# Sludge at WWTPs: Global Trends of Treatment and Disposal / Reuse

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# Outline of presentation

1. **Sludge Treatment:  Technologies & Trends**
   A. Overview
   B. Thickening
   C. Stabilization & Disintegration
   D. Dewatering
   E. Drying
   F. Incineration

2. **Sludge Disposal / Reuse:  Options & Trends**
   A. Overview
   B. Global Trends

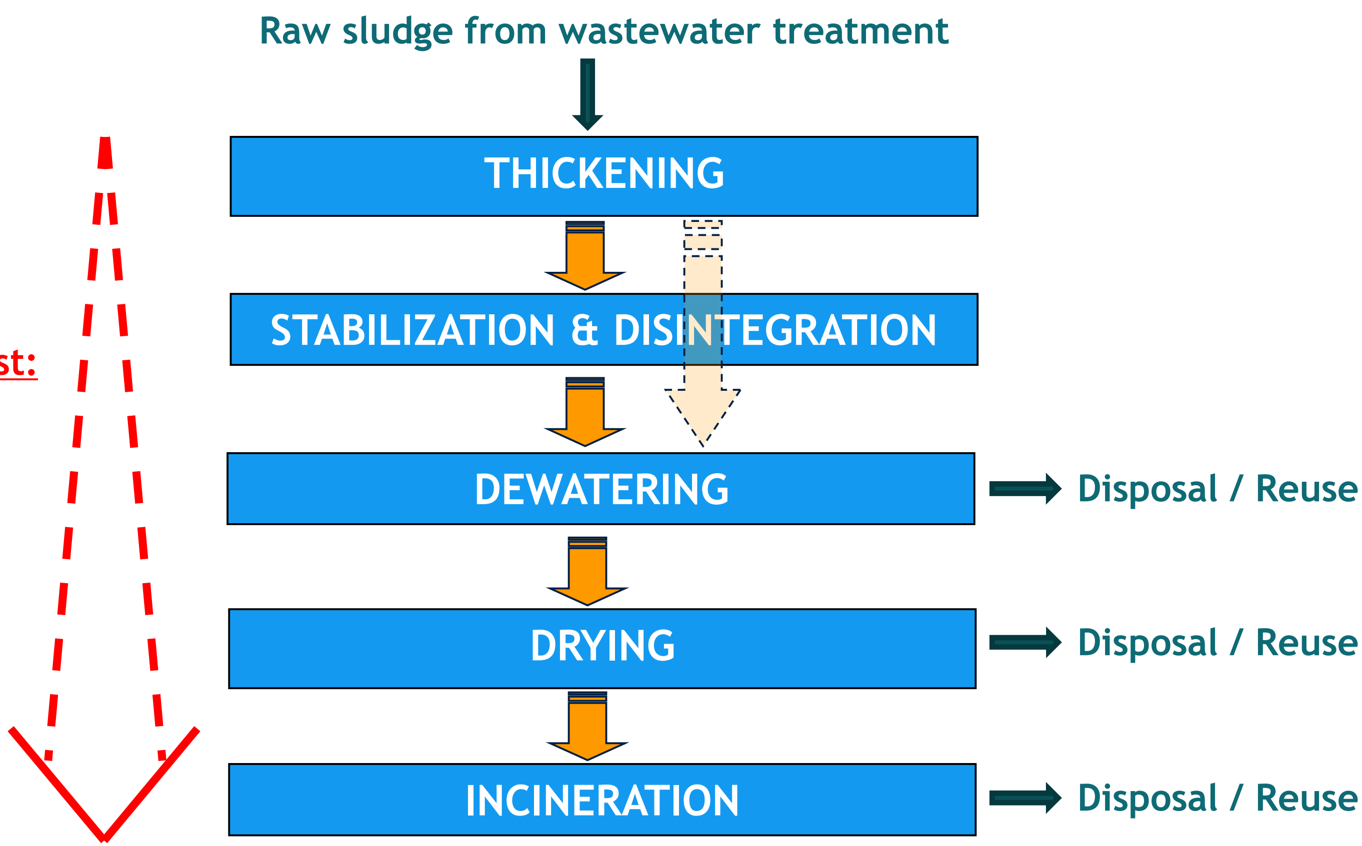
3. **Conclusions for Lebanon**

## A. Overview

Increasing cost:

