulf of Riga
Popul. 10 M
- 23 per sq. km
Gotland
Skagerrak
Kattegat
Baltic Sea
Öland
DENMARK
Riga
LATVIA
Popul. 1,95 M
- 34 per sq. km
Copenhagen
Malmö
Funen
Zealand
Bornholm
Popul. 0,95 M
- 64 per sq. km
LITHUANIA
Popul. 2,8 M
- 43 per sq. km
Vilnius
Kaliningrad
(RUSSIA)
Popul. 82 M
227 per sq. km
Kiel
Rügen
Popul. 38 M
123 per sq. km
Minsk
GERMANY
POLAND

Wastewater treatment and sludge management



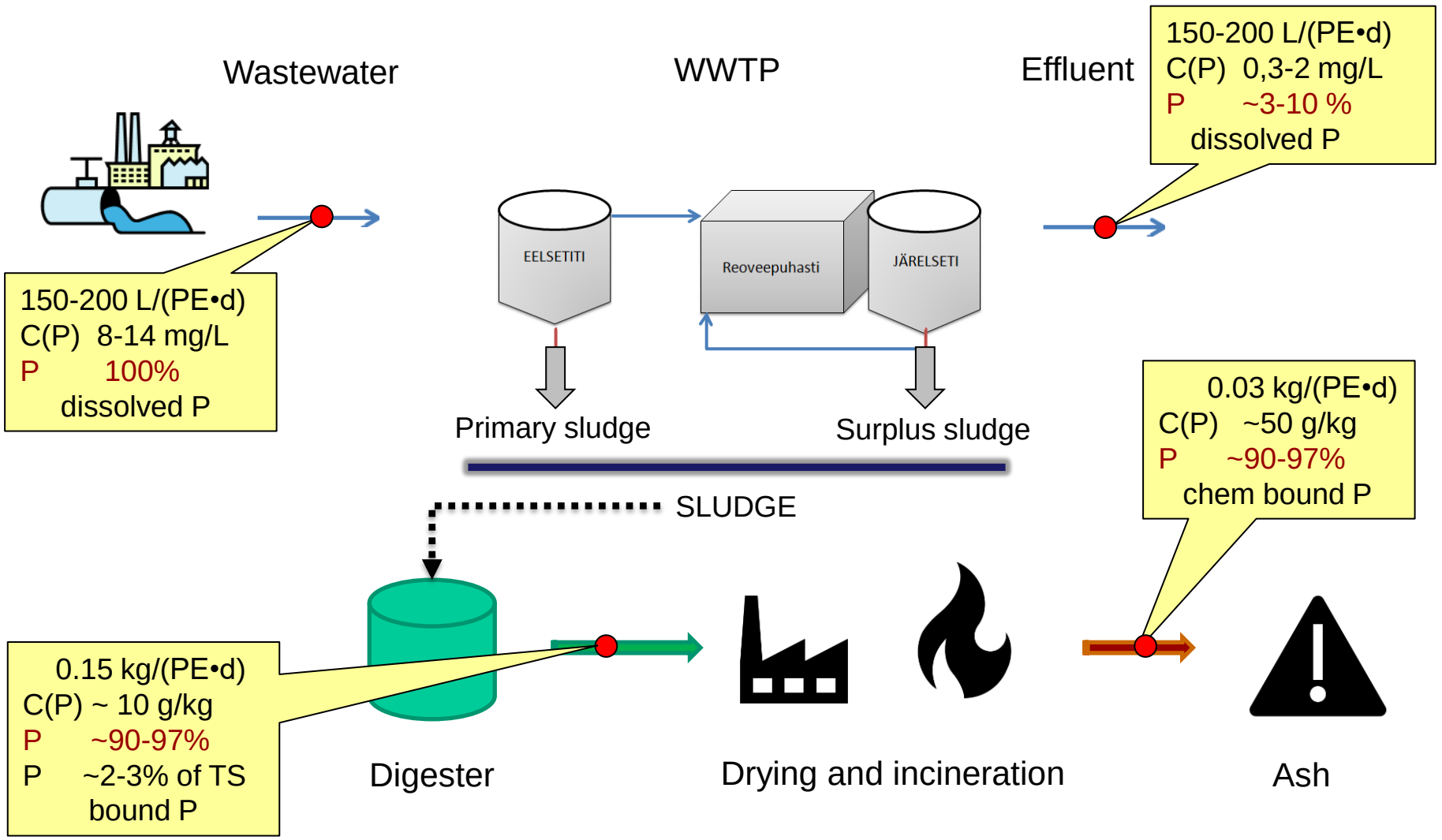
- Compostition
- Composition of primary and secondary sludge as % dry weight of the organic sludge mass

Component	Primary sludge			Secondary sludge	
	(1)	(2)	(3)	(4)	(5)
Volatile fraction	79.7	73.5	75.0	59–75	79.0
Lipids	18.6	21.0	10.3	5–12	5.8
Cellulose	18.2	19.9	32.2	7	9.7
Hemicellulose			2.5		
Proteins	17.2	28.7	19.0	32–41	53.7

Sources: (1) = O' Rourke (1968), (2) = Eastman and Ferguson (1981), (3) = Higgins et al. (1982), (4) = US EPA (1979) and *(5) = Pavlostatis (1985)*

van Haandel & van der Lubbe 2012

Phosphorous in sewage sludge



Fate of sludge

FERTILIZER

- N, P, K, Mg, ..
- Organic fertilizer
- Cheap

WASTE

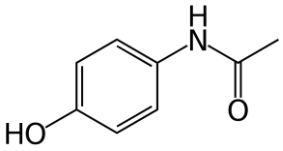
- Anthropogenic contamination

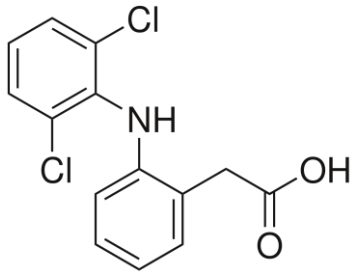
Sludge quality – how to evaluate?

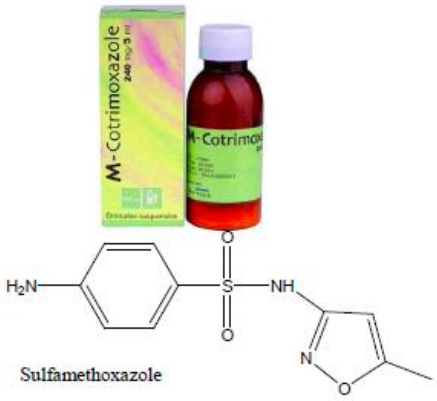
- Stabilisation
  - Content of organics
- Hygienisation
  - Content of pathogens
- Anthropogenic inorganic contaminants
  - Heavy metals (Cd, Hg, Ni, Zn, Cu, …)
- Anthropogenic (toxic) non-biodegradable organics
  - Drugs, antibiotics, hormones, PCB, …

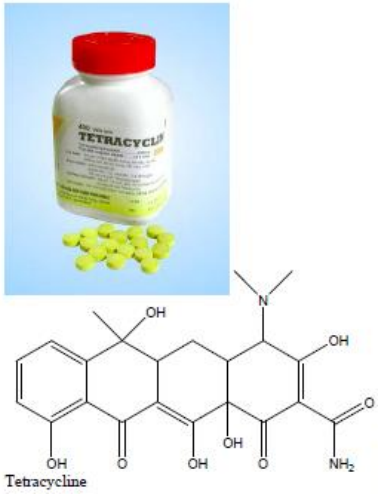
Nondegradable organic pollutants

- Hormones
  - Estrogens
- Common drugs
  - Paracetamol
  - Diclofenac
- Antibiotics
  - Fluorokinones
  - Tetracycline
  - Sulphonamides









Sludge quality – what is it already in the legislation?

- Stabilisation
  - Content of organics
- Hygienisation
  - Content of pathogens

TECHNOLOGIES

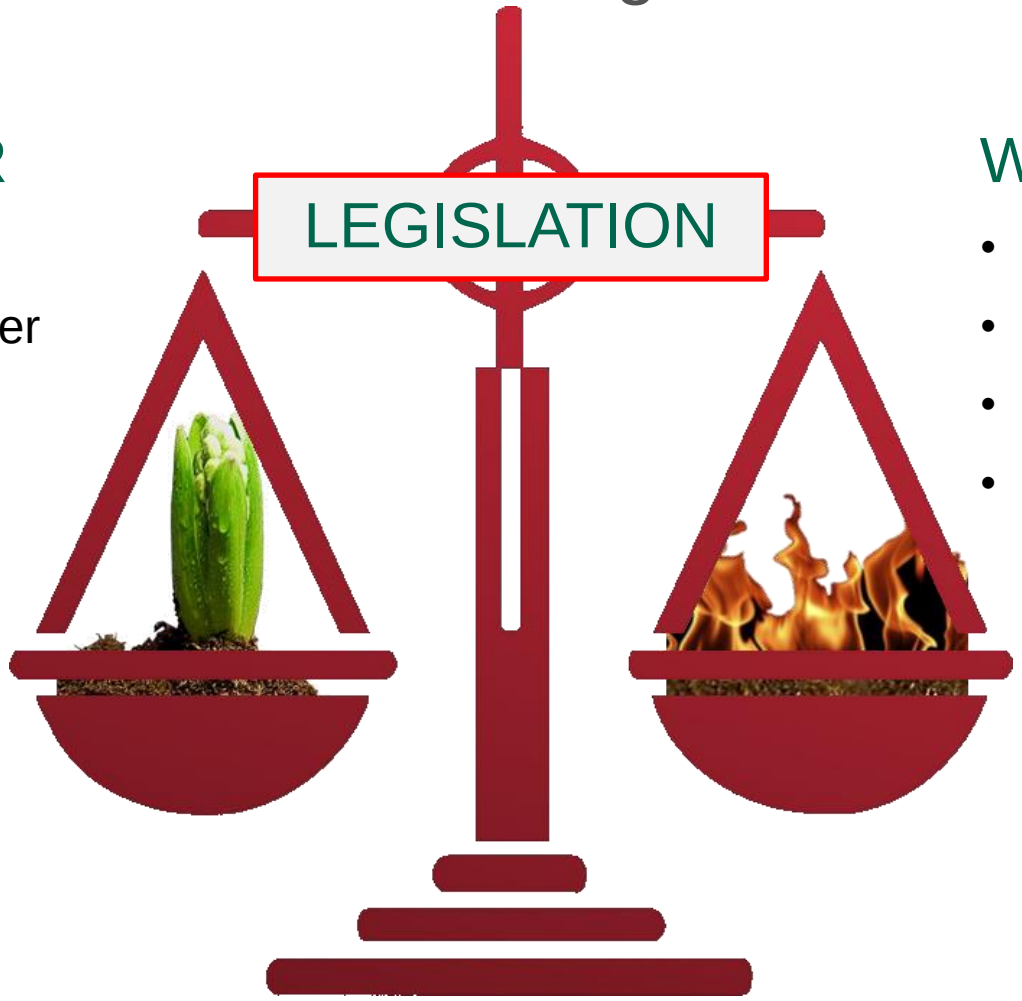
NO TECHNOLOGIES

- Anthropogenic inorganic contaminants
  - Heavy metals (Cd, Hg, Ni, Zn, Cu, …)
- Anthropogenic (toxic) non-biodegradable organics
  - Drugs, antibiotics, hormones, PCB, …

Fate of sludge

FERTILIZER

- N, P, K, Mg, ..
- Organic fertilizer
- Cheap



WASTE

- Organics
- Pathogens
- Heavy metals
- Drugs, hormones

What are the quality requirements for direct reuse?

Agriculture

Greenery

Recultivation

Sludge quality – what is it already in the legislation?

- Stabilisation
  - Content of organics
- Hygienisation
  - Content of pathogens
- Anthropogenic inorganic contaminants
  - Heavy metals (Cd, Hg, Ni, Zn, Cu, …)
- Anthropogenic (toxic) non-biodegradable organics
  - Drugs, antibiotics, hormones, PCB, …

ESTONIAN SLUDGE LEGISLATION

Stabilisation of sludge in the Estonian legislation

- Oxygen demand
  - < 10 mg O_2/g DS 96-hour period
- Content of organics – loss of ignition (VS)
  - VS has decreased more than 38%
- Content of organics (VS/TS)
  - VS/TS < 0,6
- Biogas potential
  - < 0,25 l/g VS.
- Volatile fatty acids
  - < 0,43 g KHT/g VS;

Composting

Aeobic stabilisation

Lime stabilisation

Anaerobic digestion

Sludge quality – what is it already in the legislation?

