Seethawaka EPZ
Sludge Management Study

The path to sustainable sludge management

AHK
Delegation der Deutschen Wirtschaft in Sri Lanka
Delegation of German Industry and Commerce in Sri Lanka

Supported by:

Federal Ministry
for the Environment, Climate Action,
Nature Conservation and Nuclear Safety

based on a decision of
the German Bundestag

ENVIRONMENTAL made PROTECTION in Germany

engineering 4environment
the sludge drying engineers

27.03.2026

Seethawaka Export Prozessing Zone (SEPZ)

Industrial Zone

- located 50 km east of Colombo
- mainly textile and rubber related products manufacturing, mineral processing, food manufacturing etc.
- 25.000 employees
- 26 enterprises, 13 wet processing sites with own pre-treatment
- 1 central WWTP

Source: Google Maps

Source: BOI

Central WWTP

Treatment capacity: 9.900 m³/day

Process steps:

- screening
- sand/gravel separation 0,25 hrs
- equalization 18 hrs
- oxidation/aeration 31 hrs
- final settling 5 hrs
- chlorination
- UV treatment (future)
- sludge treatment
  - thickening 385 m³
  - dewatering with polymer
    (3 belt presses Andritz VS 25 IP-1998)

Source: BOI

Central WWTP

Sludge Analysis (Dewatered Sludge)

General parameters	Unit	Value
DS content	% d.s.	17
pH	-	7,6
ignition loss	% of DS	61,4
total N	% of DS	6,4
ammonia-N	% of DS	0,81
P_2O_5	% of DS	2,0
K_2O	% of DS	0,09
MgO	% of DS	0,28
alkaline substances	% of DS	12

Organic substances	Unit	Value
AOX (adsorbable organic halogens)	mg/kg DS	520
Total PFOA+PFOS	mg/kg DS	< 0,01
Benzo(a)pyren	mg/kg DS	< 0,5
PCB	mg/kg DS	< 0,006
PCDD/F (WHO-TEQ) incl. detection limit	ng/kg DS	10,1

Heavy metals	Unit	Value
Arsenic (As)	mg/kg DS	< 2
Lead (Pb)	mg/kg DS	13
Cadmium (Cd)	mg/kg DS	0,3
Calcium (Ca)	mg/kg DS	82000
Chromium (Cr)	mg/kg DS	110
Iron (Fe)	mg/kg DS	31000
Copper (Cu)	mg/kg DS	120
Nickel (Ni)	mg/kg DS	45
Mercury (Hg)	mg/kg DS	0,1
Thallium (Th)	mg/kg DS	0,8
Zinc (Zn)	mg/kg DS	13000

Halogens and sulfur	Unit	Value
Bromine	mg/kg DS	< 250
Chlorine	mg/kg DS	1200
Fluorine	mg/kg DS	220
Sulfur	mg/kg DS	100

Calorific value an gas production	Unit	Value
upper calorific value Ho, v (wf)	kJ/kg DS	15940
lower calorific value Hu, p (wf)	kJ/kg DS	14880
gas production rate GB21 (normal condit.)	NL/kg oDS	70-174

Evaluation: low phosphorous, high N, elevated AOX, high zinc, low gas production rate

DS - dry solids; oDS - organic dry solids

Industrial WWTPs

Industrial Sludge

Sludge producing companies: 13

98 % of industr. sludge (d.s. base) is produced by 4 companies:

- Orit Apparels
- Teejay Lanka
- Teejay Lanka Prints
- Hirdaramani

Typical process steps:

- equalization
- DAF flotation
- biological aeration
- settling/clarifiying
- sand/AC/UF/RO filtration
- sludge treatment
  - thickening
  - dewatering (filter press/screw press/centrifuge)
  - 44 % of industr. sludge (d.s. base) is dried (Teejay)








AC	activated carbon
UF	ultra filtration
RO	reverse osmosis
DAF	dissolved air flotation

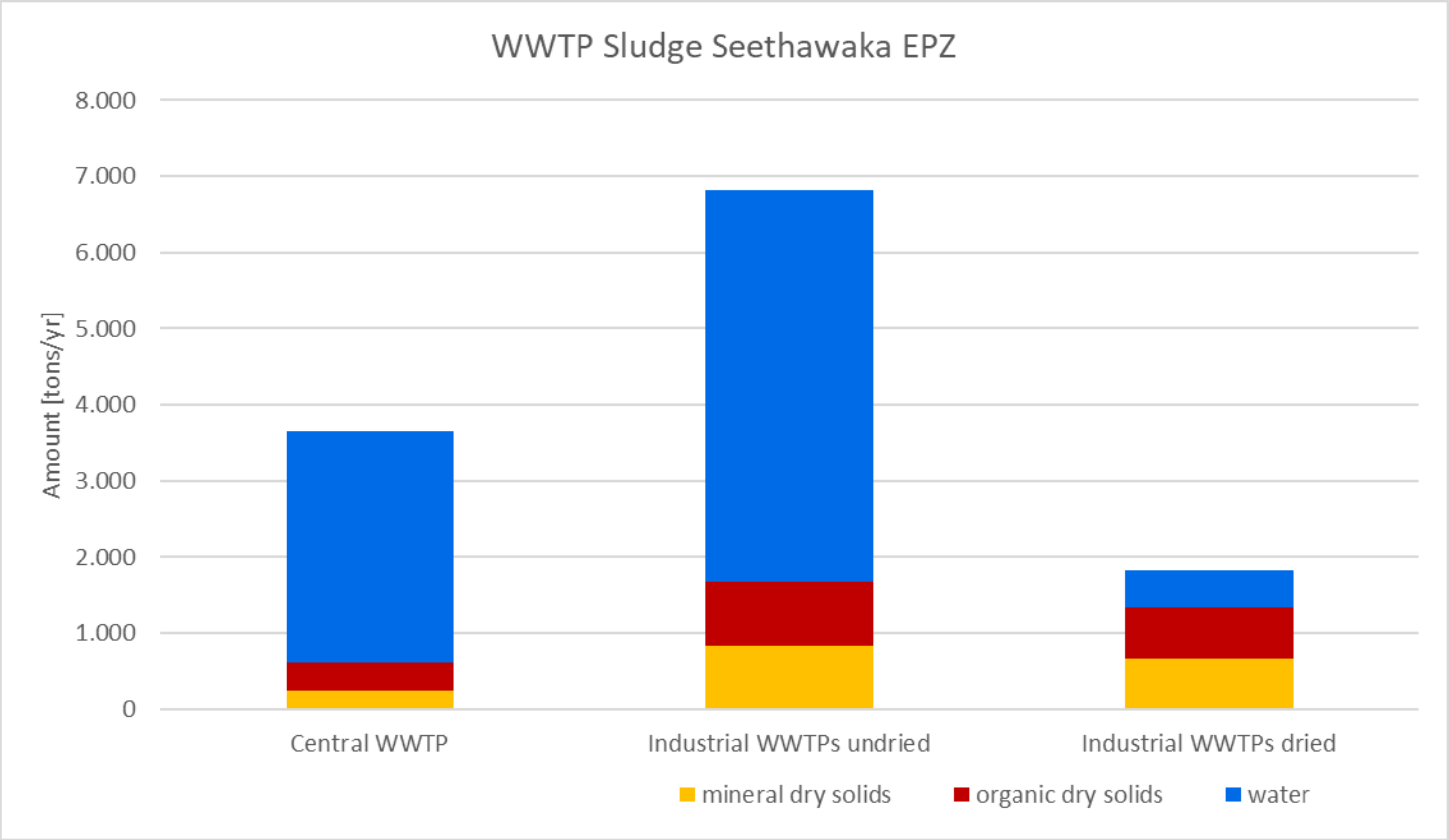
Sludge Amounts Seethawaka EPZ

	Central WWTP	Industry	Total	estim. water content
Sludge undried	3.650 t/yr	6.816 t/yr	10.466 t/yr	8.171 t/yr
Sludge dried		1.825 t/yr	1.825 t/yr	493 t/yr
Total	3.650 t/yr	8.641 t/yr	12.291 t/yr	8.664 t/yr
Total (dry solids)	621 t DS/yr	3.007 t DS/yr	3.628 t DS/yr	

Classification	scheduled waste (non-hazardous)	scheduled waste (hazardous and non hazardous)

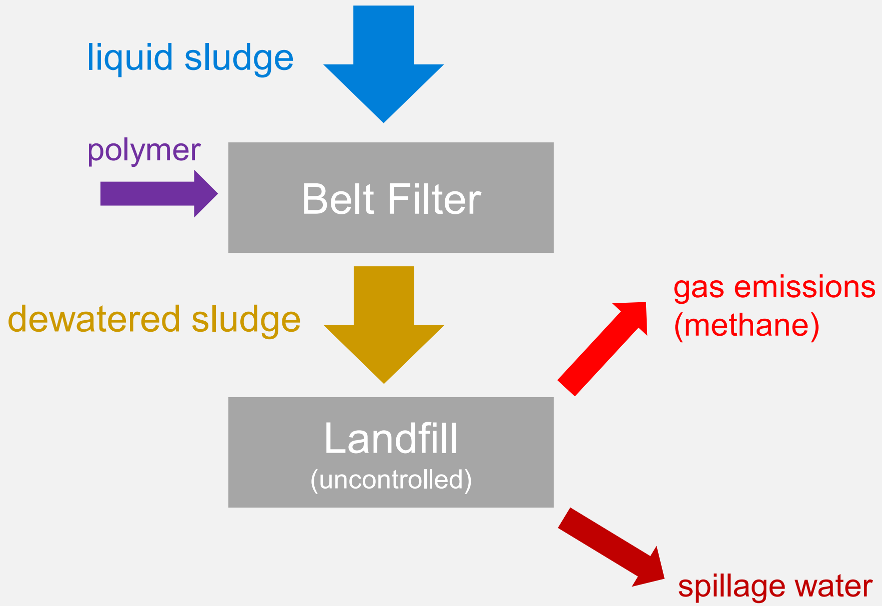
t/yr – metric tons per year

Sludge Amounts Seethawaka EPZ



Current State of Sludge Management

CWWTP sludge



+

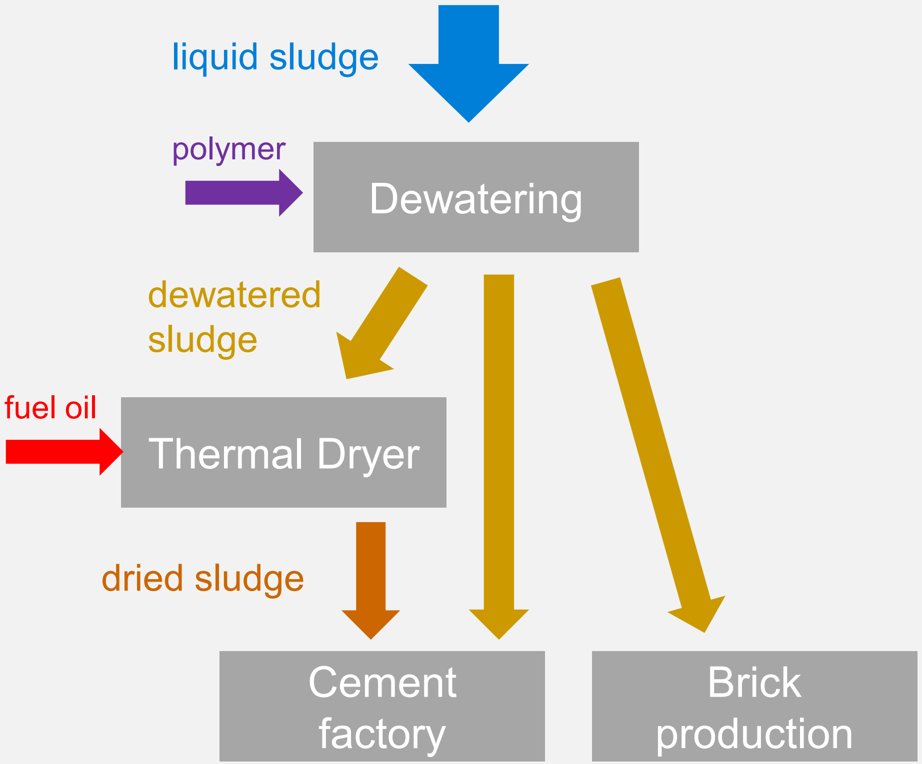
- short transport distance
- no electrical energy demand
- low fuel demand
- low disposal cost

−

- high sludge volume
- not stabilized
- no use of nutrients/minerals
- organic pollutants
- water/ground contamination
- extremely high gas emissions
  ⇨ very high carbon footprint!