(a) OPEX

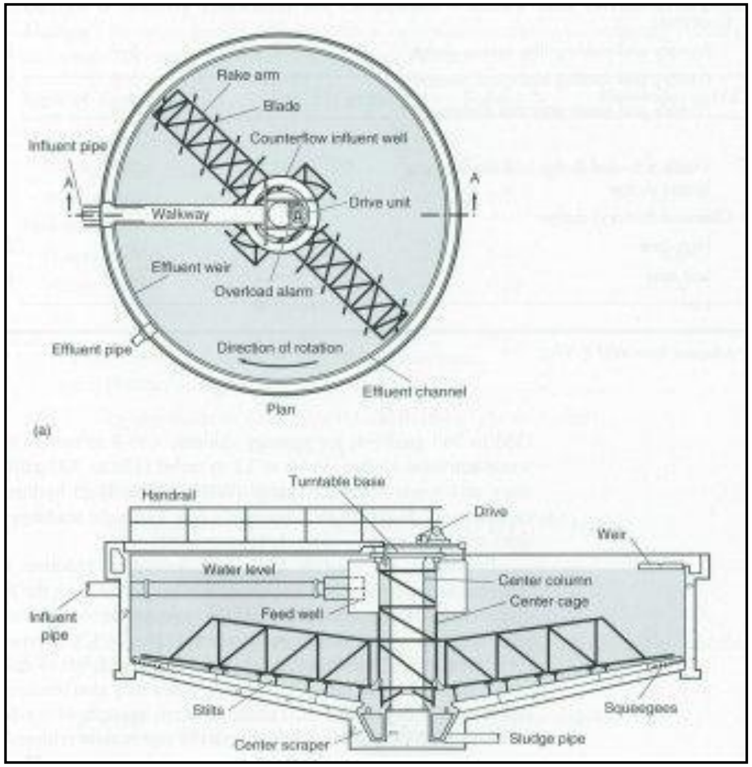
(b) CAPEX



# 1. Sludge Treatment: Technologies & Trends

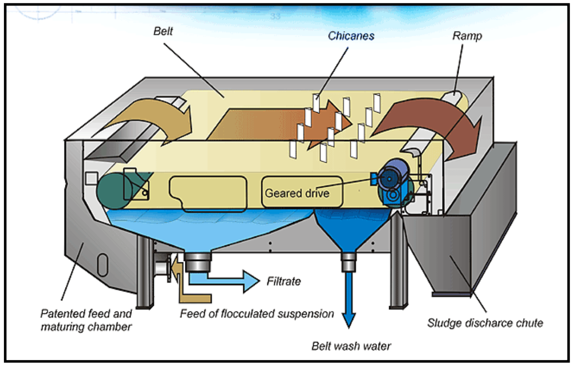
## B. Thickening (1/3)

### (i) Gravity thickening

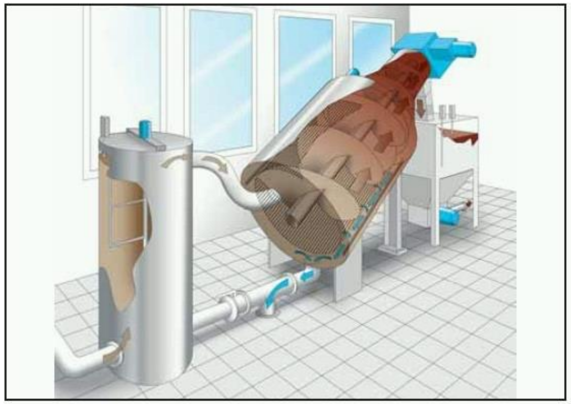



Source: Metcalf & Eddy

### (ii) Mechanical thickening




Source: Bellmer



Source: Huber

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## *Thickening continued (2/3)*