- Stabilisation
  - Content of organics

ESTONIAN SLUDGE LEGISLATION

- Hygienisation
  - Content of pathogens

ESTONIAN SLUDGE LEGISLATION

- Anthropogenic inorganic contaminants
  - Heavy metals (Cd, Hg, Ni, Zn, Cu, …)

- Anthropogenic (toxic) non-biodegradable organics
  - Drugs, antibiotics, hormones, PCB, …

Sludge hygienisation

COMMISSION REGULATION (EC) No 208/2006

of 7 February 2006

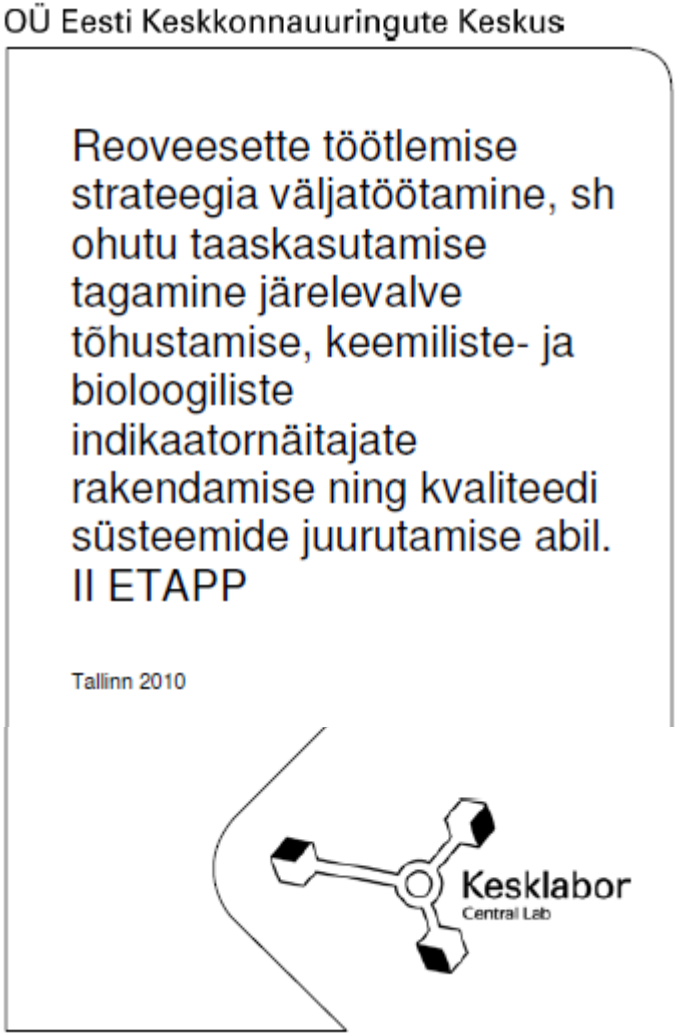
amending Annexes VI and VIII to Regulation (EC) No 1774/2002 of the European Parliament and of the Council as regards processing standards for biogas and composting plants and requirements for manure

- Content of pathogens
  - Digestion residues or compost taken during or immediately after processing at the biogas or composting plant must comply with the following standards:
    - *Escherichia coli*: 1 000 CFU/g;
    - *Enterococcaceae*: 1 000 CFU/g;

Can hygienisation be achieved?

- Windrow composting in ambient conditions needs extended periods and unstabilized sludge
  - Problems in winter period

Study by : Estonian Central lab


OÜ Eesti Keskkonnauuringute Keskus

Reoveesette töötlemise strateegia väljatöötamine, sh ohutu taaskasutamise tagamine järelevalve tõhustamise, keemiliste- ja bioloogiliste indikaatornäitajate rakendamise ning kvaliteedi süsteemide juurutamise abil. II ETAPP

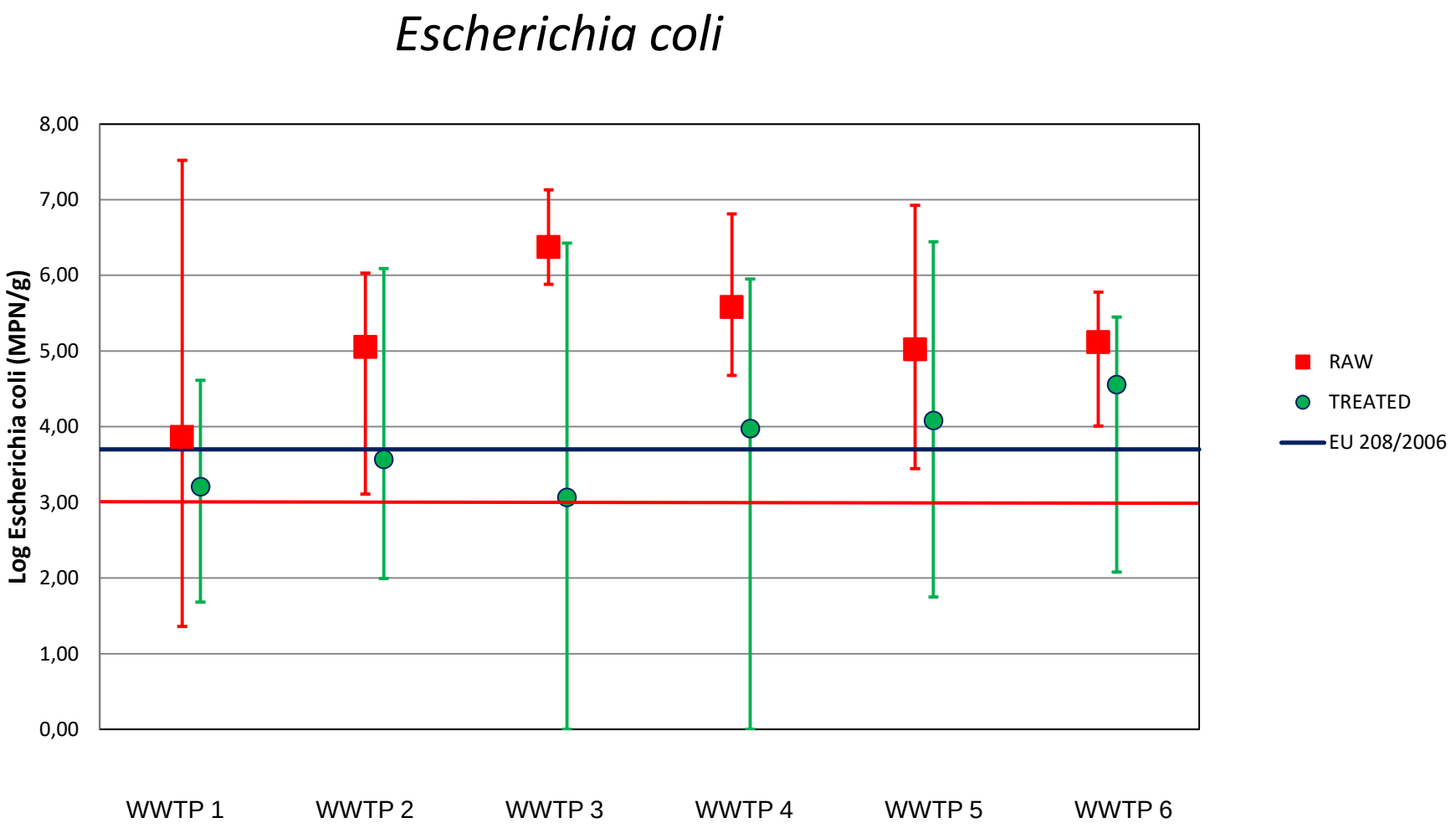
Tallinn 2010

Kesklabor
Central Lab

Development of strategy for wastewater sludge treatment, including assurance of safe reuse, application of chemical ana biological indicators and introduction of quality system.

II STAGE

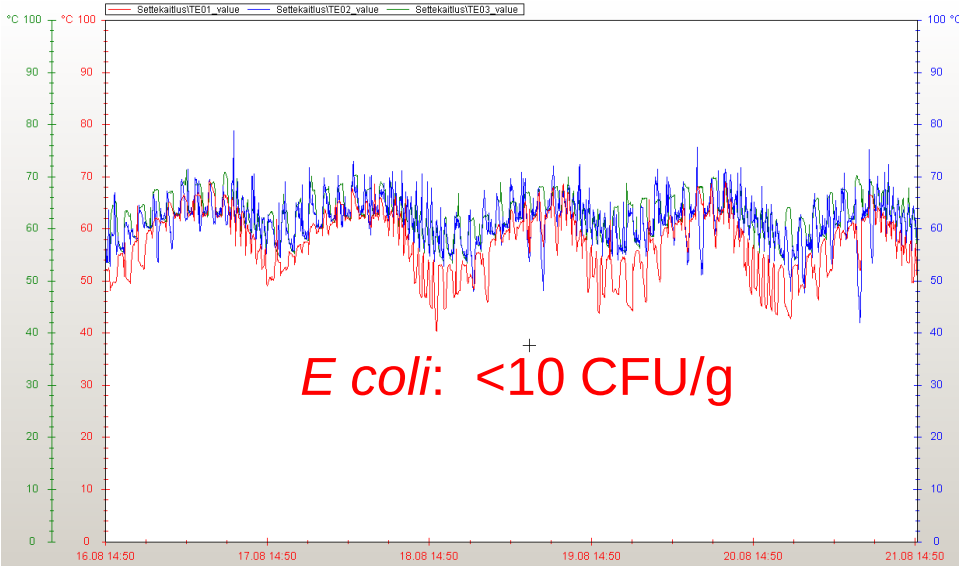
Pathogens in 6 Estonian WWTP with windrow composting



Can hygienisation be achieved?

- Windrow composting in ambient conditions needs extended periods and unstabilized sludge

- Reactor composting – properly controlled temperatures



E coli: <10 CFU/g

Can hygienisation be achieved?

- Windrow composting in ambient conditions needs extended periods and unstabilized sludge

- Reactor composting – properly controlled temperatures

- Anaerobic digestion needs hygienisation

Sludge quality – what is it already in the legislation?

- Stabilisation
  - Content of organics

ESTONIAN SLUDGE LEGISLATION

- Hygienisation
  - Content of pathogens

ESTONIAN SLUDGE LEGISLATION

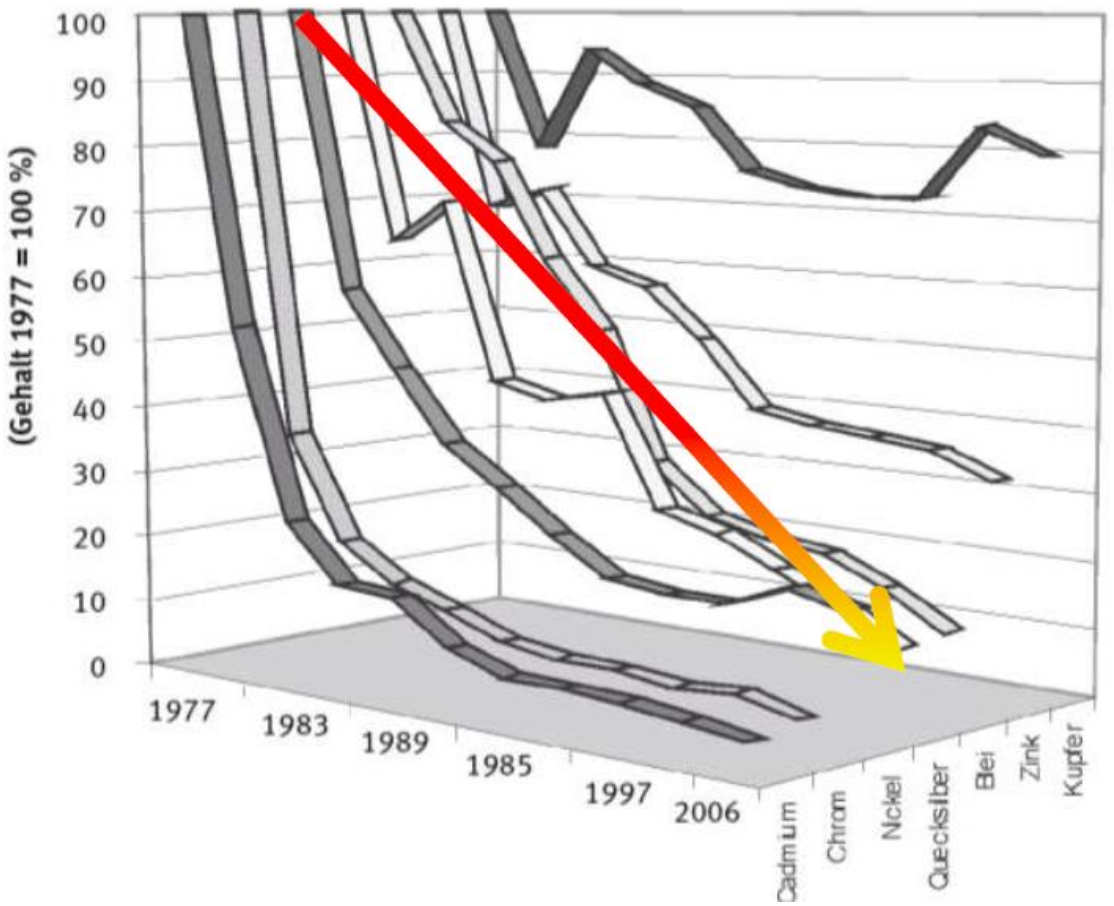
- Anthropogenic inorganic contaminants
  - Heavy metals (Cd, Hg, Ni, Zn, Cu, …)

ESTONIAN & EU LEGISLATION

- Anthropogenic (toxic) non-biodegradable organics
  - Drugs, antibiotics, hormones, PCB, …

Wastewater content of heavy metals Germany

- Heavy metals
- Heavy metals levels can be affected long term
- Means of influence
  - Legislations
  - Guidelines and practices



Heavy metals

- Limits for heavy metals in Estonian legislation are accordance with EC directive 86/278/EEC

	EU 1986 EST 2002	2014 ~~2016~~	2014
	Estonian law SLUDGE [mg/kg TS]	HELCOM SLUDGE [mg/kg TS]	ECN-QAS COMPOST [mg/kg TS]
Mercury (Hg)	16	1	0,45
Cadmium (Cd)	20	1	1,3
Lead (Pb)	750	100	130
Zinc (Zn)	2 500	2 500	600
Nickel (Ni)	300	50	40
Chromium (Cr)	1 000	300	60
Copper (Cu)	1 000	900	200

Heavy metals – levels in Estonia

- Study of Estonian wastewater sludge by Etonian Central Lab
- 8 wastewater treatment plants, total 80 sludge analyses
- Proportion of samples which are nonconforming with the respective limits

	Cd, mg/kg	Cr, mg/kg	Cu, mg/kg	Hg, mg/kg	Ni, mg/kg	Pb, mg/kg	Zn, mg/kg
Limits in tne Estonian legislation - 30.12.2002 nr 78	**20**	**1000**	**1000**	**16**	**300**	**750**	**2500**
- UNTREATED sludge - nonconforming analyses	0%	2%	0%	0%	0%	0%	1%
- TREATED sludge - nonconforming analyses	0%	0%	0%	0%	0%	0%	0%

Sludge quality – what is it already in the legislation?