Current State of Sludge Management

Industrial sludge



+

- reduced sludge volume (partially)
- no/low electrical energy demand
- destruction of organic pollutants
- no water/ground contamination
- use of minerals
- moderate carbon footprint

−

- long transport distance
- fuel demand for transport
- energy demand for thermal dryer
- high sludge volume (partially)
- very high disposal cost

Regulatory Restrictions

National Environmental Act No. 47/1980
Scheduled activities notification (Gazette 2264/18)

Part A

7. Dye and dye intermediates manufacturing or formulating industries.
15. Textile Processing (including bleaching, dyeing, printing) industries or garment washing industries or textile sand blasting industries.
29. Common waste treatment and management facilities located outside or inside of the industrial zones/industrial estates/export processing zones.
33. Any activity/ industry not included in Part A of the Schedule which discharges wastewater at the capacity of 40 cubic meters per day or more in its production process.

Part B

17. Industries involved in processing, bleaching or dyeing of natural fiber or natural fiber based industries where 25 or more workers are employed.
46. Common wastewater (industrial or sewage) treatment plant.
47. Incinerators having a feeding capacity of 5 or more metric tons per day.
50. Solid waste recycling (including plastic wastes) or recovery or processing plants having a daily input capacity of 10 or more metric tons.
51. Solid waste disposal facility or sites having a daily disposal capacity of 10 or more metric tons.
52. All toxic and scheduled waste disposal or recycling or recovering or storage facilities.
70. Any activity/industry not included in the Part B of the Schedule, where 200 or more workers per shift are employed.
71. Any activity/ industry not included in the Part B of the Schedule, which discharges wastewater capacity of 10 cubic meters or more and less than 40 cubic meters per day in its production process.

Regulatory Restrictions

National Environmental Act No. 47/1980
Scheduled activities notification (Gazette 2264/18)

Part C

12. Power looms (without sizing activities) having 5 or more machines and less than 25 machines.
30. Incinerators having a maximum feeding capacity of less than 5 metric tons per day by weight.
40. Solid waste (including plastic wastes) recycling/ recovery or processing plants having a daily input capacity of less than 10 metric tons.
41. Solid waste disposal facilities or sites having a disposal capacity of less than 10 metric tons per day (excluding household facilities).
55. Any activity/ industry not included in this Part C of the schedule where 50 or more and less than 200 workers per shift are employed.
56. Any activity/ industry not included in Part C of the schedule which discharges waste water at the maximum capacity of 3 or more cubic meters and less than 10 cubic meters per day in its production process

Part D

22. Mechanized cement blocks manufacturing industries.
39. Any activity/industry not included in Part D of the schedule, where 10 or more and less than 50 workers per shift are employed.

⇨ environmental licence is required for any sludge management/treatment process

Regulatory Restrictions

National Environmental Act No. 47/1980
Hazardous waste regulation (Gazette 1534-18)

Scheduled wastes from non-specific sources

N151	Metal hydroxide sludges from wastewater treatment system
N204	Hydroxide or sulphate or heavy metal containing sludges from wastewater treatment system
N184-187	Sludges from paint/ink/pigment/dye wastewater treatment system

Scheduled wastes from specific sources

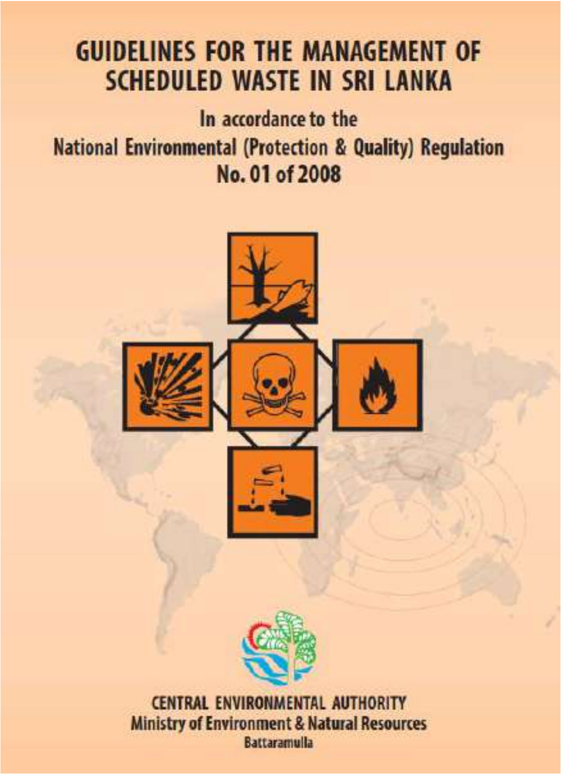
S121	Rubber or latex sludges containing heavy metals from the waste water treatment system of rubber products manufacturing plant.
S191	Waste water containing dye from textile manufacturing plant.

⇨ all WWTP sludges produced in Seethawaka EPZ are scheduled waste

Evaluation Criteria

CEA Guidelines for Scheduled Waste Management

- solid residuals must be sufficiently inert
- solid residuals must comply with acceptable disposal standards
- all possible precontainment measures should be taken to prevent, minimize and manage the possible of ground contamination due to waste transfer operations, pipe and tank fracture, site flooding etc.
- Treatment and disposal options for WWT sludge:
  - sludge conditioning and dewatering
  - incineration of sludge in centralized facility (organic waste)
  - disposal to controlled landfill



Source: CEA

Evaluation Criteria

Eco-Industrial Park Framework (World Bank)

Environmental Performance Criteria

Prerequisites

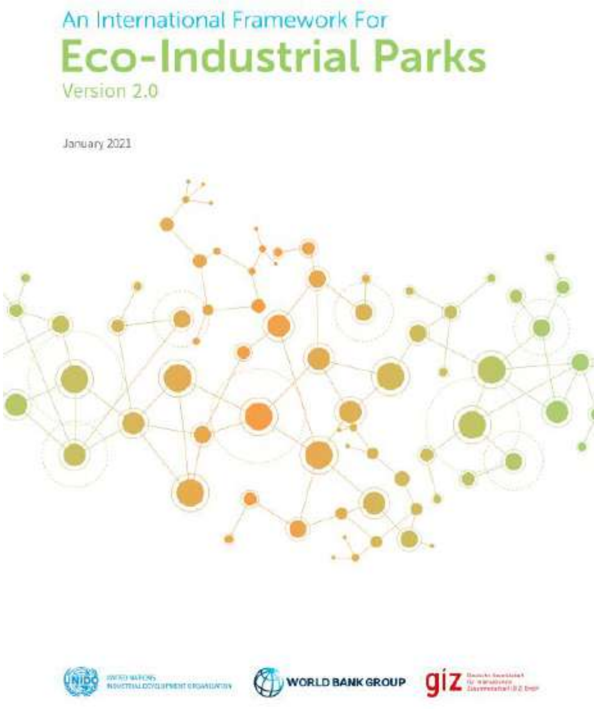
- Treatment of Sludge: central park facility for treatment available
- Disposal of sludge: monitoring system in operation for slugde leaving the SEPZ

Performance Criteria and Indicators

- Energy efficiency: Energy efficiency opportunities should be identified at the park and firm levels to reduce energy use and associated greenhouse gas emissions.
- Reduction of pollution and GHG emissions
- Sludge disposal: systematic treatment, recycling and disposal, which correctly manages unusable waste materials

  Target value: Percentage of industrial waste without re-processing, reuse or recycling options that go to sound disposal [100%]
- Disposal Cost

  Target: cost reduction, economical viability



Source: World Bank Group

Evaluation Criteria

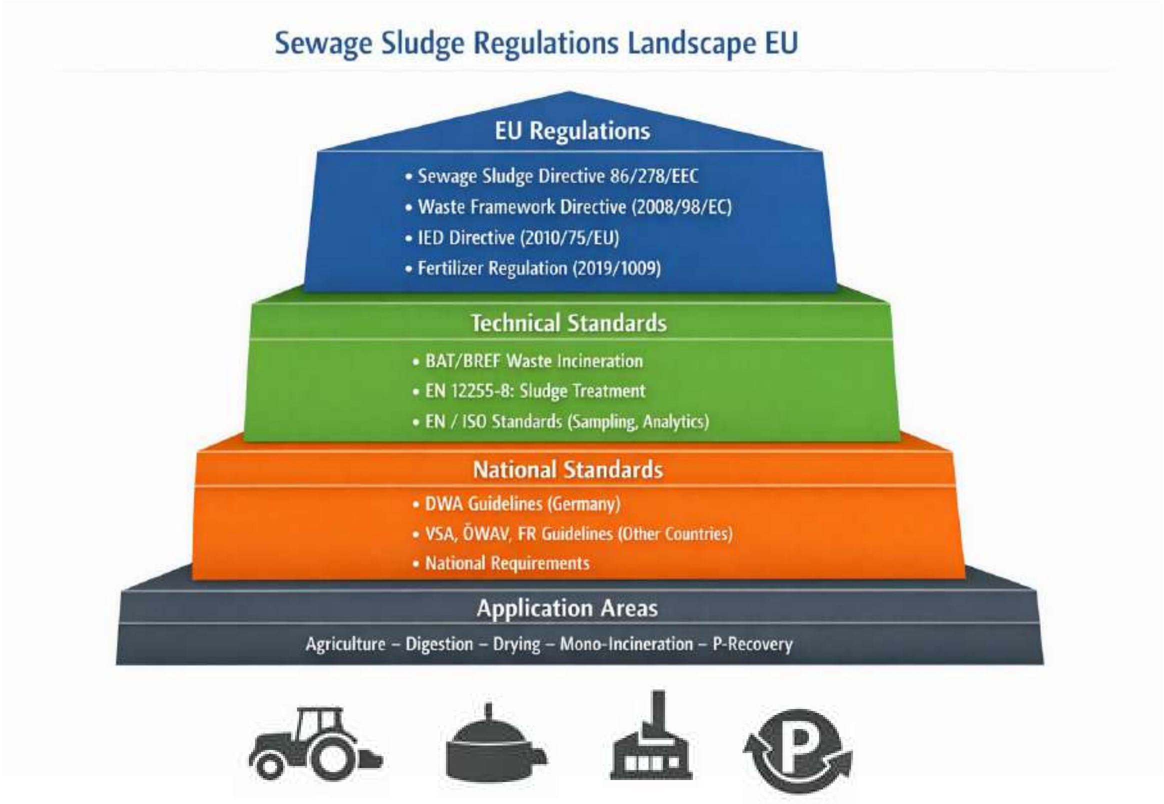
ZDHC Foundation (Zero Discharge of Hazardous Chemicals in Textile Industry)
ZDHC wastewater Guidelines conformity for sludge:

- regular monitoring of sludges
- analysis by approved laboratories
  - heavy metals
  - ZDHC relevant substances
  - organic pollutants
  - leaching behaviour
- only controlled and approved disposal/recycling
- documentation of
  - sludge amounts
  - sludge specification/origin
  - sludge treatment (dewatered, dried, stabilized etc.)
  - way of disposal
  - final destination of sludge
- non-conformity management:
  - root cause analysis (RCA)
  - corrective action plan (CAP)

Source: ZDHC Foundation

Evaluation Criteria

European Standards for Sludge Management



EU

Evaluation Criteria

European Waste Framework Directive (2008/98/EC)
Waste Hierarchy

EU

most favoured option

least favoured option

recycling of materials ⇨ (N/P recycling, fertilizer production, cement, bricks production)

energy recovery

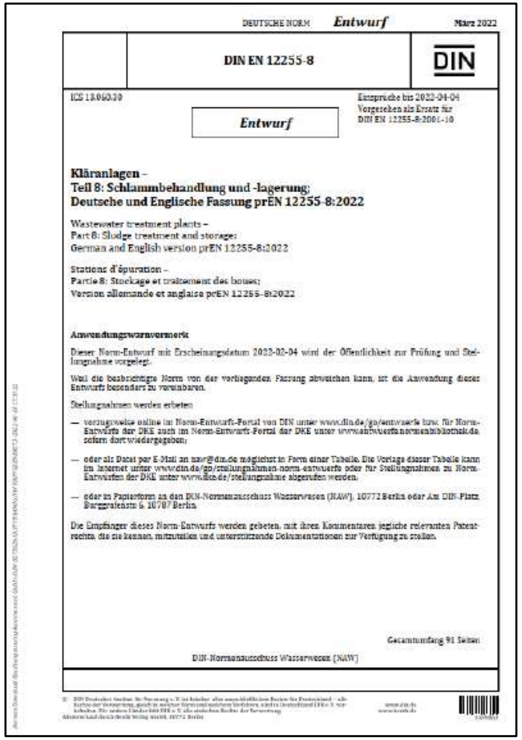
landfill

Evaluation Criteria

EN 12255-8 Standard for sludge treatment and storage

Definition of design principles and performance requirements for sewage sludge treatment and storage

- Sludge stabilization
  - Reduction of organic matter and digestability
  - Limitation of odour and pathogen risks
- Sludge dewatering
  - Volume and mass reduction
- Sludge drying
  - Volume and mass reduction
  - Stabilization by water removal
  - Increase of calorific value for incineration
- Sludge storage
  - Only for intermediate storage
  - Protection against leachate, rainwater ingress and emissions



DEUTSCHE NORM *Entwurf* März 2022

DIN EN 12255-8 DIN

ICS 13.060.30

Entwurf

Einsprüche bis 2022-04-04
Vorgesehen als Ersatz für
DIN EN 12255-8:2001-10

Kläranlagen –
Teil 8: Schlammbehandlung und -lagerung;
Deutsche und Englische Fassung prEN 12255-8:2022

Wastewater treatment plants –
Part 8: Sludge treatment and storage;
German and English version prEN 12255-8:2022

Stations d'épuration –
Partie 8: Stockage et traitement des boues;
Version allemande et anglaise prEN 12255-8:2022

Anwendungswarnvermerk

Dieser Norm-Entwurf mit Erscheinungsdatum 2022-02-04 wird der Öffentlichkeit zur Prüfung und Stellungnahme vorgelegt.

Weil die beabsichtigte Norm von der vorliegenden Fassung abweichen kann, ist die Anwendung dieses Entwurfs besonders zu vereinbaren.

Stellungnahmen werden erbeten

— vorzugsweise online im Norm-Entwurfs-Portal von DIN unter www.din.de/go/entwuerfe bzw. für Norm-Entwürfe der DKE auch im Norm-Entwurfs-Portal der DKE unter www.entwuerfe.normenbibliothek.de, sofern dort wiedergegeben;

— oder als Datei per E-Mail an naw@din.de möglichst in Form einer Tabelle. Die Vorlage dieser Tabelle kann im Internet unter www.din.de/go/stellungnahmen-norm-entwuerfe oder für Stellungnahmen zu Norm-Entwürfen der DKE unter www.dke.de/stellungnahme abgerufen werden.

— oder in Papierform an den DIN-Normenausschuss Wasserwesen (NAW), 10772 Berlin oder Am DIN-Platz, Burggrafenstr. 6, 10787 Berlin.

Die Empfänger dieses Norm-Entwurfs werden gebeten, mit ihren Kommentaren jegliche relevanten Patentrechte, die sie kennen, mitzuteilen und unterstützende Dokumentationen zur Verfügung zu stellen.

Gesamtumfang 91 Seiten

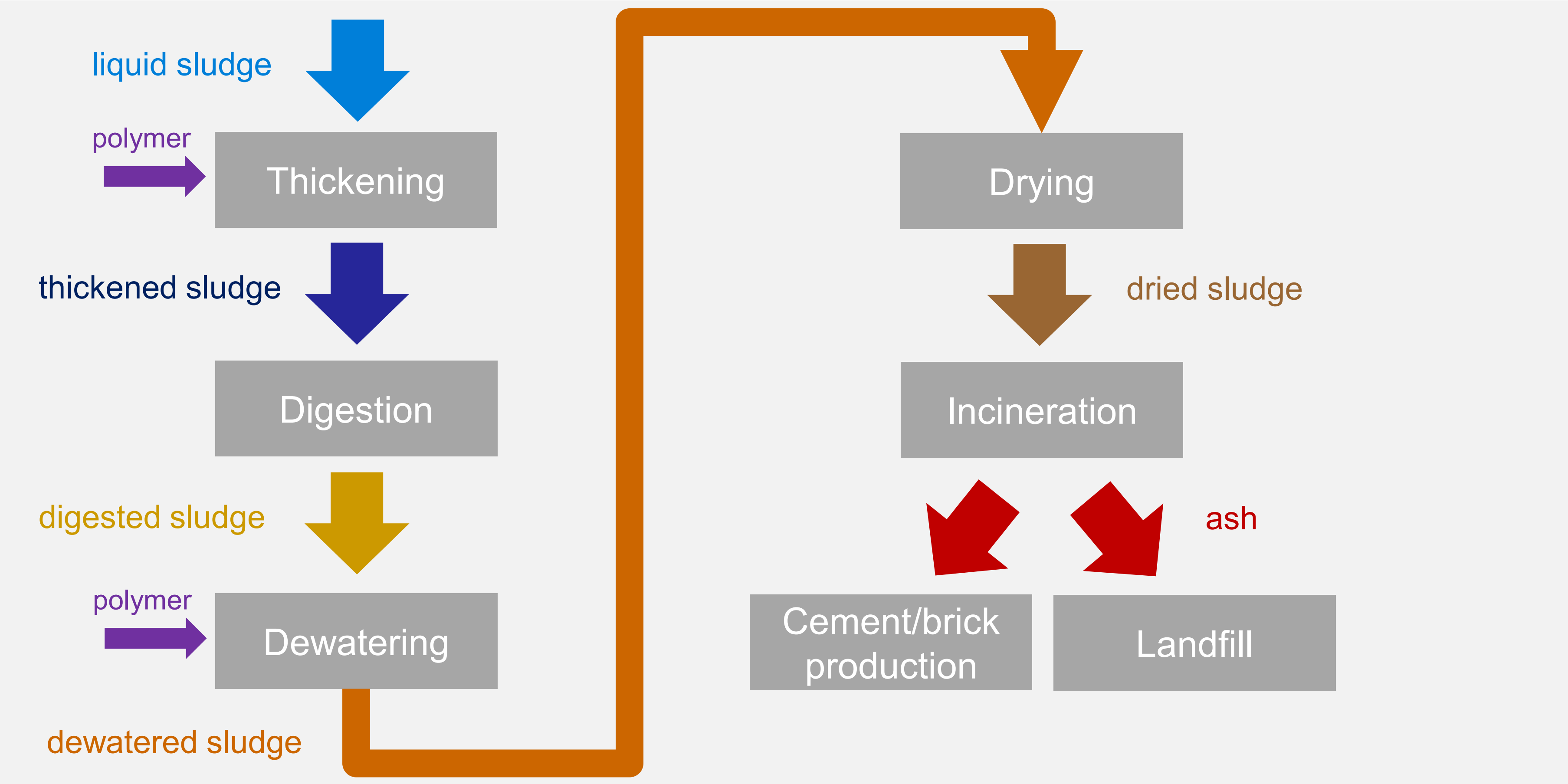
DIN-Normenausschuss Wasserwesen (NAW)

Selected Evaluation Criteria: Current State + GAP Analysis

approximated values		Current State	GAP to Target	Target
Sludge amount CWWTP		3.650 tons/yr	-3.408 tons/yr	242 tons/yr (ash)
Sludge amount Industry		8.641 tons/yr	-7.137 tons/yr	1.504 tons/yr (ash)
Sludge quality:	stabilization heavy metals org. pollutants	partial low (beside Zinc)[1] low (beside AOX)[1]	yes no yes	stable low zero
Environmental compliance with local standards		70 % (sludge not inert, partial water/ground pollution)	30 %	100 %
Traffic: Truck Transport km		150.000 km/yr[2]	-110.000 km/yr	40.000 km/yr
Use of valuable properties:	nutrients (N/P) minerals	no 83 %	yes +17 %	N recovery 100 %
Environmental performance:	water	spillage to soil and river during heavy rain	yes	no spillage/pollution
Environmental performance:	CO2eq transport CO2eq drying CO2eq landfill **CO2eq total** External: CO2eq incineration	120 t CO2eq/yr 677 t CO2eq/yr 2.518 t CO2eq/yr **3.315 t CO2eq/yr** -1.296 t CO2eq/yr	-3.115 t/yr	Total < 200 tCO2eq/yr
Energy efficiency (electric):	Energy demand	565 GJ/yr	no	< 2.500 GJ/yr
Energy efficiency (heat/fuel):	Energy demand External: Energy demand incineration	transport: 1.351 GJ/yr drying: 9.039 GJ/yr - 13.502 GJ/yr	-991 GJ/yr -9.039 GJ/yr	360 GJ/yr 0 GJ/yr[3]
Sludge management cost		330 million LKR/yr[3]	no	330 million LKR/yr