### Mechanical thickeners:

Disc thickener


Belt thickener

Screw thickener

Rotary drum thickener

# 1. Sludge Treatment: Technologies & Trends

***Thickening continued (3/3)***

| | Gravity thickening | Mechanical thickening |
|---|---|---|
| Achievable Dry Solids (%DS) | • In cold climates: max. 3-5%<br>• In warm climates: max. 3% | • Independent of climate: 5-6% |
| Chemicals | • Usually no use of chemicals | • Polymer: 2-8 g/kgDS |
| Advantages / Disadvantages | • Sludge Dewatering: increased capacity requirements and cost<br>• Large volume and cost for digesters. | • Sludge Dewatering reduced capacity requirements and cost.<br>• Digesters with substantially reduced volume and CAPEX. |

# 1. Sludge Treatment: Technologies & Trends

## C. Stabilization & Disintegration (1/6)

Note:

- Stabilization minimizes bad odour risks; helps to reduce sludge volume (apart from option with lime dosage).
- Disintegration focusses on minimized sludge volume + maximum biogas yield.

1. **Stabilization in wastewater treatment:**
   - Extended Aeration
   - Anaerobic wastewater technologies (e.g. UASB)
2. **Stabilization in sludge treatment:**
   - Anaerobic digestion with external heating / at ambient temperature
   - Separate aerobic stabilization
   - Lime dosage
3. **Disintegration (only OPTIONAL !)**
   - Ultrasonic treatment of secondary sludge
   - Thermal disintegration



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# 1. Sludge Treatment:  Technologies & Trends

## *Stabilization continued (2/6)*

**Extended Aeration:**
(Large reactors with sludge age typically > 15-20 days)

Siliana WWTP (Tunesia)

Qilidian WWTP (China)



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***Stabilization continued (3/6)***

## Anaerobic wastewater technologies:

UASB technology:

**Onca WWTP (Brazil)**

ABR technology:

**Bhubaneswar SpTP (India)**

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## Stabilization continued (4/6)

### Anaerobic digestors:

**Cylinder shaped digester**

**Egg shaped digester**

# 1. Sludge Treatment: Technologies & Trends

## Stabilization continued (5/6)

### Disintegration (hydrolysis):

**Ultrasonic plant Villach WWTP (Austria)**

(Designed for 100 m3/d sludge with 6%DS)

**Thermal hydrolysis (CAMBI process): Ringsend WWTP Dublin ( Ireland)**

# 1. Sludge Treatment: Technologies & Trends

***Stabilization continued (6/6)***

| | Extended Aeration | UASB | Anaerobic digester | Aerobic stabilization | Lime dosage | Ultrasonic treatment | Thermal treatment |
|---|---|---|---|---|---|---|---|
| Achievable stabilization | medium | good | good | medium | good | --- | --- |
| Chemicals' consumption | no | no | no | no | high | no | no |
| Energy consumption | high | low | low | high | low | medium | high |
| Energy production | no | Possible (from biogas) | Possible (from biogas) | no | no | Biogas increase by ≈ 20 (10-30)% | Biogas increase just sufficient to cover thermal needs. |
| Impact on sludge production | (similar to CAS) | Very low sludge yield | Reduction by ≈ 30% | Typically not operated as efficiently as digester | Strong vol. increase, in order of +30% | Reduction by ≈ 10 (5-20)% | Improved dewatering results |
| Advantages / Disadvantages | Simple operation, but high OPEX. | Requires post-treatment. Only efficient in warm climate. | **Standard technology globally** | High OPEX; often limited stabilization effects. | Odor risks + cost of lime + increased sludge volume | Ease of operation, but limited effect. Amortization 5-10 years. | High-tech; usually only economic with > 4000 tons DS/year |



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# 1. Sludge Treatment: Technologies & Trends