- Stabilisation
  - Content of organics

  ← ESTONIAN SLUDGE LEGISLATION

- Hygienisation
  - Content of pathogens

  ← ESTONIAN SLUDGE LEGISLATION

- Anthropogenic inorganic contaminants
  - Heavy metals (Cd, Hg, Ni, Zn, Cu, …)

  ← ESTONIAN & EU LEGISLATION

- Anthropogenic (toxic) non-biodegradable organics
  - Drugs, antibiotics, hormones, PCB, …

  ← NO LEGISLATION JUST HESITATION

Baltic Marine Environment Protection Commission

Group on Sustainable Agricultural Practices — AGRI 1-2014
Copenhagen, Denmark, 20-21 November 2014

Document title	Drafting of HELCOM Recommendation on sewage sludge handling
Code	9-2
Category	INF
Agenda Item	9 – Phosphorous recycling
Submission date	17.11.2014
Submitted by	Sweden and Germany
Reference	2013 Ministerial Declaration

Parameter	Concentration (mg/ kg DS)	Concentration (mg/kg P)
Cd	1	40
Cu	900	21 400
Ni	50	1 400
Pb	100	1 600
Zn	2 500	800
Hg	1	40
Cr	300	2 100
Ag	5	180
As	18	-
Tl	1.5	-
U	50 mg Uran/ kg P2O5	-
B(a)P (Benzo(a)pyren)	1	-
PCB (Polychlorinated Biphenyls)	0.1	2

Sludge quality – what is it already in the legislation?

- Stabilisation
  - Content of organics

  ESTONIAN SLUDGE LEGISLATION

- Hygienisation
  - Content of pathogens

  ESTONIAN SLUDGE LEGISLATION

- Anthropogenic inorganic contaminants
  - Heavy metals (Cd, Hg, Ni, Zn, Cu, …)

  ESTONIAN & EU LEGISLATION

- Anthropogenic (toxic) non-biodegradable organics
  - Drugs, antibiotics, hormones, PCB, …

  NO LEGISLATION JUST HESITATION

Which sludge treatment technologies should be used?

- Stabilisation
  - Content of organics

  ← composting
  anaerobic - biogas
  aerobic stabilisation …

- Hygienisation
  - Content of pathogens

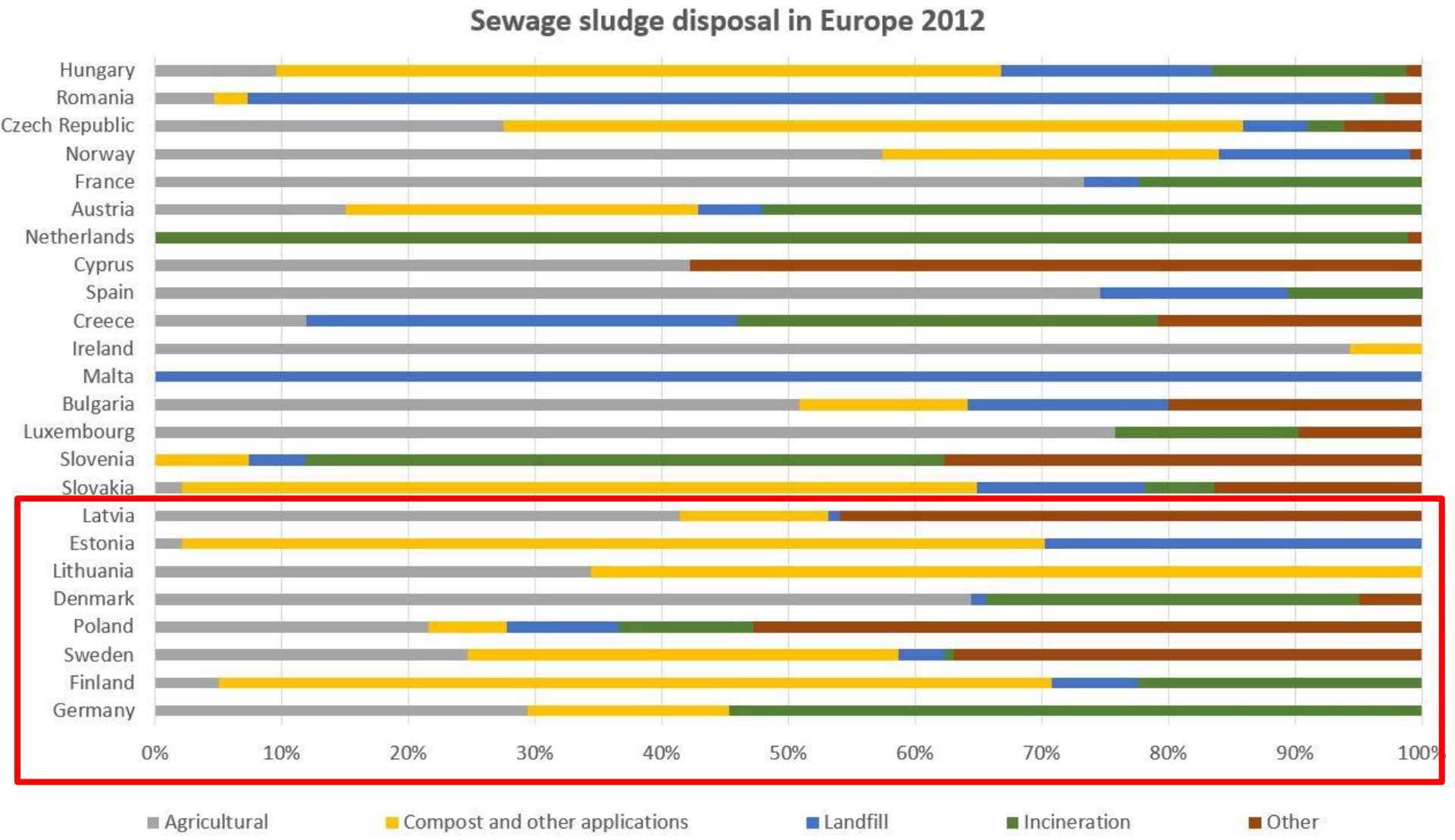
  ← composting
  hygienisation …

- Anthropogenic inorganic contaminants
  - Heavy metals (Cd, Hg, Ni, Zn, Cu, …)

  ← drying -
  incineration

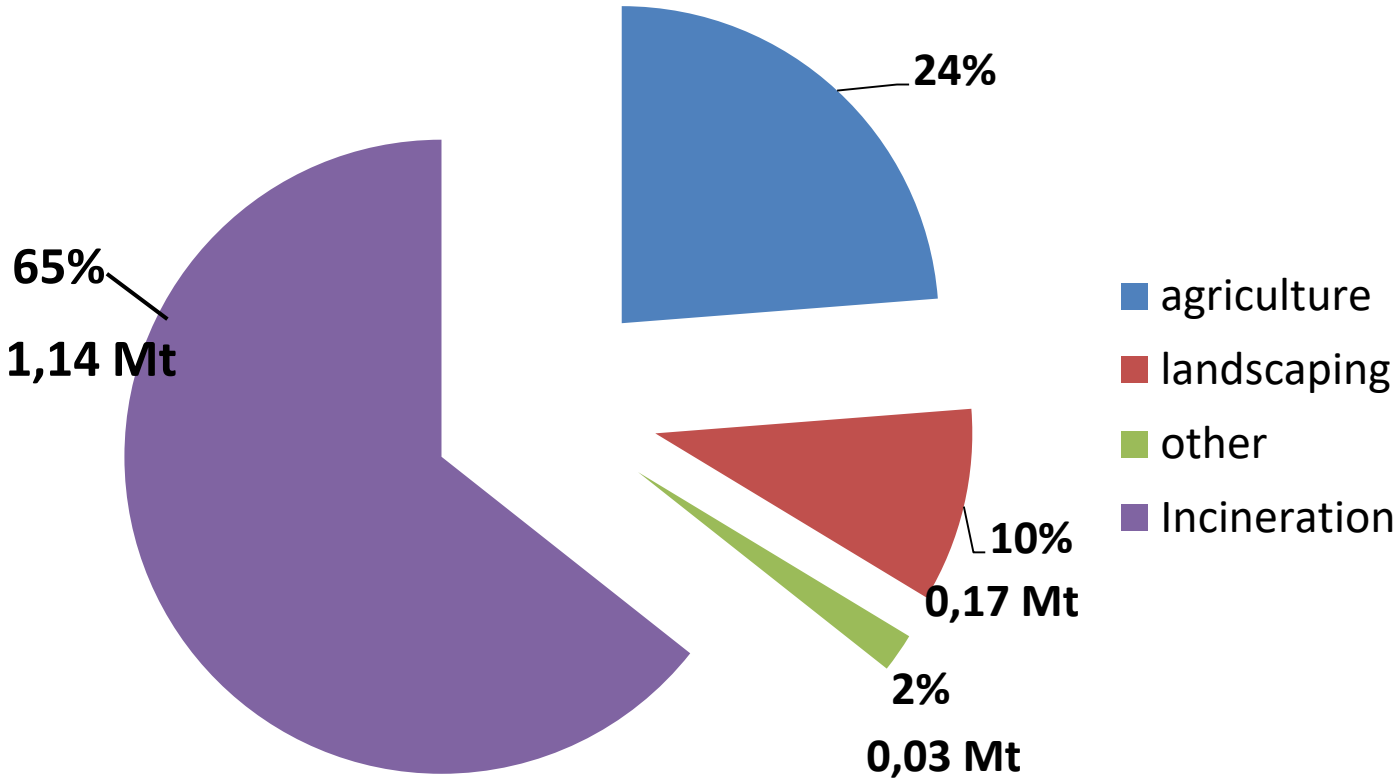
- Anthropogenic (toxic) non-biodegradable organics
  - Drugs, antibiotics, hormones, PCB, …

  ← drying -
  incineration



Data: ec.europa.eu/eurostat

Disposal pathways of sewage sludge in Germany (municipal WWTP)



Disposal
2016 in total: 1,77 Mt

Dr. Claus Gerhard Bergs Federal Ministry for the Environment

New German Sewage Sludge Ordinance: Consequences

Revision of the sewage sludge ordinance („Klär-schlammverordnung“) includes as main regulations:

- WWTPs with a capacity of more than **100 000** inhabitants have to **recycle phosphorus** after a transition period of 12 years
- WWTPs with a capacity of more than **50 000** inhabitants have to recycle phosphorus after a transition period of 15 years
- Direct use of sewage sludge as fertilizer is not allowed after the transition period of 12/15 years
- Exemptions for small and medium WWTP - these WWTP can use sewage sludge even after the transition period as fertilizer

What is done with sludge in Estonia?