[1] as from available analysis
[2] increases to 260.000 km/yr, when landfill of CWWTP cannot be used anymore
[3] without thermal drying cost (Teejay), increases to 550 million LKR/yr, when landfill of CWWTP cannot be used anymore

General Technological Overview of possible Sludge Treatment Steps



Treatment Options: Thickening

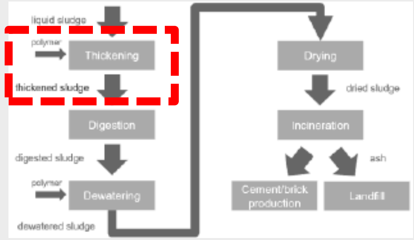
Sludge Thickening

- prerequisite for digestion
- increase of dry solids content from 2-3 % to 4-8 %
- use of polymers
- machinery options
    - belt thickener
    - screw thickener
    - oval-plate thickener

Evaluation

⊕ standard process

⊖ additional need of polymers



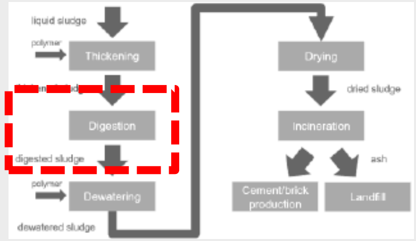
Treatment Options: Digestion

Sludge Digestion

- production of methane by microorganisms
- preliminary performance test results with CWWTP sludge: ~ 43-107 m³ gas production per ton of dry solids
- production of electricity and heat by gas motor
- optional high-load digestion: optimised process with shorter residential time and higer yield ⇨ lower investment cost
- optional nutrient recovery (N)

Evaluation

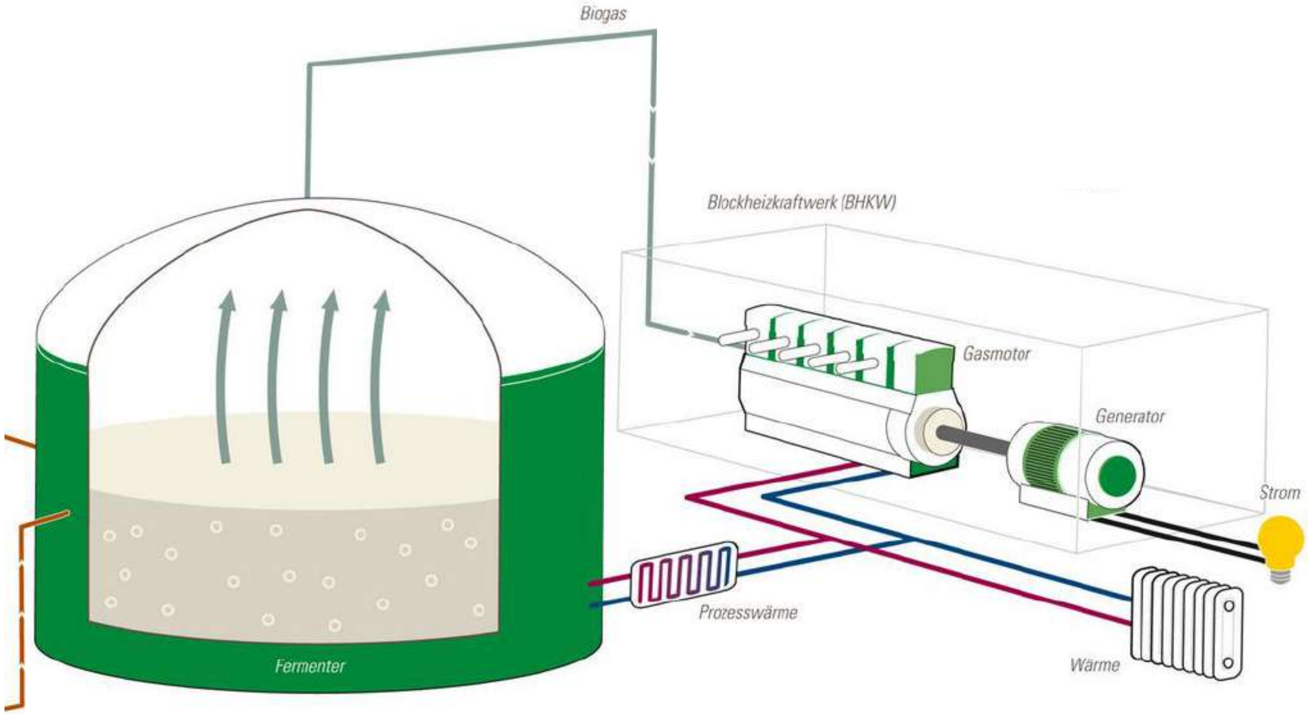
⊕ electric energy and heat production
⊖ digestion pilot tests on site required for proof of functionality




HansPeter Schröer/pixabay

Treatment Options: Digestion

Sludge Digestion with Gas Motor



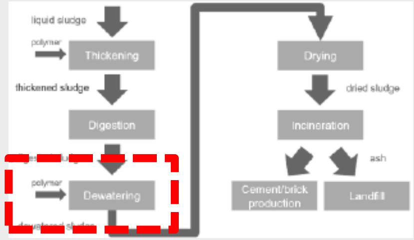
Treatment Options: Dewatering

Sludge Dewatering

- reduction of dry solids content from 2-8 % to 15-30 % by mechanical force
- use of polymers
- machinery options
  - belt press (as installed)
  - screw press
  - chamber filter press
  - centrifuge/decanter

Remarks

❓ dewatering result depends on sludge characteristics, polymer and machinery
⇨ optimization tests recommended



Treatment Options: Drying

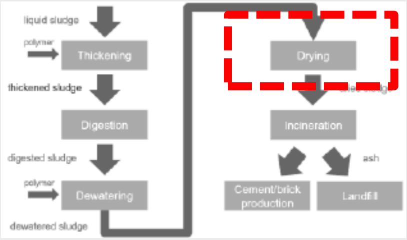
Sludge Drying

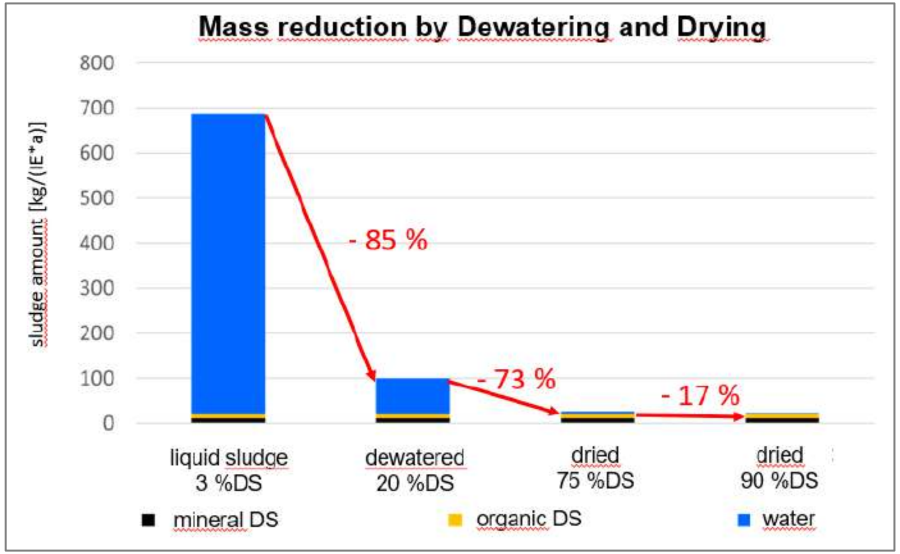
- dewatered sludge contains 70-85 % water
- reduction of dry solids content from 15-30 % to 70-90 % by evaporation
- evaporation needs energy (2.500 kJ/kg)
- established sludge drying technologies:
  - solar drying
  - belt drying
  - drum drying
  - disc drying
  - thin film drying

Remarks

! energy source is decisive for feasibility

! drying cost are dominated by energy cost





Sludge Drying Technologies

Disc Dryers	
Heat transfer mechanism	contact
Heat source	steam thermal oil
Drying range	partial drying (full drying)

Thin Film Dryers	
Heat transfer mechanism	contact
Heat source	steam thermal oil vapors/hot water (vacuum dryer)
Drying range	partial drying full drying (90 %DS)

Sludge Drying Technologies

Belt Dryers	
Heat transfer mechanism	convection
Heat source	hot water steam thermal oil
Drying range	full drying (90 %DS)
Capacity range	medium - large

Drum Dryers	
Heat transfer mechanism	convection
Heat source	hot air direct burner (gas/oil)
Drying range	full drying (90 %DS)
Capacity range	medium - large

Source: Huber

Source: Andritz

Sludge Drying Technologies

Solar Dryers	
Heat transfer mechanism	radiation convection
Heat source	solar radiation ambient air
Drying range	partial drying full drying


Source: Thermo-System


Source: Thermo-System

Solar Thermal Dryers	
Heat transfer mechanism	radiation convection
Heat source	solar rediation ambient air hot water
Drying range	partial drying full drying


Source: Thermo-System

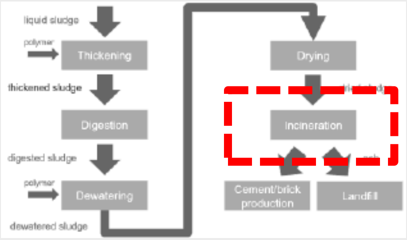
Treatment Options: Incineration

Sludge Incineration

- incineration of organic fraction
- destruction of organic pollutants
- mass reduction depending on sludge 40-70 %
- product: ash
- sludge incineration technologies:
    - fluidized bed incinerator
    - multiple-hearth incinerator
    - rotary kiln incinerator
    - melting furnace
    - co-incineration in cement factory

Remarks

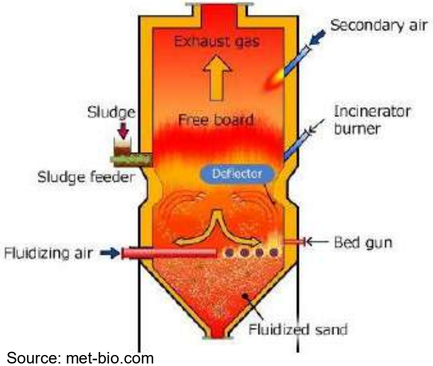
! suitable technology depends on sludge properties and legal aspects



Sludge Incineration Technologies

Fluidized bed incinerators	
Process principle	incineration chamber with fluidized air and sandbed
Process options	fixed bed circulating bed
Input material	partially dried sludge (4-5 MJ/kg)
Remarks	most widespread technology

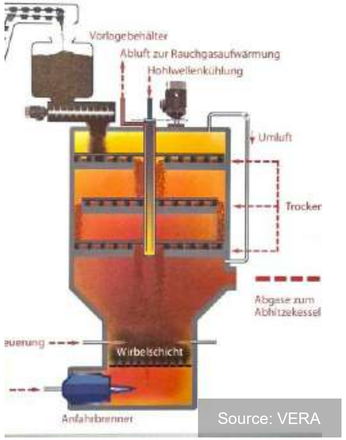

Source: ndr.de



Source: met-bio.com

Multiple-hearth incinerators	
Process principle	incineration on multiple levels with horizontal + downwards moving sludge bed
Input material	partially dried sludge (6-8 MJ/kg)
Remarks	only few installations


Source: Thermo-System

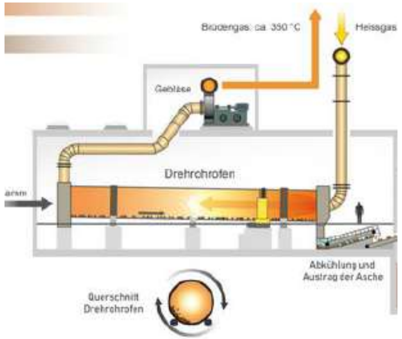


Source: VERA

Sludge Incineration Technologies

Rotary kiln incinerators	
Process principle	rotating drum as incineration chamber
Process options	with external energy source (e.g. from WTE plant)
Input material	partially dried sludge (6-9 MJ/kg) w/o ext. energy
Remarks	only few installations

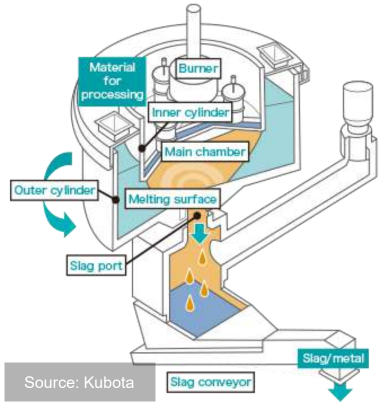

Source: IBU-Tec



Source: aarelauf.ch

Melting furnace	
Process principle	incineration within a rotating chamber with melting of surface sludge layer
Input material	dried sludge (8-12 MJ/kg)
Remarks	vitrified product, high emissions (NOx), high operator qualification requirement very high cost


Source: Kubota

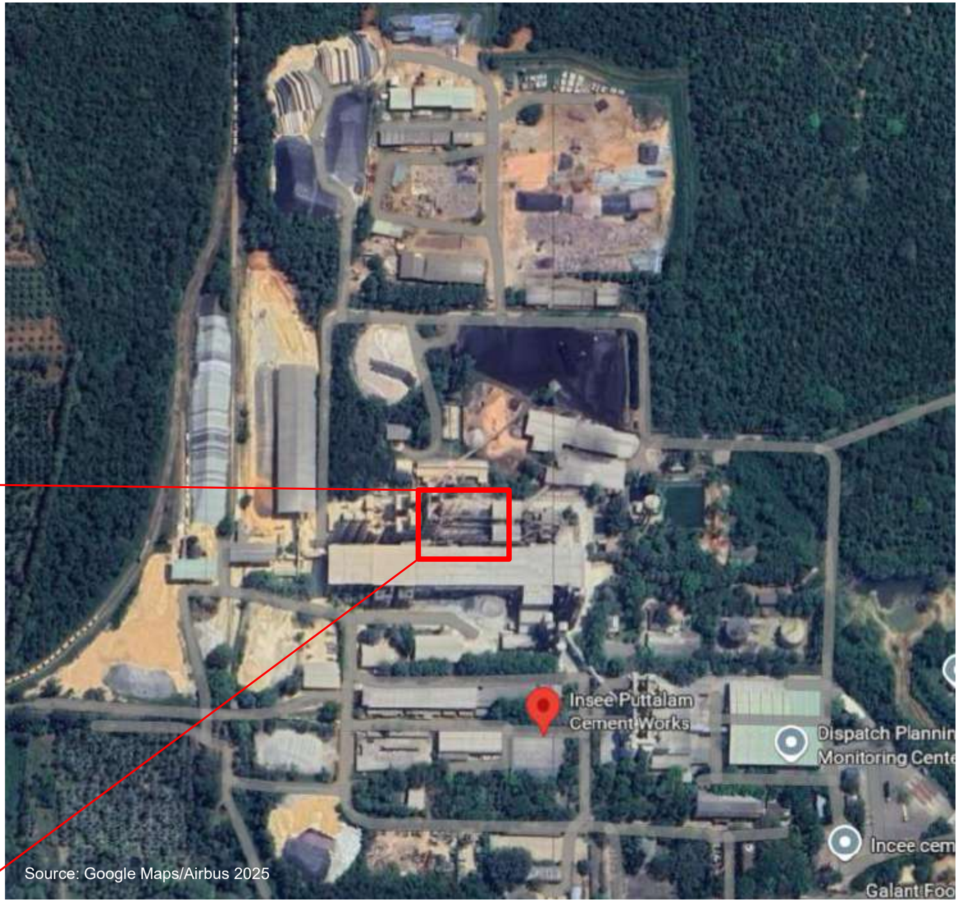


Source: Kubota

Sludge Incineration Technologies

Co-incineration in Cement factory	
Process principle	co-incineration in rotating cement kiln drum
Input material	dewatered/dried sludge
Remarks	− long transport distance − coal as additional fuel − high gate fee + ash is used as product


Source: Google Earth/Airbus 2025



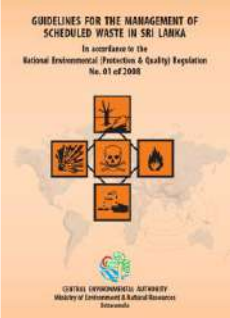
Source: Google Maps/Airbus 2025

Regulatory Restrictions for Scheduled Waste Incineration in Sri Lanka

! CEA Guidelines for scheduled waste management 2008
6.3.3 Standards for incineration plants

Minimum incinerator operating temperature for non-halogenated or non-polynuclear aromatic hydrocarbons:
1000 °C at fully mixed heigth, 1200 °C at the outlet of the secondary chamber

Minimum incinerator operating temperature for halogenated or polynuclear aromatic hydrocarbons:
1200 °C at fully mixed heigth, minimum designed temperature 1300 °C



! Emission regulation (gazette 2126/36)
incinerators: 1000-1250 °C (2-3 s)
limit values (s. table)
applicable to hazardous and non-hazardous sludge!

INCINERATORS

Rated Output Capacity (C)	*Type of Pollutant*	*Emission Limit*
C< 1 Metric Ton/Hour	Sulfur Dioxide (SO_2)	70mg/Nm³
	Nitrogen Oxides (NO_x)	400mg/Nm³
	Particulate Matter (PM)	150mg/Nm³
	Smoke	20% Opacity
	Carbon Monoxide (CO)	50mg/Nm³
	Hydrogen Chloride (HCl)	20mg/Nm³
	Mercury (Hg)	0.01mg/Nm³
	Lead (Pb)	0.05mg/Nm³
	Dioxin and Furans	Shall be controlled by temperature and retention time as set out in Regulation 14
C≥ 1 Metric Ton/Hour	Sulfur Dioxide (SO_2)	70mg/Nm³
	Nitrogen Oxides (NO_x)	300mg/Nm³
	Particulate Matter (PM)	100mg/Nm³
	Smoke	10% Opacity
	Carbon Monoxide (CO)	50mg/Nm³
	Hydrogen Chloride (HCl)	15mg/Nm³
	Mercury (Hg)	0.001mg/Nm³
	Lead (Pb)	0.01mg/Nm³
	Dioxin and Furans	Shall be controlled by temperature and retention time as set out in Regulation 14

? AOX content of 520 mg/kgDS in CWWTP sludge,
unknown Halogen contents of industrial sludges
⇨ requirement of 1300 °C is probable

! the only available technology for sludge incineration above 1000 °C is melting furnace technology

Evaluation of Technological Options - Thickening

Criteria	Evaluation
Preferred technical option	Thickening is required with digestion, all machinery options are suitable
Technical feasibility	proven technology - specifications from digestion required - polymer selection+optimization required - preliminary tests recommended
GAP improvement	sludge reduction in combination with digestion
Risk assessment	- safety risk: low - technical/cost risk: foreign matter/contaminats ⇨ separation before thickening increased polymer consumption ⇨ preliminary dewatering tests - environmental risk: low - regulatory risk: low
Timeline (best case)	no time-critical component

Evaluation of Technological Options - Digestion

Criteria	Evaluation
Preferred technical option	Digestion is an optional process (only for CWWTP sludge) Preferred: high-load digestion, if technically feasible
Technical feasibility	standard digestion: proven technology for biogas production, but digestion tests on site required (verification and quantification of digestability of sludge) high-load digestion: new technological option with improved characteristics, intensive digestion tests on site required (verification and quantification of digestability of sludge, parameter optimization)
GAP improvement	- sludge reduction by organic degradation and improvement of dewatering (up to 600 tons/yr) - production of electric energy (480 GJ/yr) and waste heat for drying (600 GJ/yr) - reduction of transport/CO2-emissions - optional nutrient recovery but: reduction of calorific value of sludge (⇨ worsening of incineration energy balance)
Risk assessment	- safety risk: methane explosion risk ⇨ proper design and construction is crucial - technical/cost risk: foreign matter/contaminats ⇨ separation before digestion insufficient biogas production ⇨ preliminary design tests - environmental risk: methane emissions due to leakage possible ⇨ proper design and construction - regulatory risk: low
Timeline (best case)	intensive on-site tests would have to be conducted; preparation 2026; tests in 2027; evaluation + design 2028; construction of real size plant 2029

Evaluation of Technological Options - Dewatering

Criteria	Evaluation
Preferred technical option	Further use of existing filter presses as long as - spareparts are available - dewatering results are good - maintenance efforts are acceptable potential optimization of dewatering result by polymer selection+optimization. otherwise replacement of belt filter presses by new belt filter or screw presses: - low-wear technology - low energy demand - low maintenence
Technical feasibility	- proven technology - preliminary dewatering tests recommended, polymer selection+optimization required
GAP improvement	- potential slight sludge reduction by optimization
Risk assessment	- safety risk: low - technical/cost risk: insufficient dewatering performance, increased polymer consumption ⇨ preliminary dewatering tests (for new system) foreign matter/contaminats ⇨ separation before dewatering - environmental risk: low - regulatory risk: low
Timeline (best case)	not time-critical, existing units can be further used and replaced in due time

Evaluation of Technological Options - Drying

Criteria	Evaluation
Preferred technical option	Solar Drying process is most favourable due to - low energy requirement - low operation cost - high share of locally available components - low TVOC emissions - optional use of low-temperature waste heat - no explosion risks
Technical feasibility	- proven technology - proper aeration and control system is crucial for efficiency of the drying process - use of waste heat from biogas motor should be tested and quantified during digestion/biogas project
GAP improvement	- significant sludge reduction by evaporation of water (7000-8000 tons/yr) - significant reduction of transport/CO_2 - increase of calorific value (for incineration) - no water/ground pollution - significant saving of disposal cost, economically highly feasible (!)
Risk assessment	- safety risk: low - technical/cost risk: foreign matter/contaminats ⇨ separation before drying insufficient drying performance ⇨ selection of experienced supplier with proven ventilation and control system - environmental risk: low risk of odour emissions with specific sludges ⇨ optional odour treatment - regulatory risk: low
Timeline (best case)	construction of real size plant possible in 2026