The sludge study

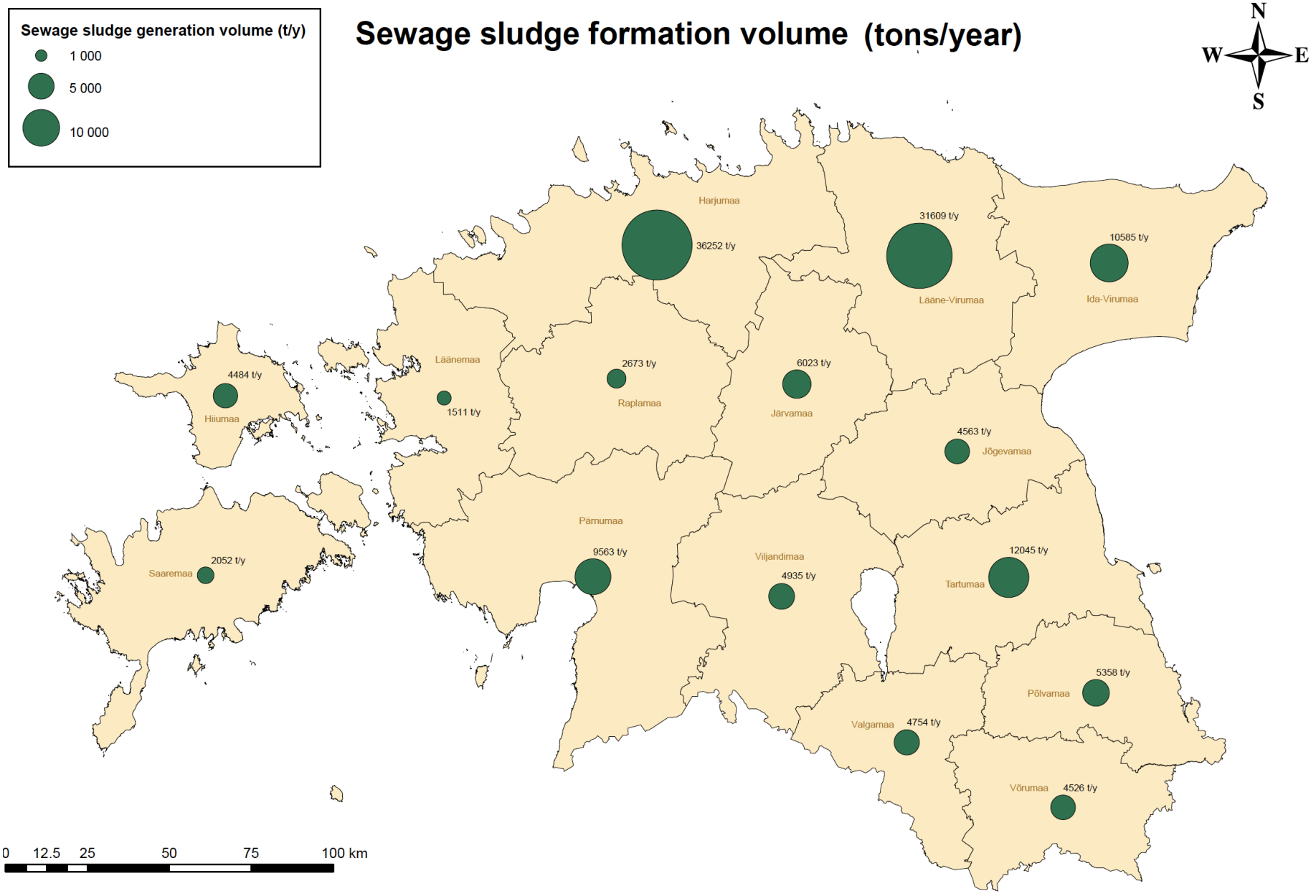
- The Estonian Ministry of the Environment contract

- Investigation of the sludge management strategy in Estonia
- Development of the solutions for regional sludge treatment and elaboration of the waste discontinuation criteria for wastewater sludge

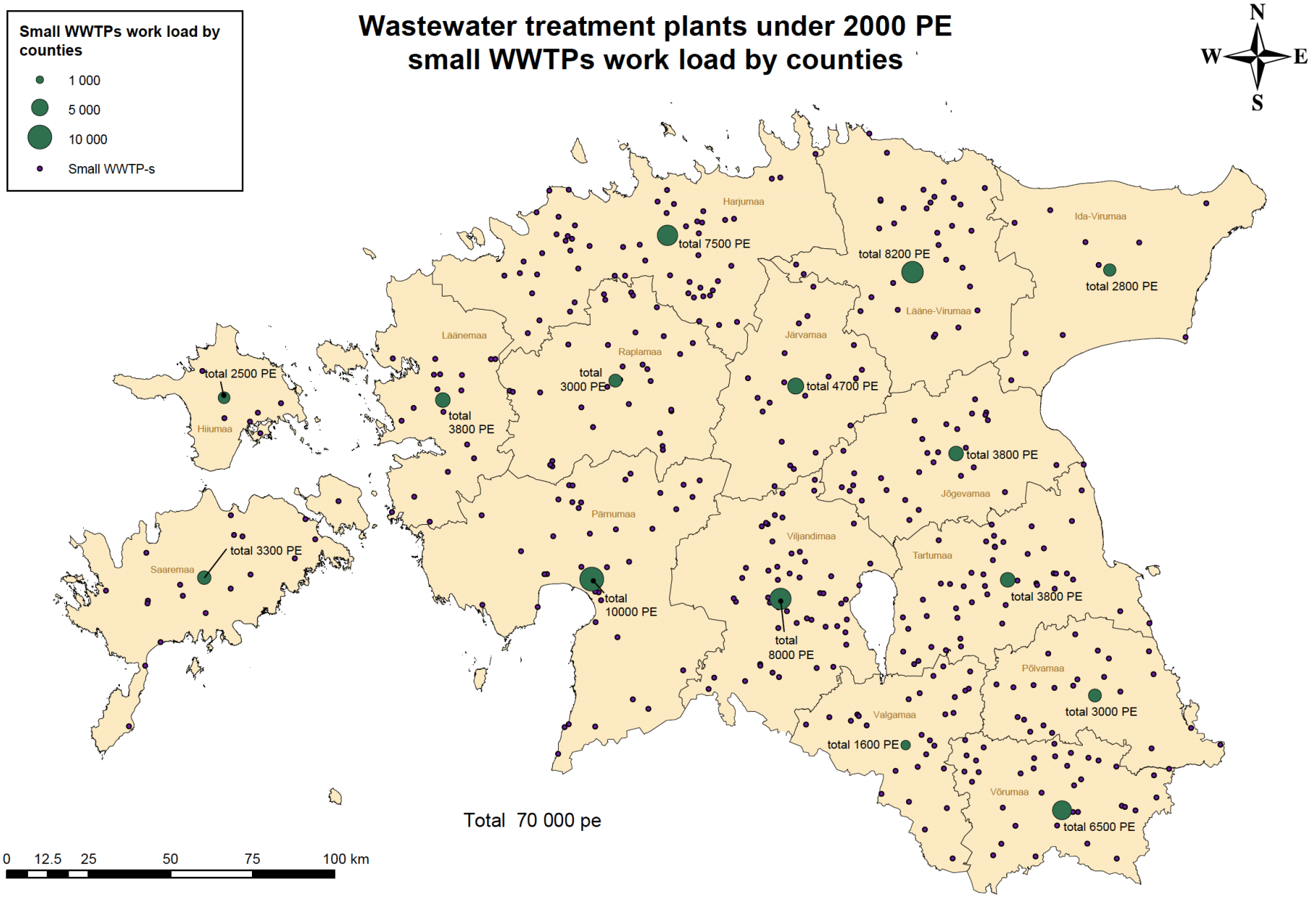
- 2014 –2016

  – Stage I – Overview of the sludge management
  – Stage II – Sludge usage and clarification of the sludge potential users
  – Stage III – Discontinuation criteria
  – Stage IV – Financial and economic study for sludge management

Sewage sludge formation volume (tons/year)



Wastewater treatment plants under 2000 PE
small WWTPs work load by counties



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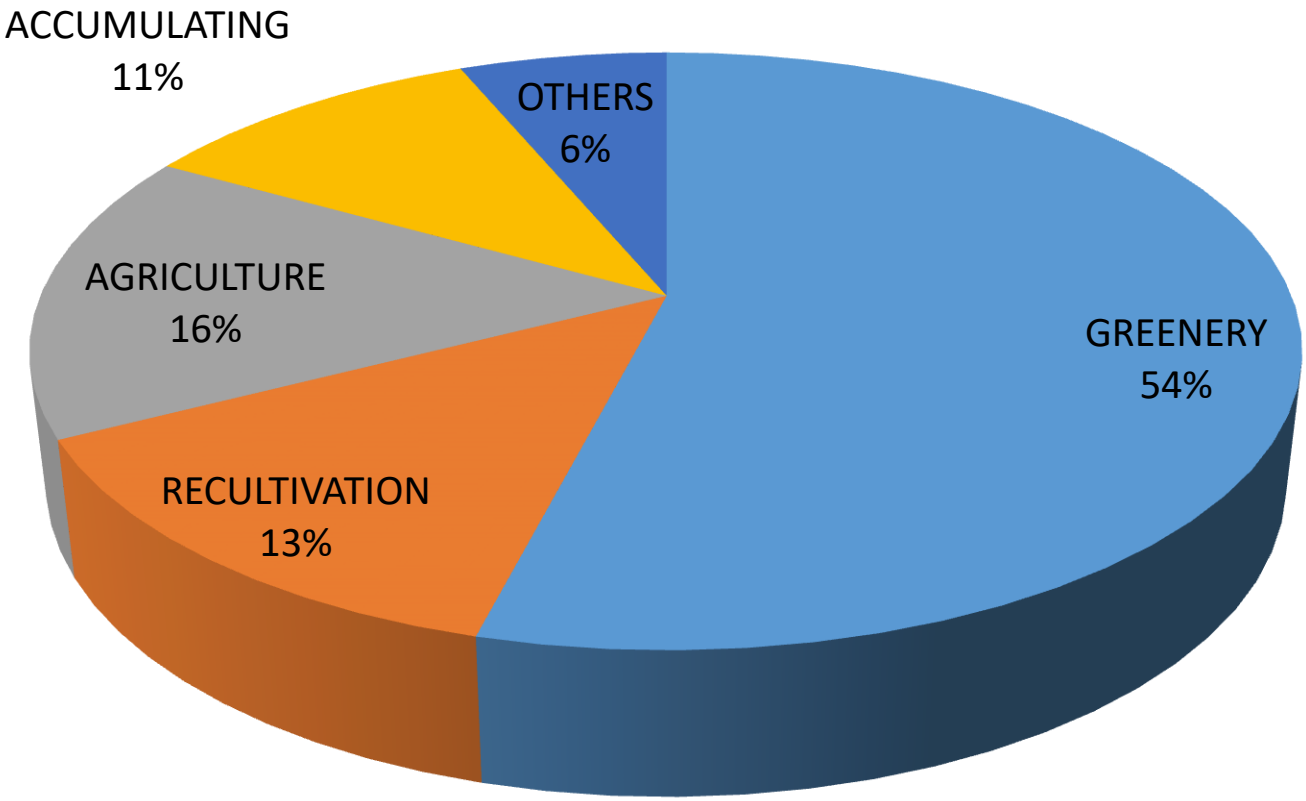
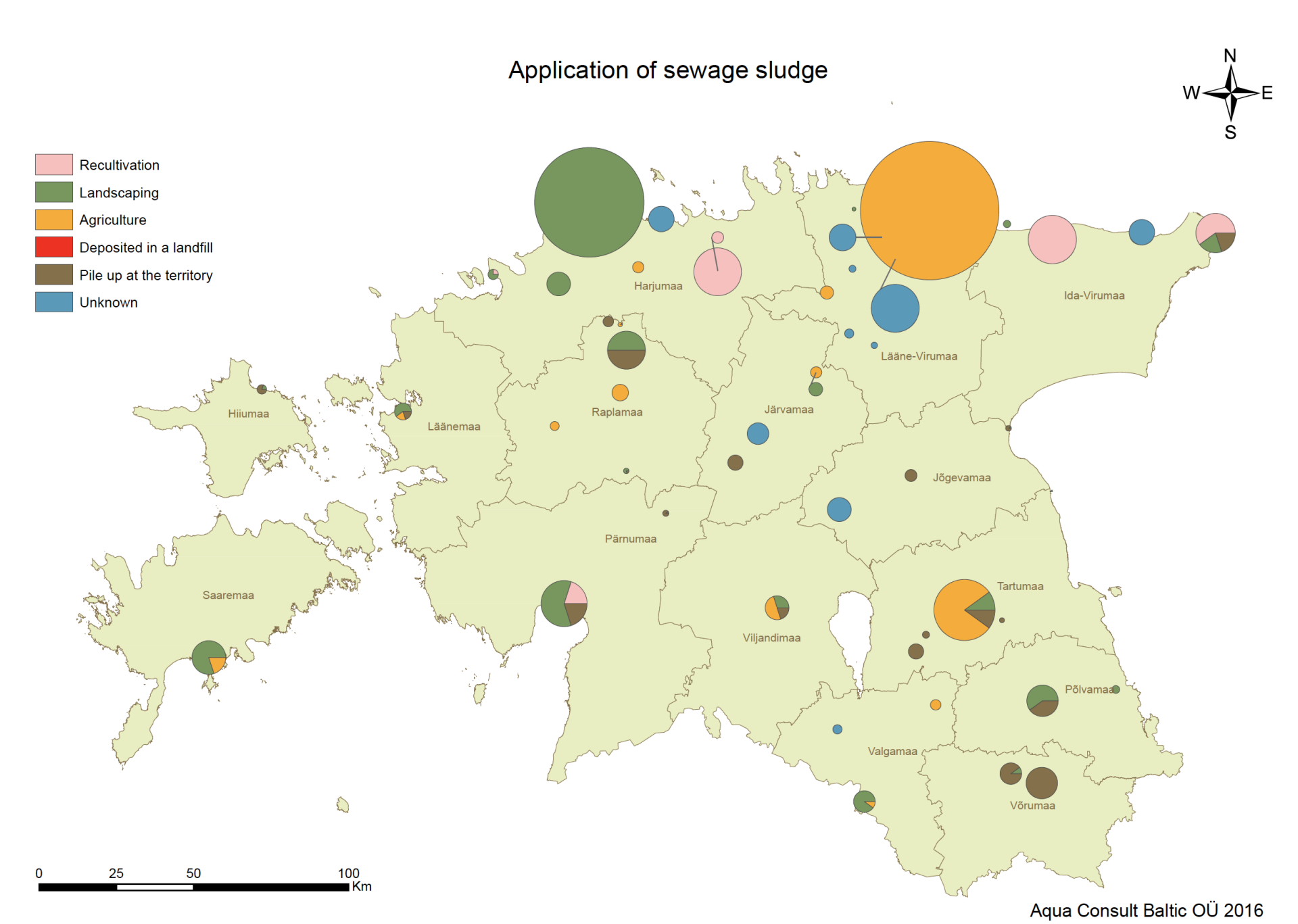
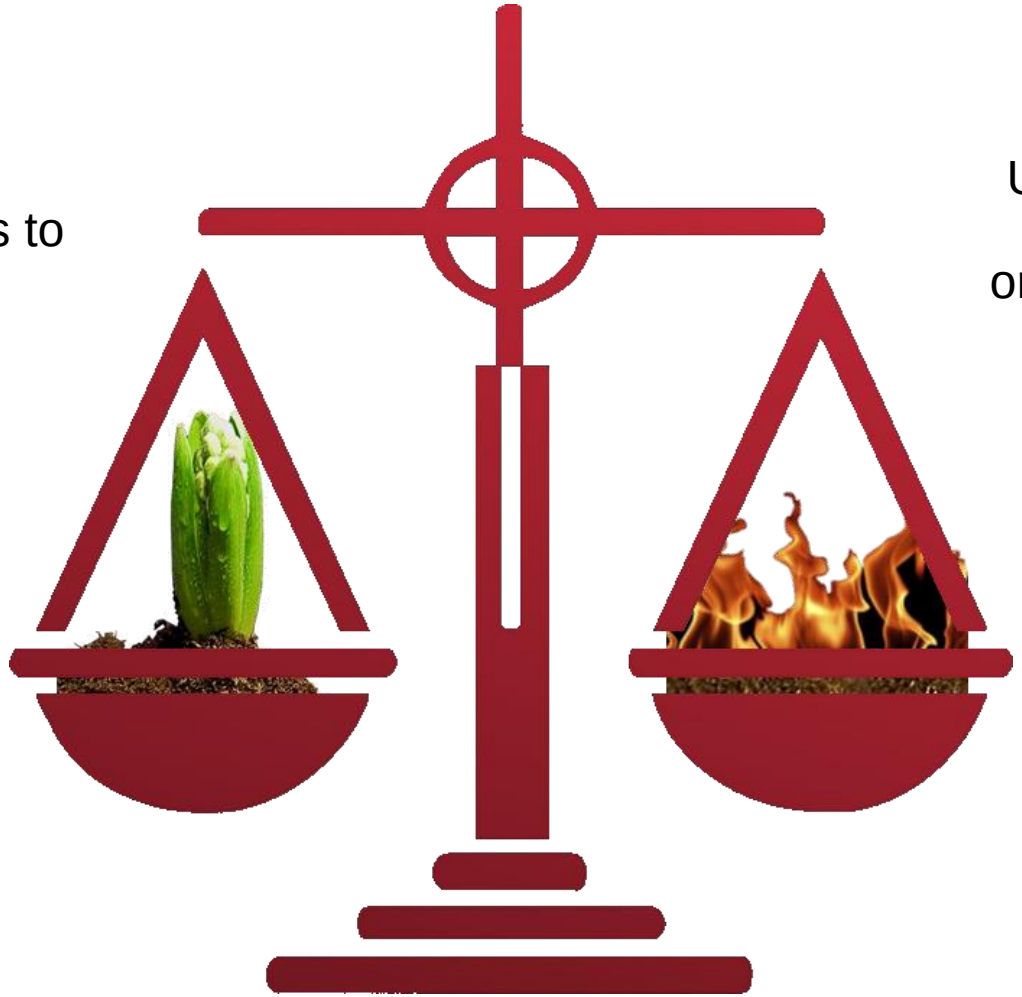
Sludge usage in Estonia