Evaluation of Technological Options - Incineration

Criteria	Evaluation
Preferred technical option	All shown incineration technologies would be technically suitable, but melting furnace process is the only technology with process temperatures above 1200 °C. Therefore Melting furnace is the only option - having the chance to meet legal requirements (> 1200 °C) - producing vitrified ash for futher use as construction material/brick raw material Alternative: delivery of dried sludge to cement factory (⇨ INSEE)
Technical feasibility	- furnace core temperature 1300 °C. Compliance with legal requirement „1200 °C at fully mixed height" must be verified - suitability for SEPZ sludges must be verified ⇨ preliminary tests recommended
GAP improvement	- transport amount reduction by incineration (3000 tons/yr) - reduction of transport/CO_2 - inertization of ash, further use as cement or brick products
Risk assessment	- safety risk: low - technical/cost risk: technical problems due to specific ash melting behaviour ⇨ preliminary analysis and melting tests of all sludges ⇨ proper design of interfaces ⇨ process guarantee from manufacturer foreign matter/contaminats ⇨ separation before incineration - environmental risk: emissions ⇨ exhaust gas treatment according to emissions standards - regulatory risk: NOx emissions ⇨ NOx level has to be assessed, treatment has to be defined, compliance of furnarce technology with legal requirements ⇨ see details
Timeline (best case)	supplier selection, analysis and melting tests 2026, design of real size plant 2027, construction 2028, startup 2029

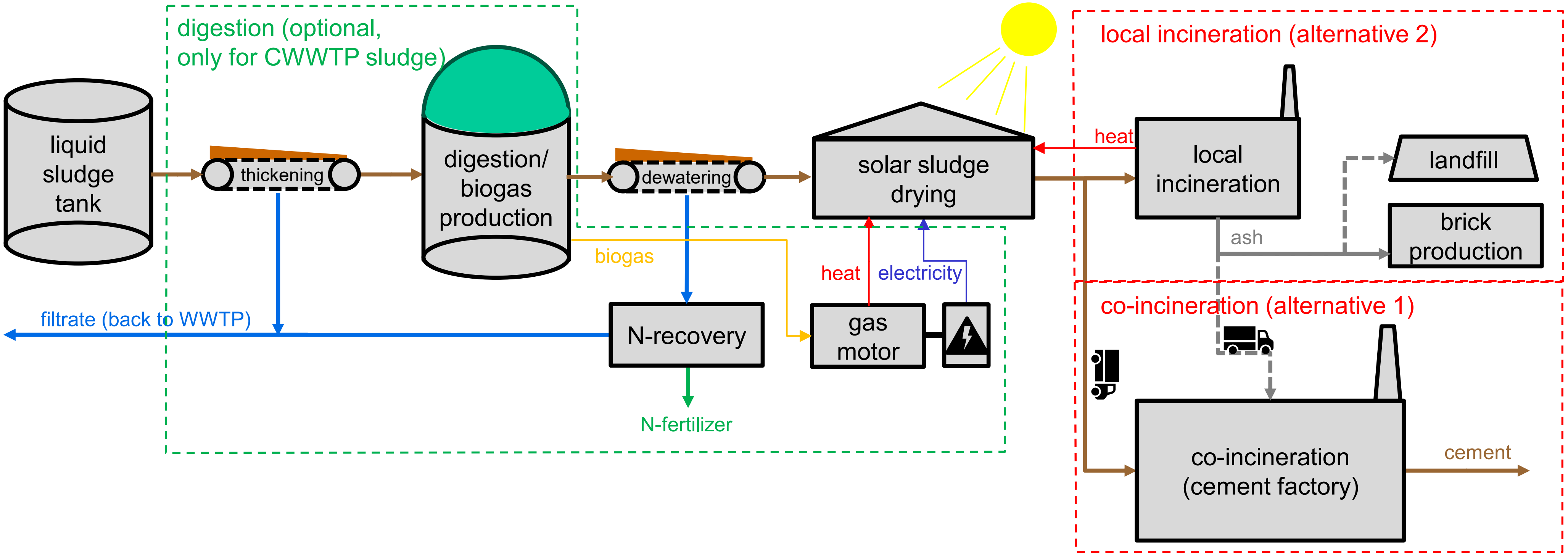
Evaluation of Technological Options - Incineration

Examination of compliance of incineration technology with legal standards required for

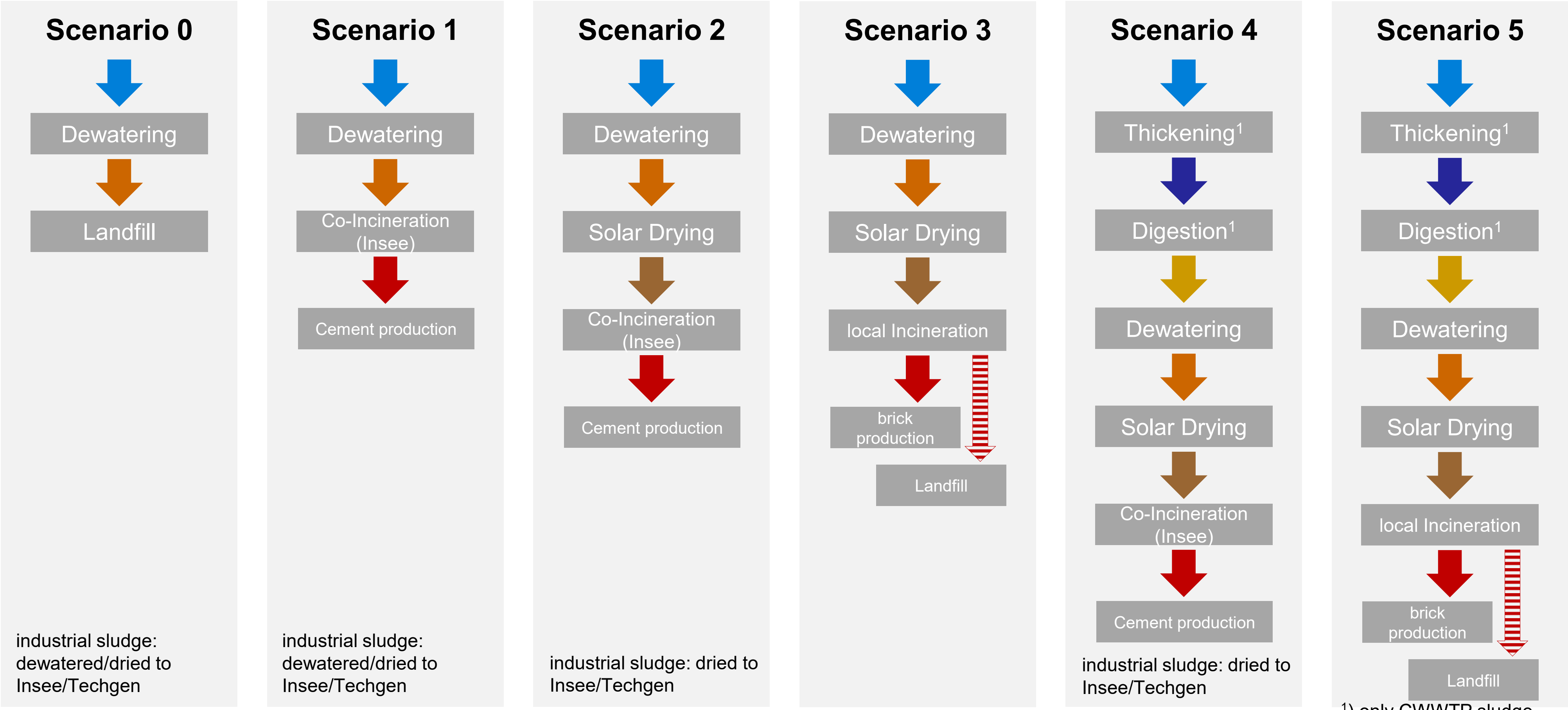
- Incinerator design
- Requirements for Gas cleaning
- Incineration temperature
- residential time
- emission levels corrected to applicable oxygen level
- burner specification
- oxygen level
- carbon monoxide level
- turndown restrictions
- combustion efficiency
- emission control system

Proof of compliance has to be conducted with technology provider in advance to avoid complications with EPL

Concept Scenarios Overview



Concept Scenarios Overview



[1]) only CWWTP sludge

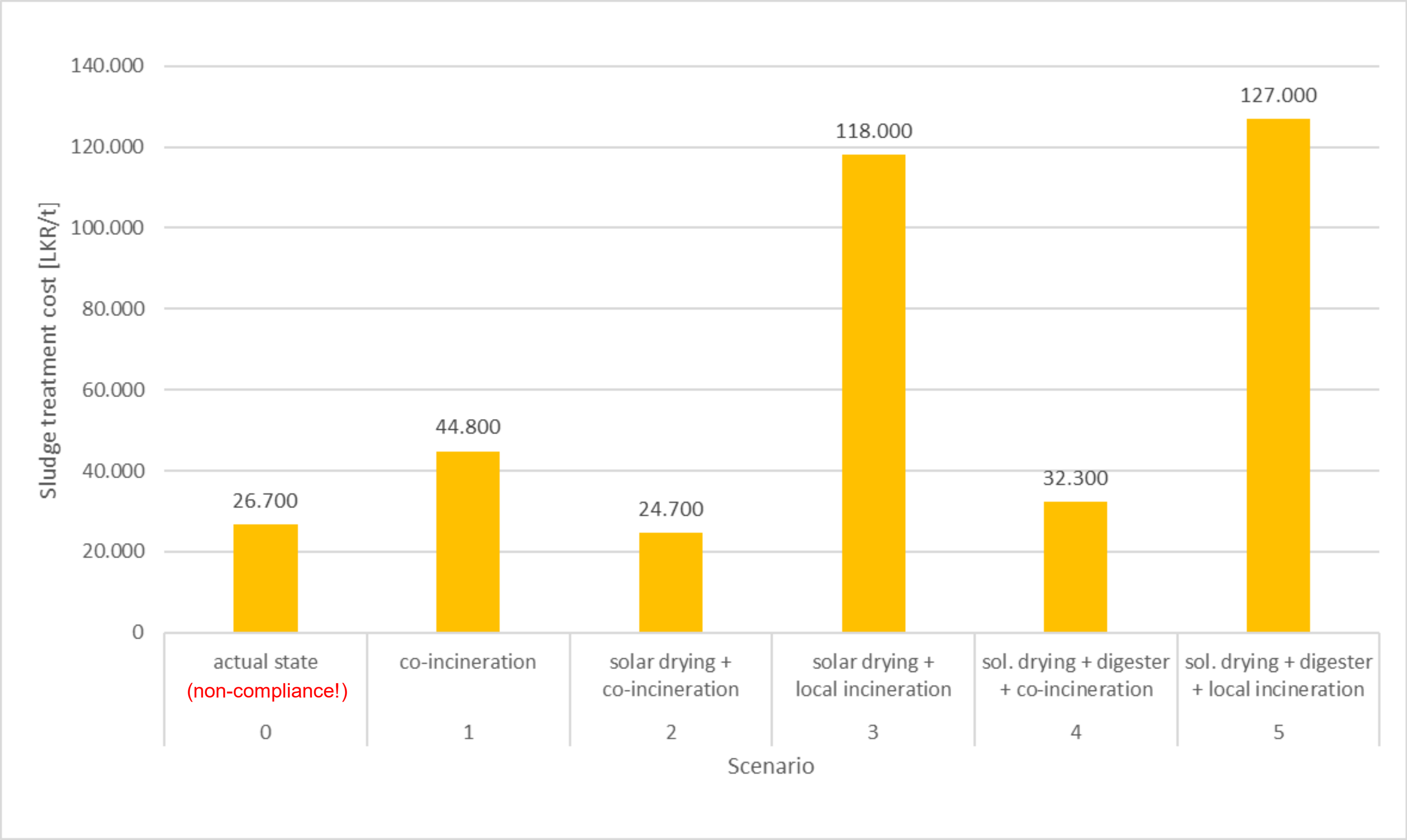
Economic Evaluation of Concept Scenarios