Application of sewage sludge
N
W
E
S
Recultivation
Landscaping
Agriculture
Deposited in a landfill
Pile up at the territory
Unknown
Harjumaa
Ida-Virumaa
Lääne-Virumaa
Hiiumaa
Läänemaa
Raplamaa
Järvamaa
Jõgevamaa
Pärnumaa
Saaremaa
Tartumaa
Viljandimaa
Põlvamaa
Valgamaa
Võrumaa
0
25
50
100
Km
Aqua Consult Baltic OÜ 2016

What should be done with sludge in Estonia ?

Good sludge quality in regards to heavy metals



Unknown risks from anthropogenic organic contaminants

Sludge management concept for Estonia

Principles

- Sludge management has to be feasible
  - Minimise the effect on water price
- Sludge management centres
  - Sludge transportation from small WWTP to the centres

Sludge usage in Estonia

- Sewage sludge ordinance defines sludge usage as “waste”
- Starting from 2013 registration of sludge usage as waste final deposit is required
  - Sludge usage for real estate has been one of the major usage areas
  - Sludge usage for private usage (greenery, lawn) is ceased

Market competition

- End of waste has been legalised for biowaste compost (2013) and digestate (2016)
- There are two legalised products, which compete with sewage sludge (waste) at the market

Media

- Sludge usage in greenery is very vulneralbe

- Media publications can affect the strategy of water company and behaviour of the populatoion

Citations

- „The do not know what happens, if sludge-related antibiotics are introduced into the soil – all kinds of **fungus and abdorted bacteria** can develop. „

Kompostmuld Foto: Jaanus Lensment / Postimees

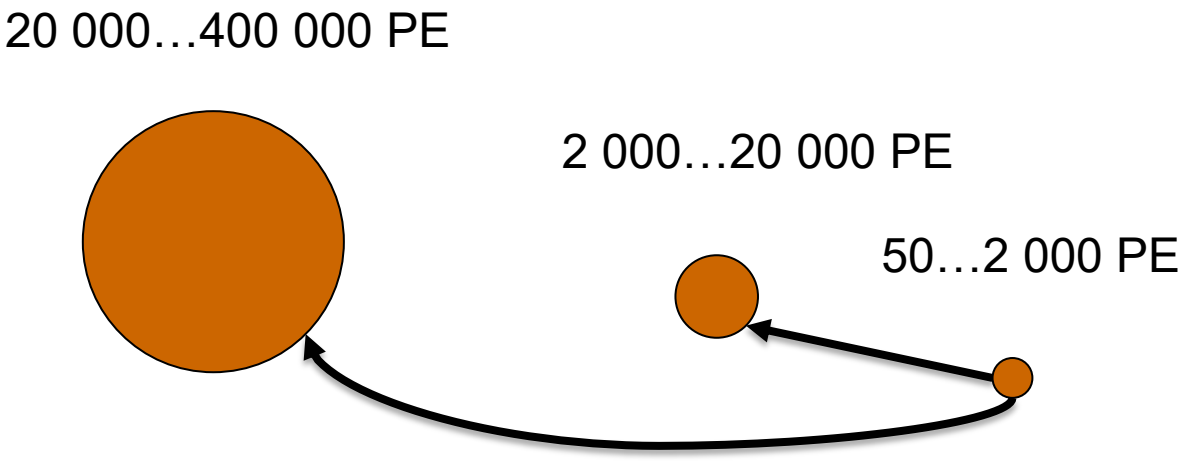
Põllumajandusuuringute keskus: Tallinna Vee tasuta jagatav kompostmuld sisaldab ravimijääke

29. aprill 2015 **10:47** Lisa järjehoidja

Tallinna Vesi jagab alates eelmisest nädalast settemullast tehtud haljastusmulda, mis sisaldab põllumajandusuuringute keskuse sõnul mullale kahjulikke ravimijääke, baktereid ja raskemetalle.

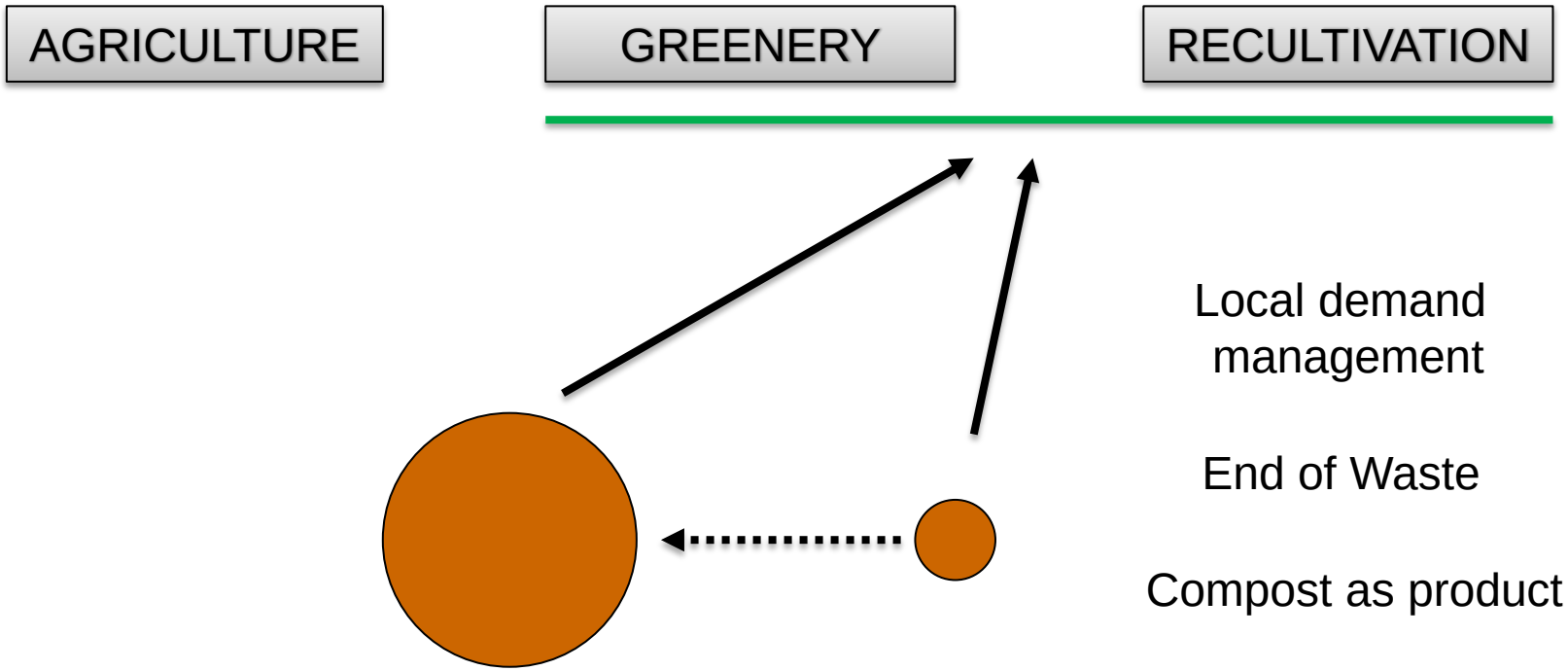
Flexible sludge management concept for Estonia

A – Dewatering and sludge treatment centres



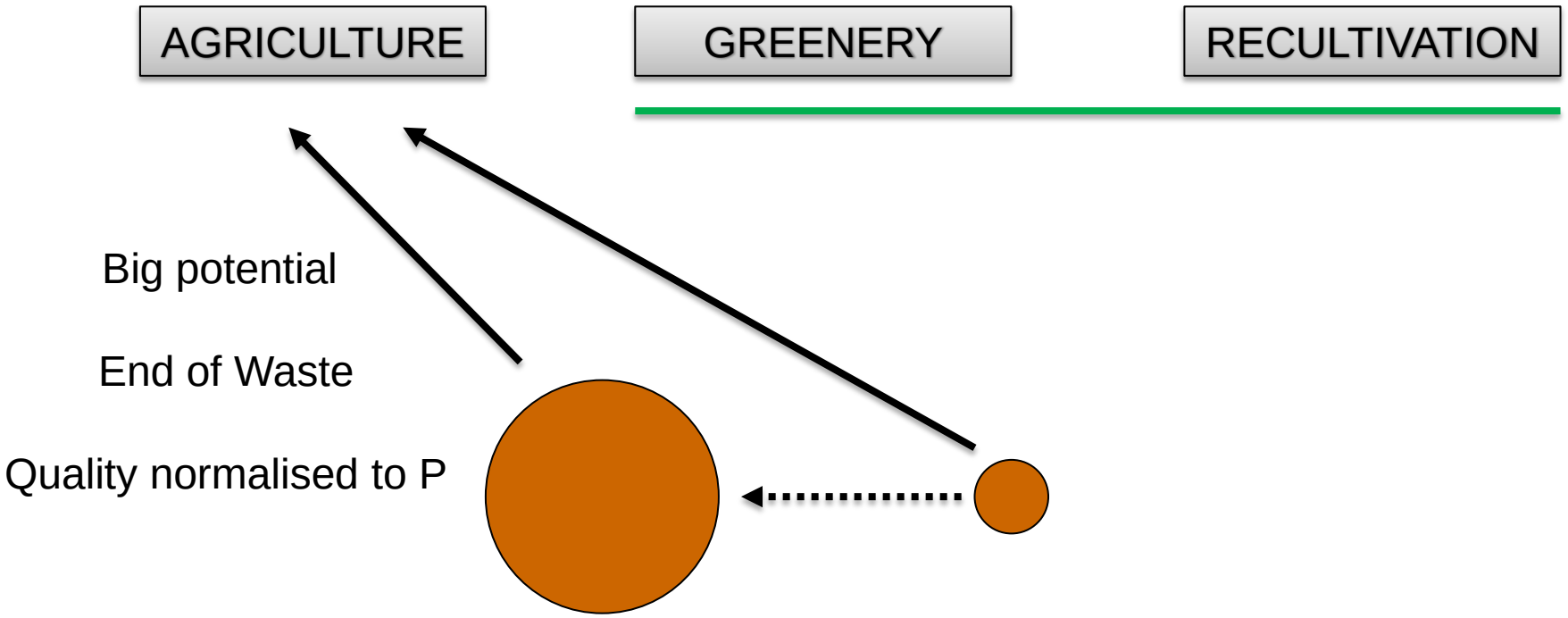
Flexible sludge management concept for Estonia