Sludge treatment cost and operational requirements

	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Description	actual state	after landfill is full to co-incineration	solar drying+ co-incineration	solar drying+ local incineration	sol.drying+digester+ co-incineration	sol.drying+digester+ local incineration
CWWTP sludge destination	dewatered to landfill	dewatered to Insee	dried to Insee	ash to brick production	digested+dried to Insee	ash to brick production
Industrial sludge destination	dewatered/dried to Insee/Techgen	dewatered/dried to Insee/Techgen	dried to Insee/Techgen	ash to brick production	digested+dried to Insee/Techgen	ash to brick production
CAPEX	-	-	680 million LKR	12.700 million LKR	1.630 million LKR	13.700 million LKR
OPEX	330 million LKR/yr	550 million LKR/yr	250 million LKR/yr	460 million LKR/yr	270 million LKR/yr	500 million LKR/yr
Sludge treatm. cost total	330 million LKR/yr	550 million LKR/yr	300 million LKR/yr	1.450 million LKR/yr	400 million LKR/yr	1.570 million LKR/yr
Sludge treatm. cost specific	26.700 LKR/t	44.800 LKR/t	24.700 LKR/t	118.000 LKR/t	32.300 LKR/t	127.000 LKR/t
Required area	-	-	9.000 m²	11.000 m²	10.000 m²	12.000 m²
Required operator skills	-	-	low-medium	very high (24/7)	medium	very high (24/7)
Maintenance requirement	-	-	low	very high	medium	very high
Min. required lead time	-	immediately	6 months	3 years	3 years	3-4 years

with t metric ton of sludge
yr year
CAPEX and OPEX are estimated from empirical data, depreciation period 15 yrs, financing rate 2 %/yr

Economic Evaluation of Concept Scenarios



engineering 4environment
the sludge drying engineers

Preferred Concept

Scenario 2

Dewatering

Solar Drying

Co-Incineration (Insee)

Cement production

industrial sludge: dried to Insee/Techgen

+

- compliant with legal requirements
- best economical feasibility
- short implementation period
- lowest operation cost
- moderate operator skills required
- significant sludge reduction
- batchwise drying process ⇨ traceability

–

- initial investment required
- area required
- depending on gate fee at Insee (but reduced sludge amount)
- long transport distance

Preferred Concept - Sludge Dewatering Equipment

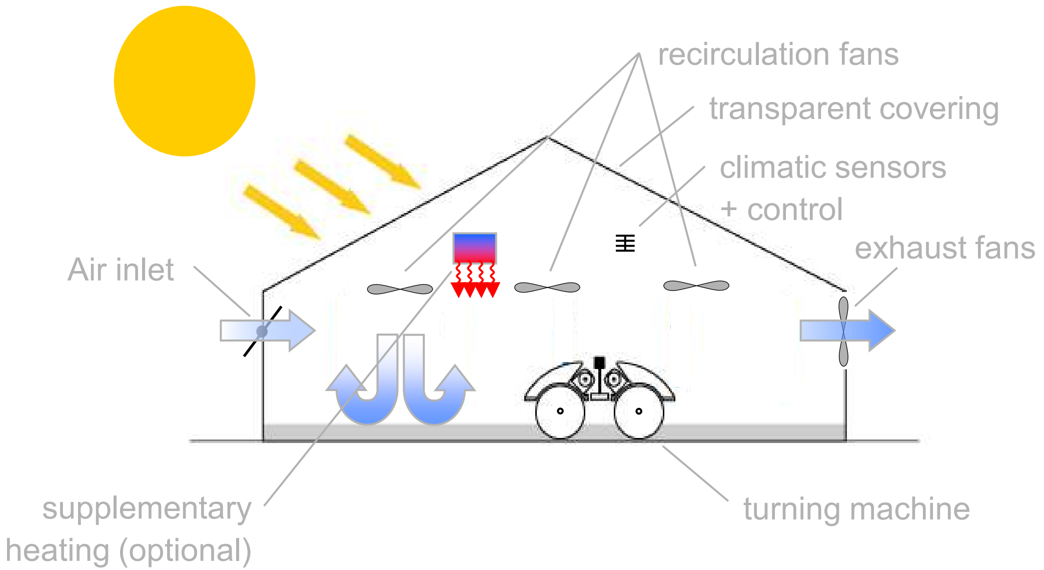
Further use of existing belt filter presses as long as
- spareparts are available
- dewatering results are good
- maintenance efforts are acceptable

potential optimization of dewatering result by polymer selection+optimization.

At due time replacement of filter presses by new filter presses or screw presses:
- low-wear technology
- low energy demand
- low maintenence

Source: IEA

Preferred Concept - Solar Sludge Drying Plant

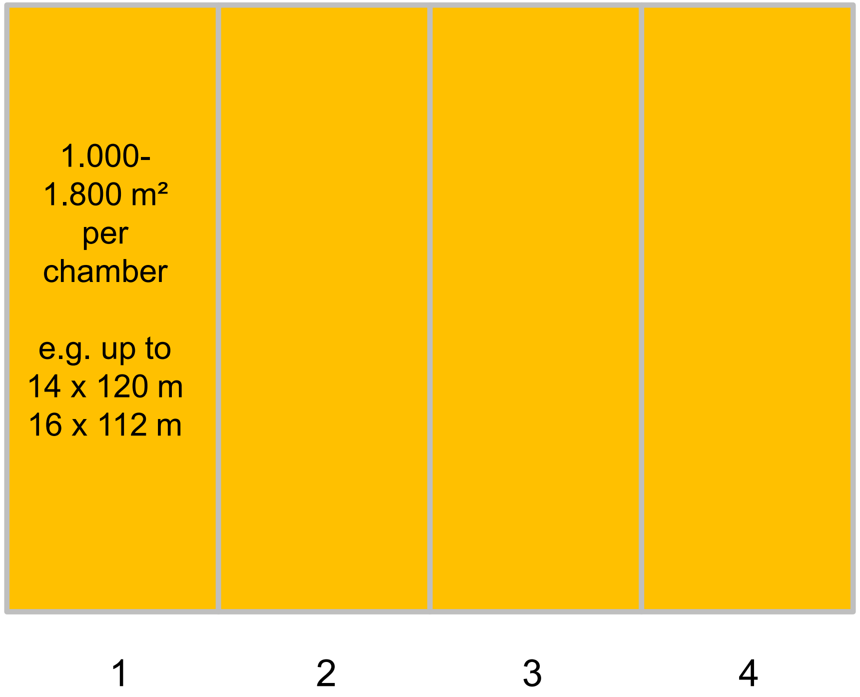


Important Specifications (see specification document)

- Covering material (transparency, lifetime)
- Ventilation system (moving/ventilation rate)
- Turning machine
- Control system
- Corrosion and UV protection
- frecuency converters for ventilators
- energy efficient components
- ease of maintenance

Preferred Concept - Solar Sludge Drying Plant

Required Drying Area: approx. 5.800 m²

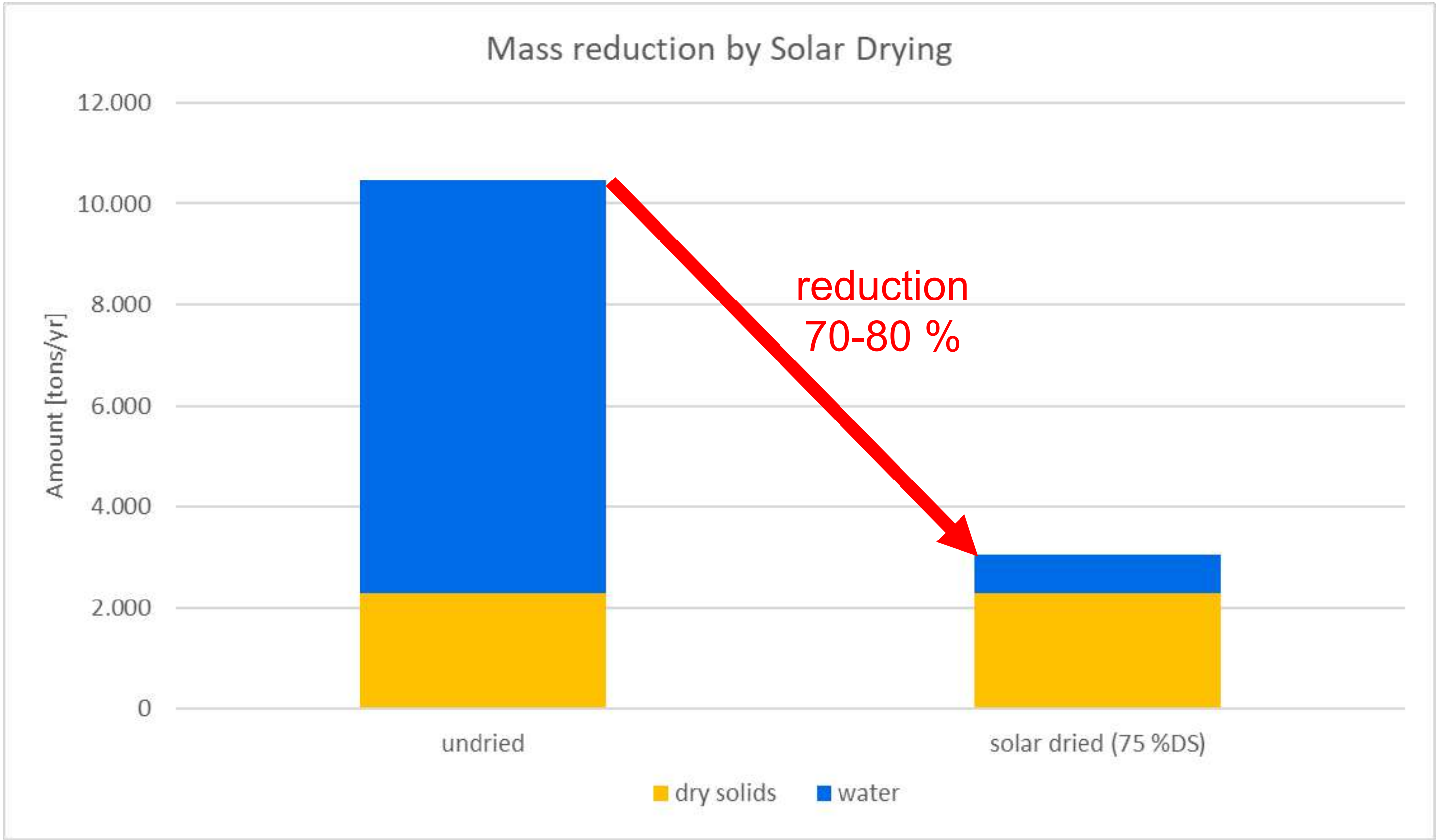


4 chambers required for total slugde drying, 2 chambers for BOI Central WWTP sludge, depending on available area and chamber dimensions