B – Sludge treatment centres for high quality sludge



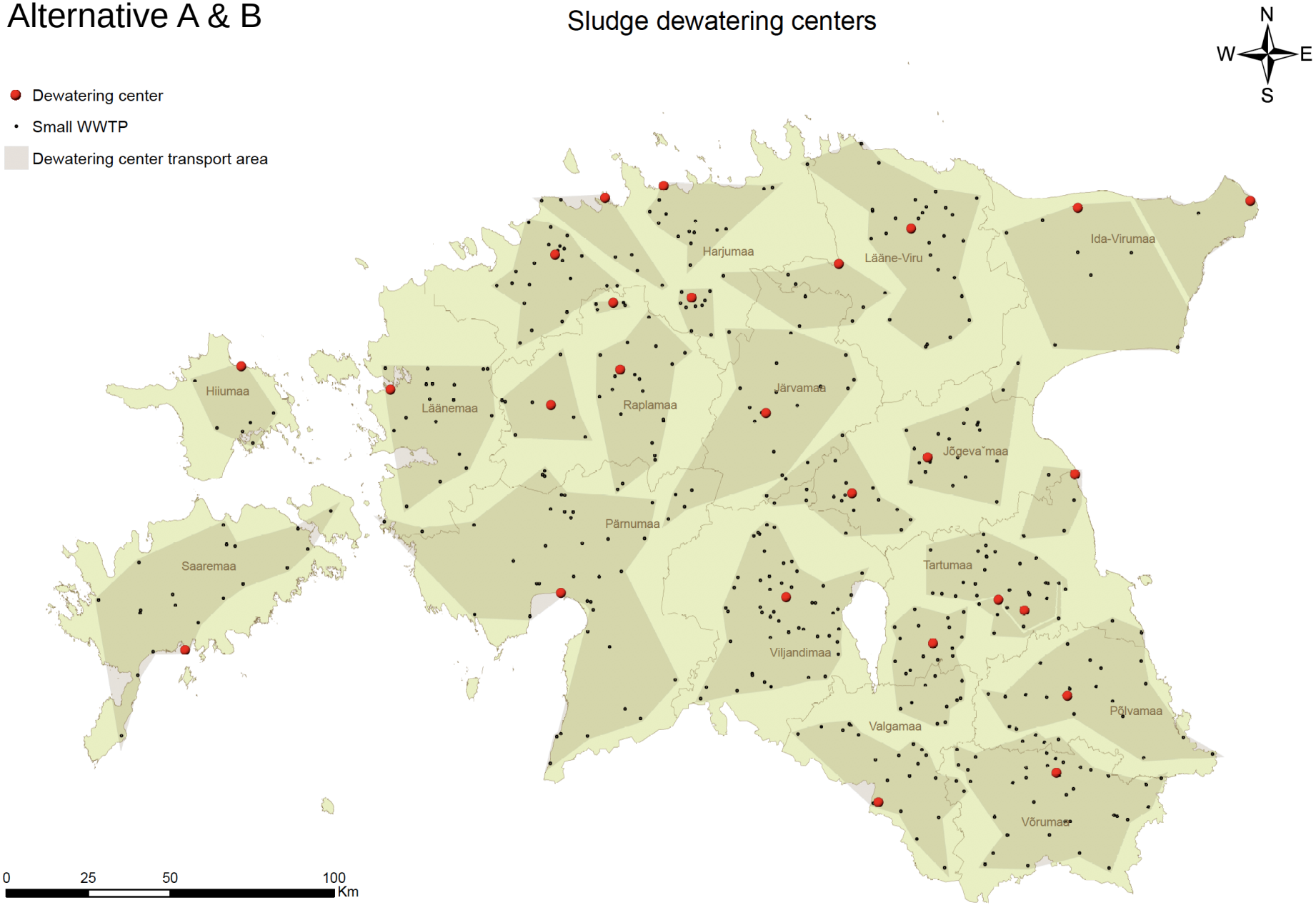
Flexible sludge management concept for Estonia

B – Sludge treatment centres for high quality sludge



Alternative A & B

Sludge dewatering centers



Aqua Consult Baltic OÜ 2016

Sludge management concept for Estonia

- Direct use of sludge should not be banned for good-quality sludge
  - Direct reuse of nutrients
- Gradual, demand-based adaption of drying and incineration
- Propagation of direct use of good quality sewage sludge by defining End of Waste (EoW) criteria for sewage sludge.

Ordinance

- Requirements for preparation of sewage sludge fertilizer product

Reoveesettest toote valmistamise nõuded

Vastu võetud 19.07.2017 nr 24

End-of-waste law in Estonia

2013 - EoW for **biowaste compost** (2013)

- https://www.riigiteataja.ee/akt/119122015010

2013 - **Certification body** in Estonia is *Foundation 'Certification Centre of Recycled Materials'*

2014-2015 – development of certification documents

2015 Dec – Case 1 sertification

2016 Feb – National Accreditation Center issued sertificate


EESTI AKREDITEERIMISKESKUS
ESTONIAN ACCREDITATION CENTRE

AKREDITEERIMISTUNNISTUS
ACCREDITATION CERTIFICATE

Eesti Akrediteerimiskeskus kinnitab käesolevaga, et
The Estonian Accreditation Centre hereby confirms that

vastab EVS-EN ISO/IEC 17065:2012 nõuetele kui sertifitseerimisasutus
conforms to the requirements of EVS-EN ISO/IEC 17065:2012 as a certification body

Akrediteerimisulatus on esitatud tunnistuse lisas
The scope of accreditation is specified in the annex

Registreerimisnumber: PC026
Registration number:

Akrediteering kehtib kuni: 16.02.2021
Accreditation is valid until:

Tallinnas, 17.02.2016

Kristina Saarniit
Juhataja Director

- 2016 – EoW for **biowaste digestate**
  - https://www.riigiteataja.ee/akt/119052016009
- 2017 – EoW for **sewage sludge**
  - https://www.riigiteataja.ee/akt/128072017004
  - 2017 first sertification process failed (excessive Cd)
  - 2018 several sertifications in progress

Estonian end of waste (EoW) legislation for sludge

- CERTIFICATION PROCESS

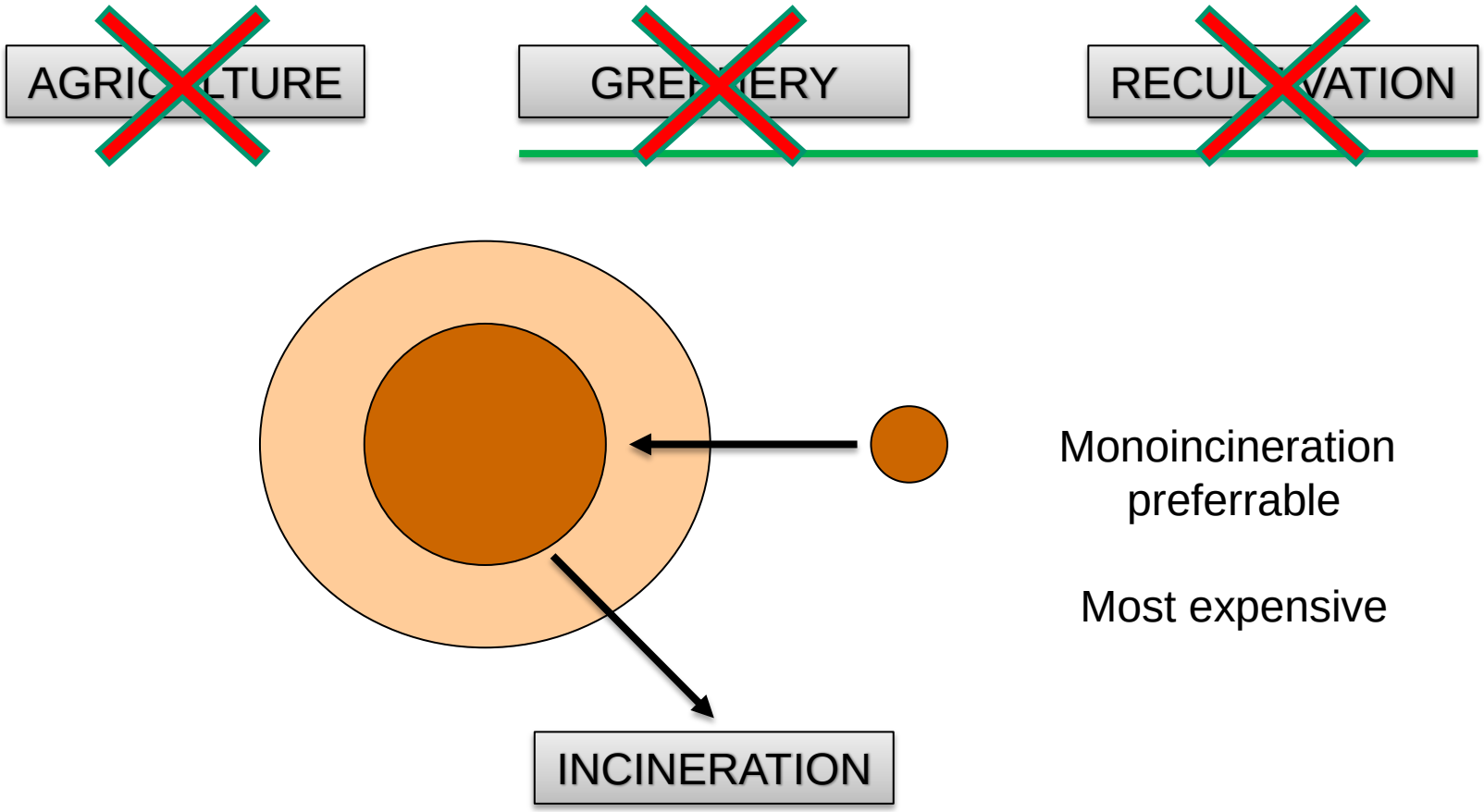
REQUIREMENTS

- Stability (oxygen demand, biogas, VS/TS, …)
- Hygienisation (*Salmonella*, *E coli*, helminth eggs)
- Other unwanted (weed seeds)
- Heavy metals

	Agricultural usage [g/kg P]
Lead (Pb)	7,5
Cadmium (Cd)	0,2
Chromium (Cr)	15,0
Copper (Cu)	45,0
Nickel (Ni)	4,0
Mercury (Hg)	0,1
Zinc (Zn)	125

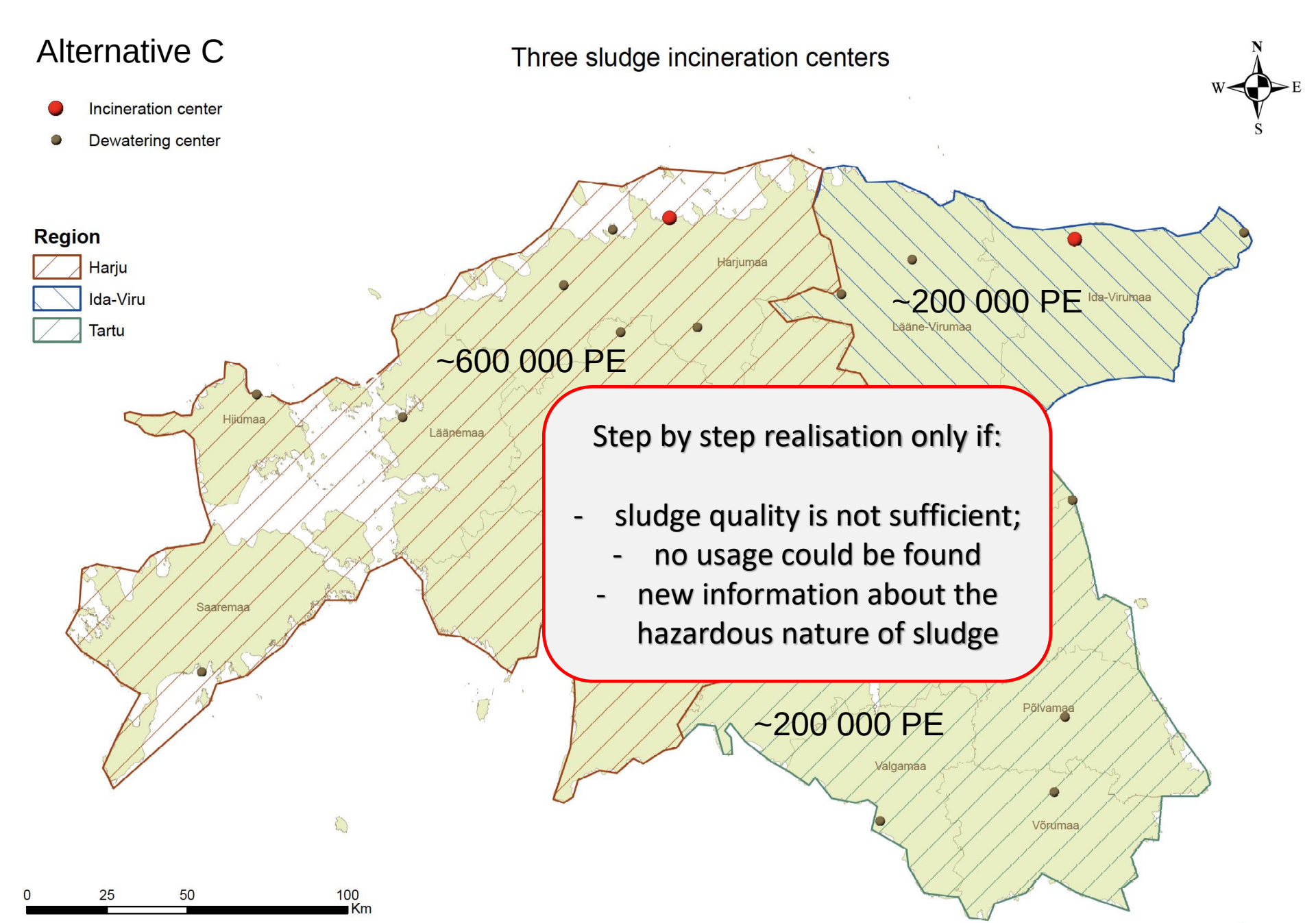
Flexible sludge management concept for Estonia

C – When sludge quality is not sufficient



Alternative C

Three sludge incineration centers

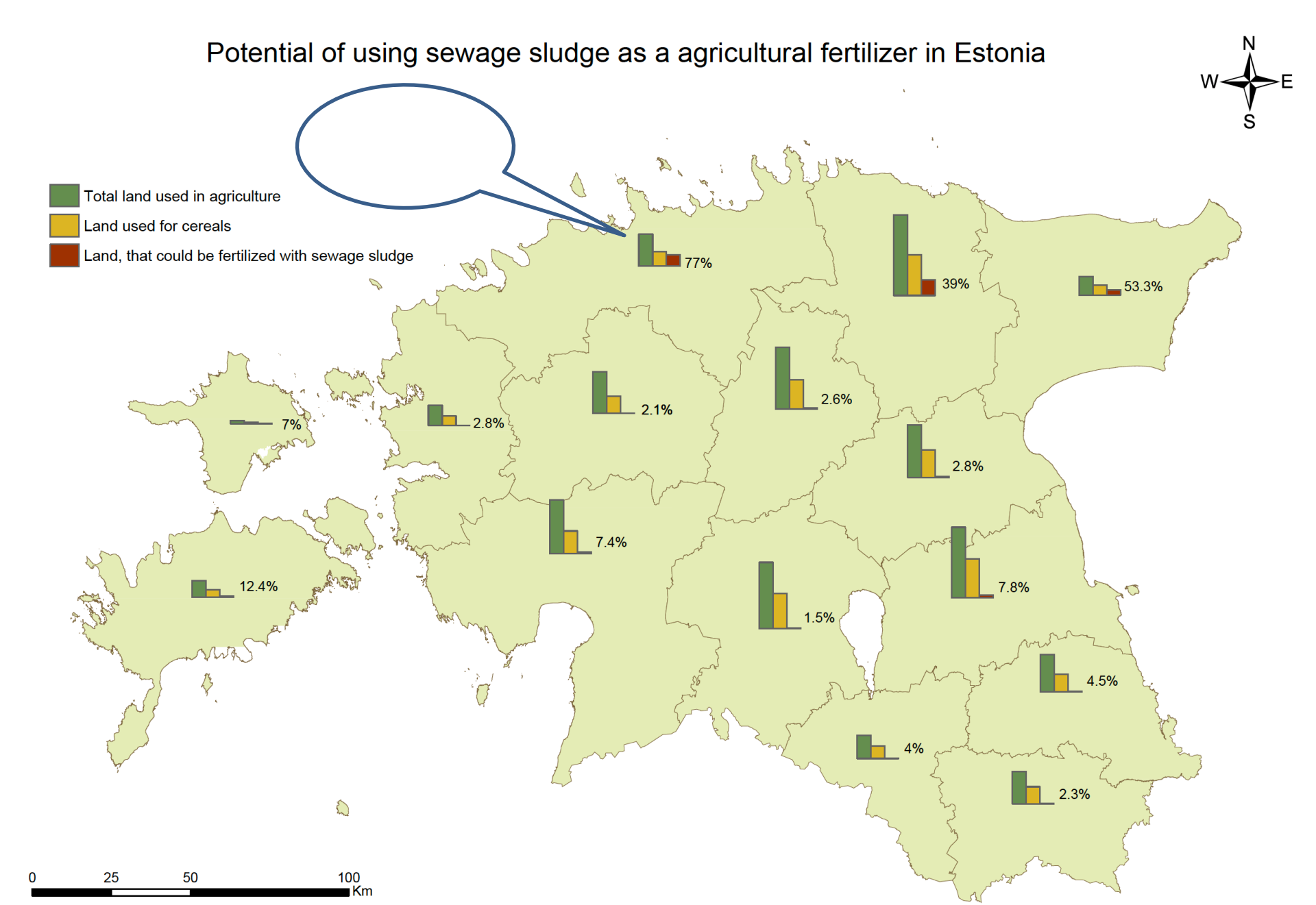


Aqua Consult Baltic OÜ 2016

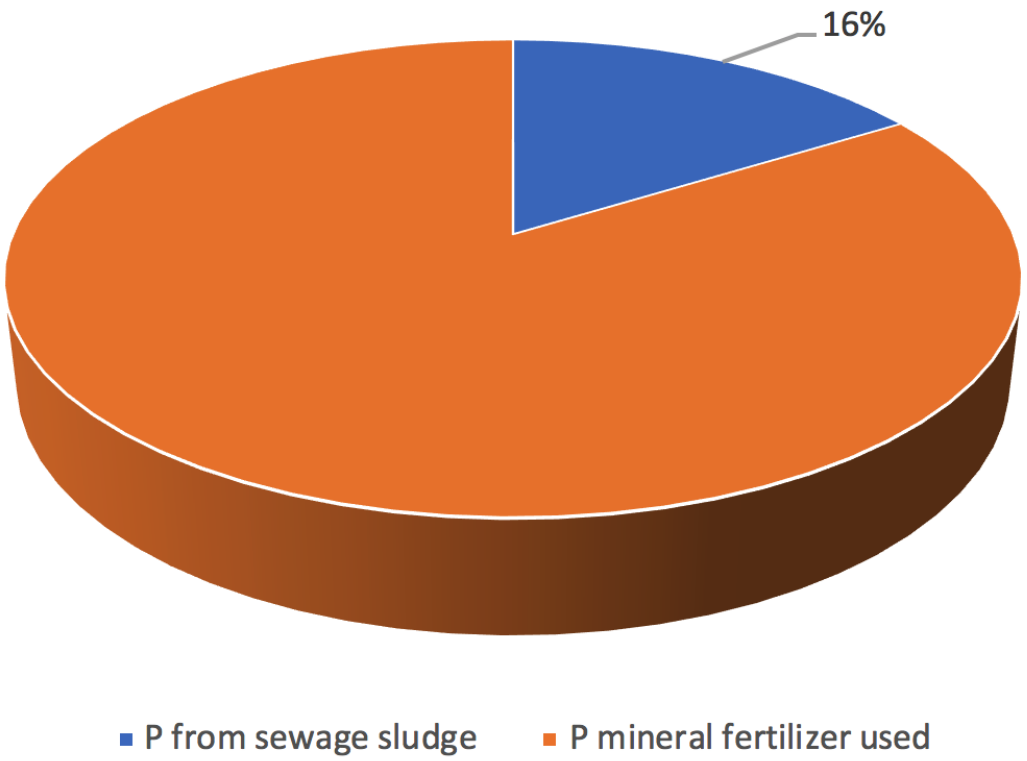
P-recovery potential from a WWTP

REUSE OR RECOVERY

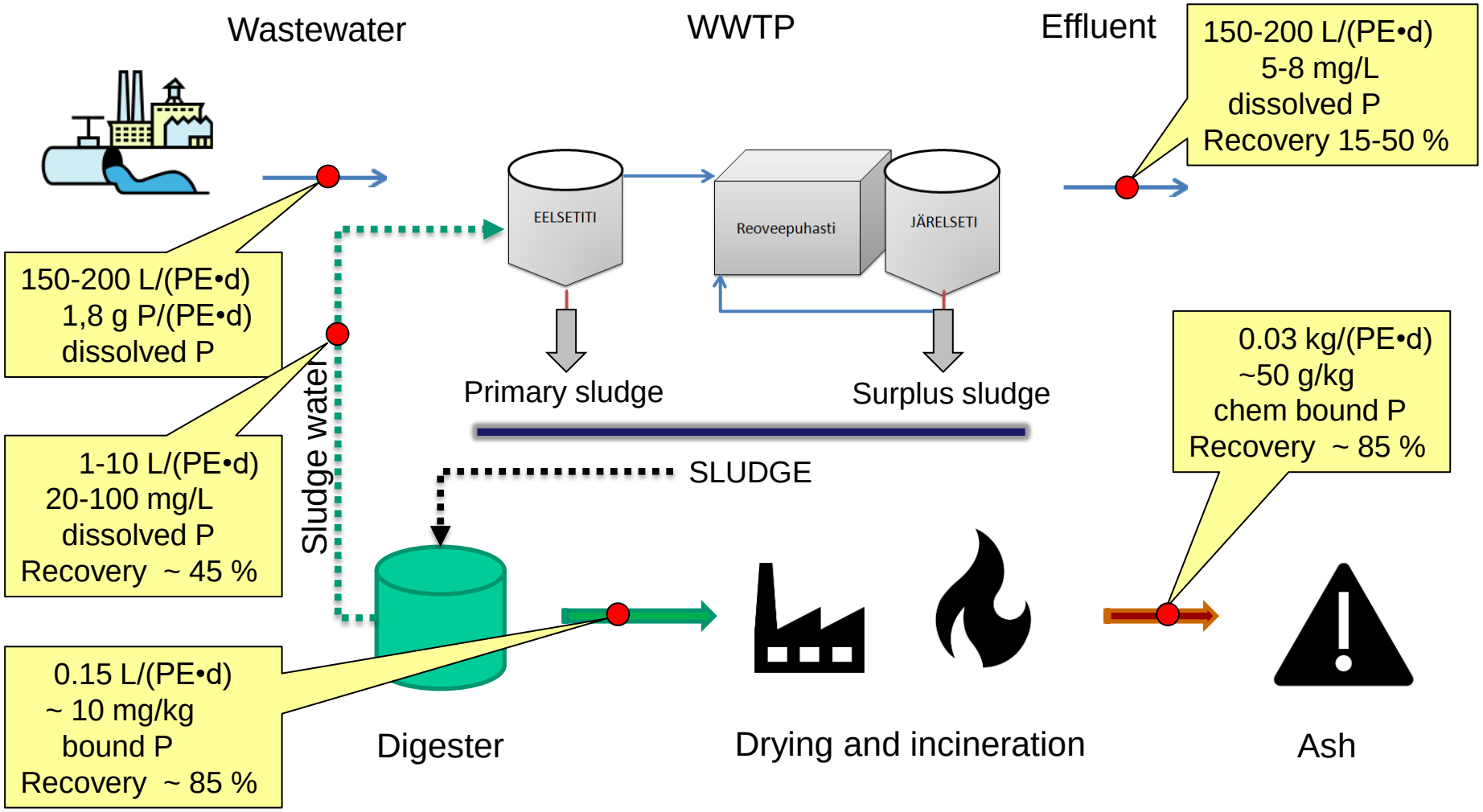
Potential of using sewage sludge as a agricultural fertilizer in Estonia