Covering material specification:

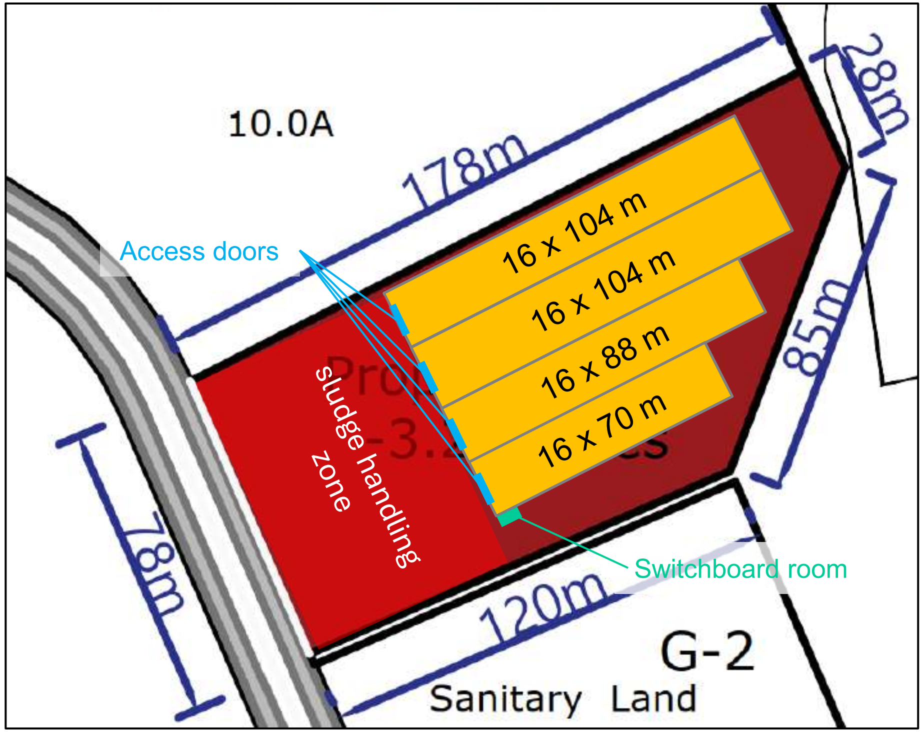
- highly transparent corrugated Polycarbonate single sheet (UV-stabilized)
- Alternative: single sheet glass
  - higher transparency and lifetime
  - higher investment cost
  - less area requirement (- 6 %) 5.500 m² instead of 5.800 m²

Preferred Concept - Solar Sludge Drying Plant



Preferred Concept - Solar Sludge Drying Plant

Solar Dryer Location (Example)



location has to be verified on site

Preferred Concept - Solar Sludge Drying Plant

Infrastucture required

- paved road, sludge handling zone
- electricity
- air conditioned switchboard room
- internet connection
- rainwater drainage
- front loader for loading/unloading
- unloading area for trucks with back wall
- restrooms for workers and truck drivers, if not available elsewhere

Exhaust air treatment

- with the sludge quality shown during the Seethawaka on-site visit in November 2025 and the given analyses, it is not expected to require an exhaust air treatment
- anyway it makes sense to keep an area in the size of 10-20 % of the drying area at the backside of the dryer for future requirements (e. g. in case of changing sludge quality)

Preferred Concept - Solar Sludge Drying Plant

Estimated Investment Budget (only dryer)

	2 chambers (3.400 m² solar)	4 chambers (5.800 m² solar)
Concrete works (local)	200-350.000 €	350-600.000 €
Greenhouse building (local)	150-200.000 €	250-350.000 €
Drying technology equipment (imported)	440.000 €	800.000 €
not included	- shipping cost - installation of mechanical and electrical equipment - air conditioned switchboard room - electricity supply - internet connection - sludge transport by front loader - roads and pavements	- shipping cost - installation of mechanical and electrical equipment - air conditioned switchboard room - electricity supply - internet connection - sludge transport by front loader - roads and pavements

very rough estimation,
local cost have to be verified!

GAP Analysis with Preferred Concept (Scenario 2)

approximated values		Current State	GAP to Target	Target	Preferred Concept (Scenario 2)	Improvement (% of initial GAP)
Sludge amount CWWTP		3.650 tons/yr	-3.408 tons/yr	242 tons/yr (ash)	827 tons/yr	83 %
Sludge amount Industry		8.641 tons/yr	-7.137 tons/yr	1.504 tons/yr (ash)	4.010 tons/yr	65 %
Sludge quality:	stabilization heavy metals org. pollutants	partial low[1] low[1]	yes no yes	stable low zero	largely stable low low	improved unchanged unchanged
Environmental compliance with local standards		70 % (sludge not inert, partial water/ground pollution)	30 %	100 %	100 %	100 %
Traffic: Truck Transport km		150.000 km/yr	-110.000 km/yr	40.000 km/yr	114.000 km/yr	33 %
Use of valuable properties:	nutrients (N/P) minerals	no 83 %	yes +17 %	N recovery 100 %	no 100 %	unchanged 100 %
Environmental performance:	water	spillage to soil and river during heavy rain	yes	no spillage/pollution	no spillage/pollution	100 %
Environmental performance:	CO2eq transport CO2eq drying CO2eq landfill **CO2eq total** External: CO2eq incineration	120 t CO2eq/yr 677 t CO2eq/yr 2.518 t CO2eq/yr **3.315 t CO2eq/yr** -1.296 t CO2eq/yr	-3.115 t/yr	Total < 200 tCO2eq/yr	91 t CO2eq/yr 118 t CO2eq/yr 0 t CO2eq/yr **209 t CO2eq/yr** -3.201 t CO2eq/yr	**99 %** -1.905 t CO2eq/yr
Energy efficiency (electric):	Energy demand	565 GJ/yr	no	< 3.000 GJ/yr	1.365 GJ/yr	incr. 800 GJ (comply)
Energy efficiency (heat/fuel):	Energy demand External: Energy demand incineration	transport: 1.351 GJ/yr drying: 9.039 GJ/yr - 13.502 GJ/yr	-991 GJ/yr -9.039 GJ/yr	360 GJ/yr 0 GJ/yr[3]	1.027 GJ/yr 0 GJ/yr - 36.197 GJ/yr	33% 100 % -23.000 GJ/yr
Sludge management cost		330 million LKR/yr[2]	no	330 million LKR/yr	300 million LKR/yr	reduction 9 %

[1] as from available analysis
[2] without thermal drying cost (Teejay)
[3] after change of heat source to renewable energy (Teejay)

Feasibility Aspects of Solar Drying (BOI sludge)

- BOI sludge (3.650 tons/yr) has to be disposed to INSEE from mid 2026, when local landfill is full
  ⇨ yearly sludge management cost will increase by 220 millions LKR/year

- Sludge amount can be reduced by solar drying from 3.650 tons/yr to approx. 830 tons/yr
  ⇨ mass reduction approx. 2.800 tons/yr
  ⇨ savings due to solar drying: approx. 170 million LKR/yr

- Investment for Solar drying plant for BOI CWWTP sludges
  approx. 300-350 millions LKR depending on configuration and local construction cost
  ⇨ Return of investment: approx. 2 years
  ⇨ Solar drying is highly feasible!

Action Plan for Implementation of Solar Drying Plant

- Determination of size of solar drying plant (only for CWWTP sludge or all EPZ sludge)
- Allocation of budget
- Creation of time schedule
- Determination of definite location of the plant
- Local engineering
- Application for EPL
- Execution of functional tender
- Construction of solar sludge drying plant
  - step 1: for CWWTP sludge
  - step 2: for industrial sludge
- Startup of the plant
- Intensive monitoring and evaluation of drying process during the first months (mass balance, DS content, ignition loss, energy demand)

Conclusions

- Sludge quality
  - sludge ist mostly mechanically dewatered, partly already dried (Teejay)
  - average water content 70 % (8.700 tons/yr)
  - low heavy metal content, beside Zinc
  - low organic pollutants, beside elevated AOX (adsorbable organic halogens)
  - high N content ⇨ potential of N-recovery after digestion
  - low gas production rate ⇨ medium-low performance of digestion expected

- Solar drying is the preferred technology to solve most of the given problems
  - Solar drying is highly technically and economically feasible
  - Solar drying can reduce sludge amount of undried sludge by 70-80 %
  - Drying area requirement approx. 5.800 m² for total sludge, 2.200-2.400 m² for BOI sludge
  - Suitable location is available on site
  - The solution can be implemented within several months
  - Overall sludge Management cost can be reduced by 9 % (330⇨300 millions LKR/yr; 26.700⇨24.700 LKR/t)
  - The increased calorific value of the dried sludge saves coal and CO_2-emissions in the co-incineration

- Sludge digestion is currently not economically feasible basing on the available data
  - digestion may reduce sludge amount slightly and produce electrical energy
  - measured gas production rates were relatively low
  - specific cost increase by approx. 30 %
  - detailed investigation into sludge digestion should be made before investment, but economical benefit is not expected

Conclusions

- Local incineration at > 1000 °C would reach most of the objectives, but is not economically feasible
  - due to legal requirements, incineration temperature above 1.000/1.200 °C is obligatory
  - this criterion cannot be fulfilled by common sludge incineration technology, but requires melting furnaces, which are highly sophisticated metallurgical equipments at very high cost
  - delivery of dried sludge to co-incineration (cement plant) is much cheaper
  - if temperature requirement could be avoided and standard incineration technology at 850 °C could be used, sludge management cost for local incineration would be still double the cost of solar drying + co-incineration

- Future outlook: Centralized sludge Mono-incineration at 850 °C could further reduce cost
  - if temperature requirement could be avoided and standard incineration technology at 850 °C would be allowed, a centralized sludge incineration plant may potentially reduce the sludge management cost and reduce dependency on the only cement plant.
    - ⇨ legal requirements have to be modified
  - size of incineration plant should be minimum 20.000 t DS/yr (approx. 5 x SEPZ)
  - centralized sludge incineration plant should be located at the site of a large WWTP
  - integration of brick manufacturing from ash

- Monitoring of all sludges should be improved
  - regular measurement of DS content and ignition loss
  - monitoring of AOX levels
  - search for reasons of elevated AOX levels, reduction of AOX levels in order to increase future chance of incineration at 850 °C
  - ash melting behaviour study of all sludges (CWWTP+industry) could serve as a basis for the implementation of an incineration process in the future

Thank you for your attention!

Contact

engineering4environment GmbH
Dr.-Ing. Steffen Ritterbusch
Vischerstr. 16
70563 Stuttgart - Germany
+49 151 750 99 717
steffen.ritterbusch@eng4e.com