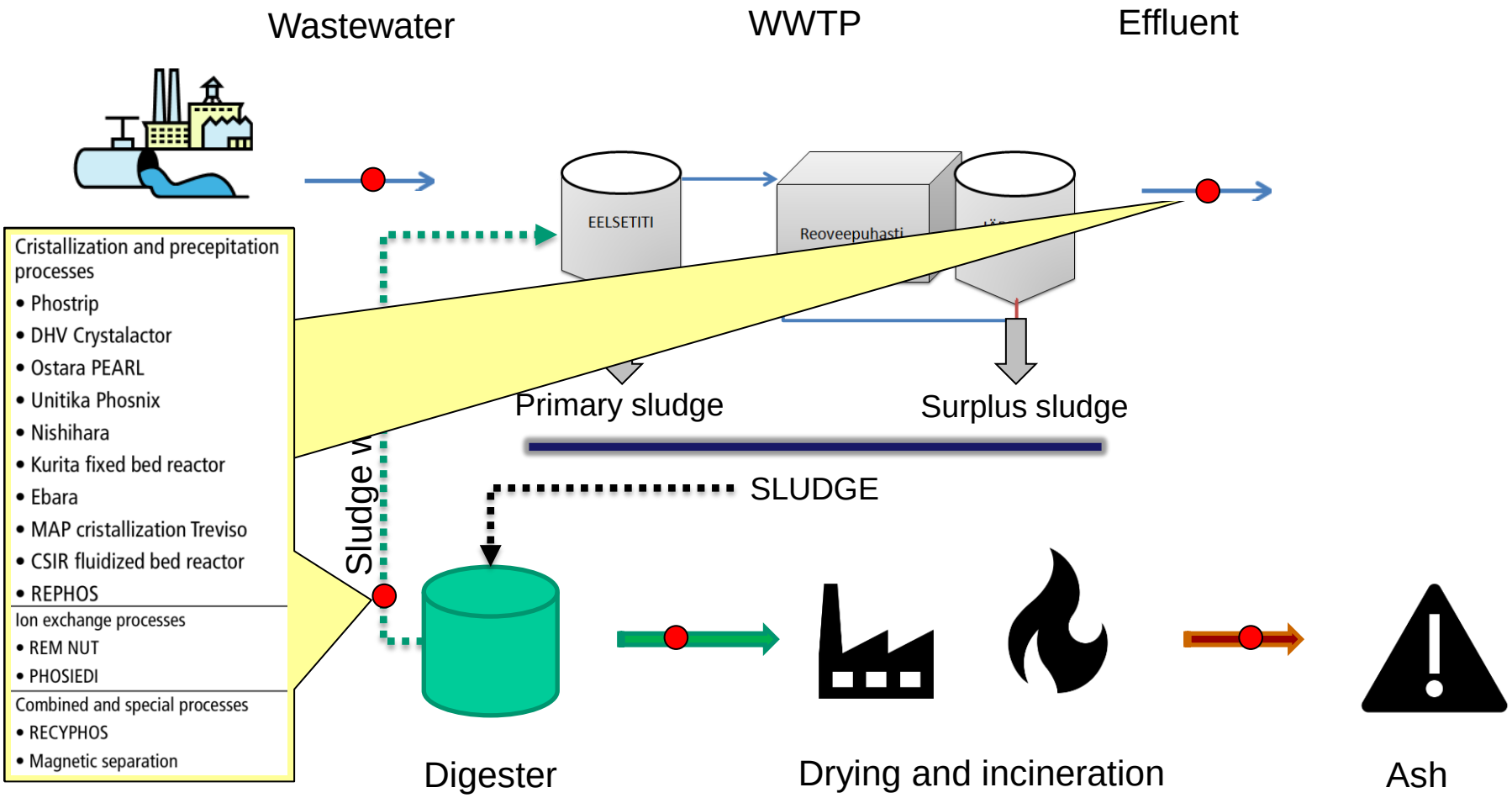
Total agricultural need for P-fertilizer in Estonia



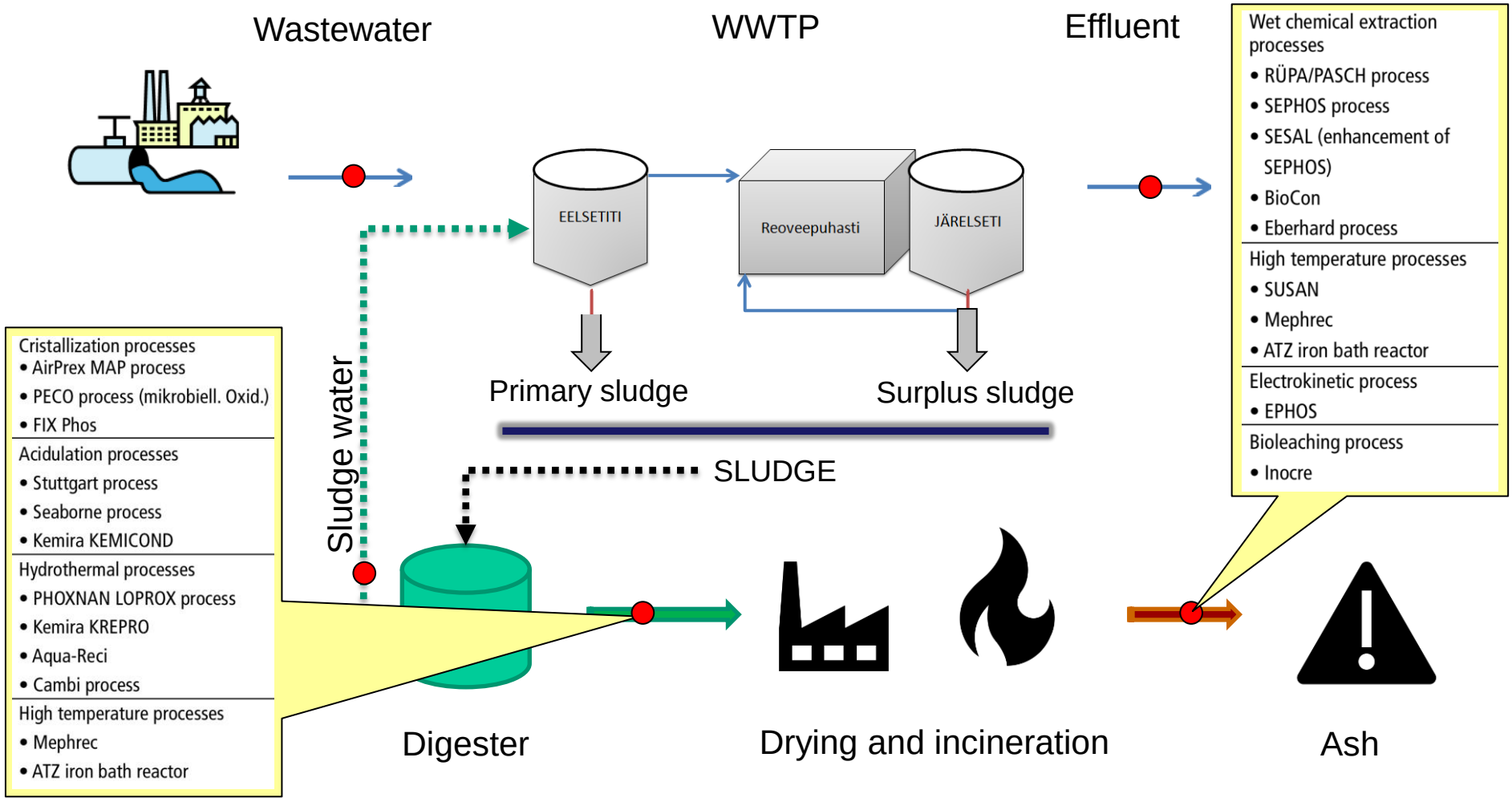
Phosphorous recovery from sewage sludge



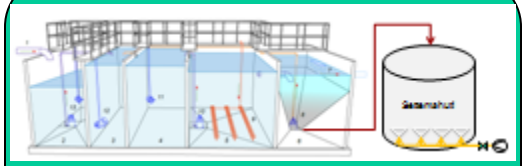
Phosphorous recovery methods



Phosphorous recovery methods



TECHNOLOGIES



Local dewatering and transport to bigger plant

Reactor composting

Anaerobic digestion

Lime stabilisation

Extended aerobic

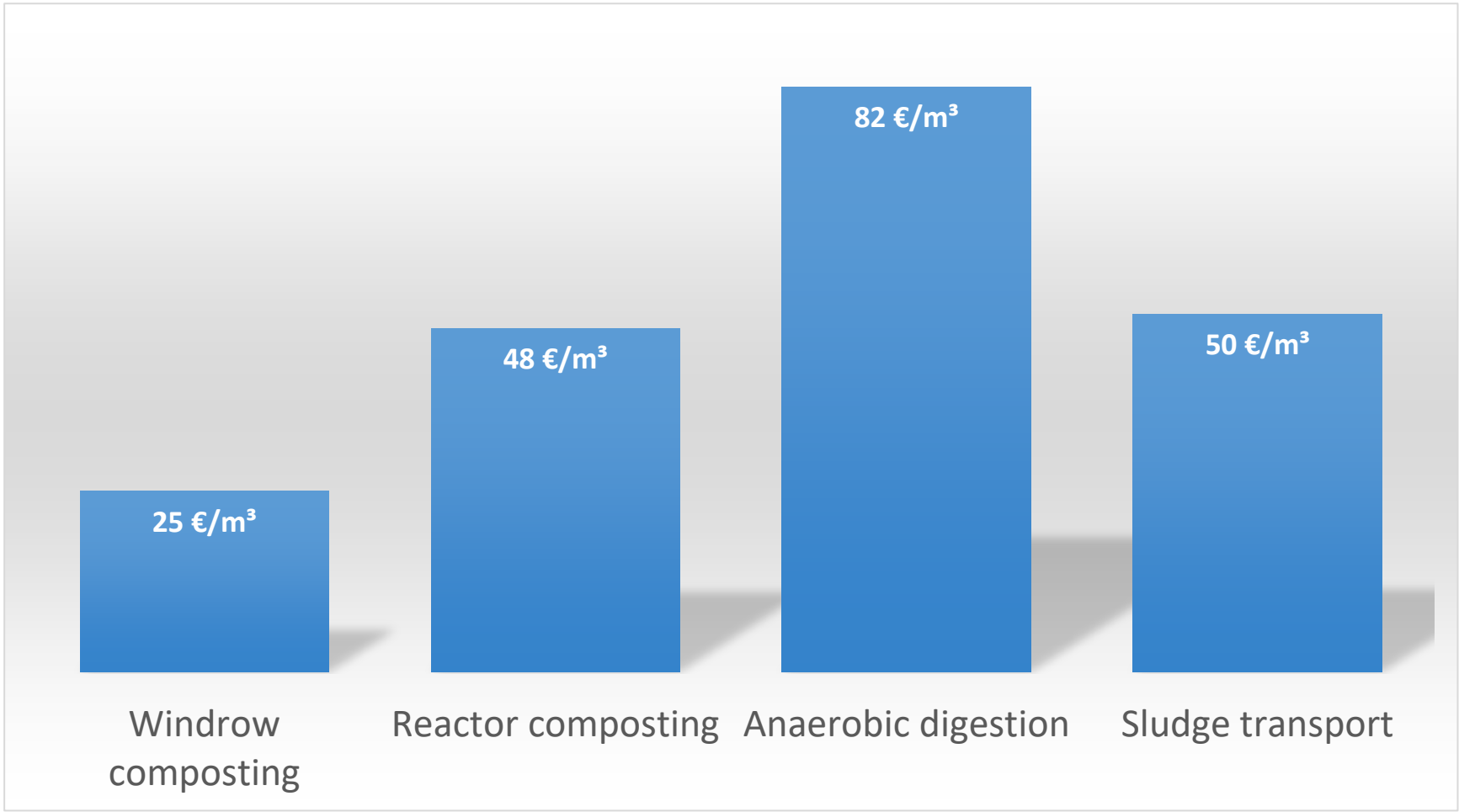
Sludge beds & humification

Windrow composting

Drying / incineration

5 ... 50 … 100 … 500 … 1000 … 5000 … 10 000 … 50 000 … 100 000 … 500 000 PE

Cost of sludge treatment in Estonia



Feasibility of technologies

- Biogas plant (anaerobic digestion)
  - Feasibility starts from 50 000…100 000 PE
  - Investment for 100 000 PE ~ 6 M€

- Drying plant
  - Feasibility starts from 100 000…200 000 PE
  - Investment for 200 000 PE ~ 6 - 8 M€

- Drying and incineration plant
  - Feasibility starts from 200 000…400 000 PE
  - Investment for 200 000 PE ~ 10 - 12 M€

- P – recovery plant ???
  - Only for regional centres
  - Possibly in conjuncgtion with incineration

Conclusion

- Estonia has continued with direct usage of sewage sludge in agriculture, greenery and recultivation (**N & P reuse**).
- In order to facilitate reuse of quality sludge Estonia has legalised **EoW** for sewage sludge.
- Local sludge treatment centres for small WWTP-s is foreseen to manage quality and cut the costs.
- Step by step application of incineration and **P recycling** technologies for sewage sludge is **postponed** and realised on demand

Thank you!

taavo.tenno@aquaconsult.ee
www.aquaconsult.ee