## D. Dewatering (1/2)

### (i) Natural dewatering

Drying Beds

### (ii) Mechanical dewatering

Belt Filter Press

Chamber Press


Screw Press


Centrifuge

# 1. Sludge Treatment: Technologies & Trends

## *Dewatering continued (2/2)*

| | Drying Beds | Centrifuge | Belt Filter Press | Screw Press | Chamber Press |
|---|---|---|---|---|---|
| Achievable DS(%) dewatered sludge | ≈ 20-40%, dependent on climate | • EA: 18-24%<br>• CAS: 22-30% | • EA: 15-22%<br>• CAS: 20-28% | • EA: 18-24%<br>• CAS: 20-28% | • EA: 18-24%<br>• CAS: 22-30%<br>(with polymer cond.) |
| Chemicals' consumption | (no chemicals required) | 8-14 g polymer/kgDS | 6-12 g polymer/kgDS | 6-12 g polymer/kgDS | 6-12 g polymer/kgDS |
| Energy consumption | (only for sludge pumping to drying beds + filtrate pumping to treatment) | 40-60 kWh/ton DS | 20-30 kWh/ton DS | 8-16 kWh/ton DS | 30-40 kWh/ton DS |
| Advantages / Disadvantages | • Simple/cheap to operate.<br>• Intermittent sand replace-ment needed.<br>• Large footprint. | • Continuous operation.<br>• Closed units.<br>• Noise!<br>• Low odor risks. | • Continuous operation.<br>• Easy to operate & maintain. | • Continuous operation.<br>• Relatively new on the market => maintenance? | • Intermittent operation. |

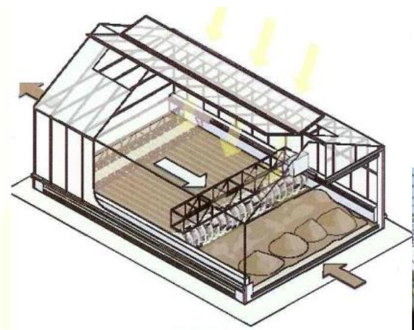
*Data source: German Advisory Leaflet DWA-M 366, Feb.2013*

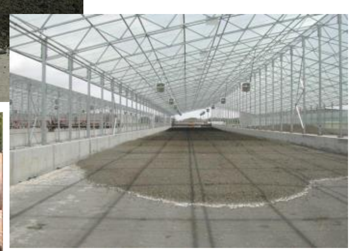
*EA … Extended Aeration. CAS … Conventional Activated Sludge (with sludge digesters)*

# 1. Sludge Treatment: Technologies & Trends

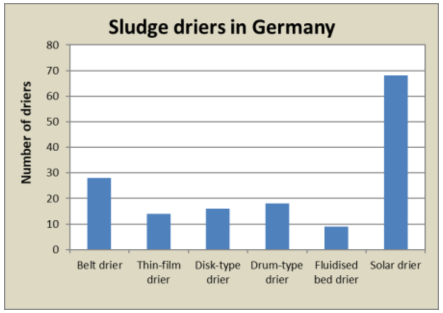
## E. Drying (1/3)

### (i) Solar Drying





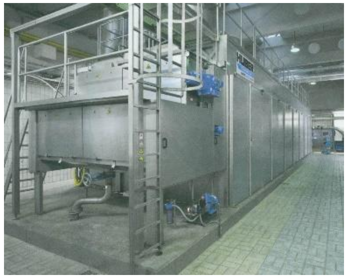
### (ii) Thermal Drying

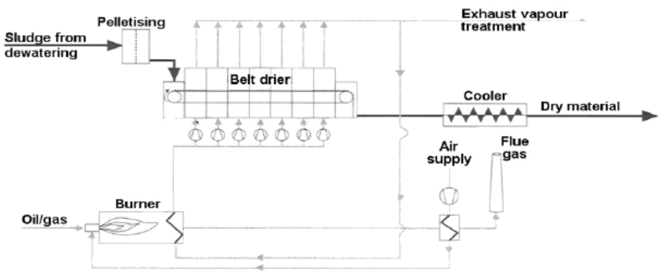



*Source: Geyer (2013)*

=> Belt drier is most common type of thermal driers

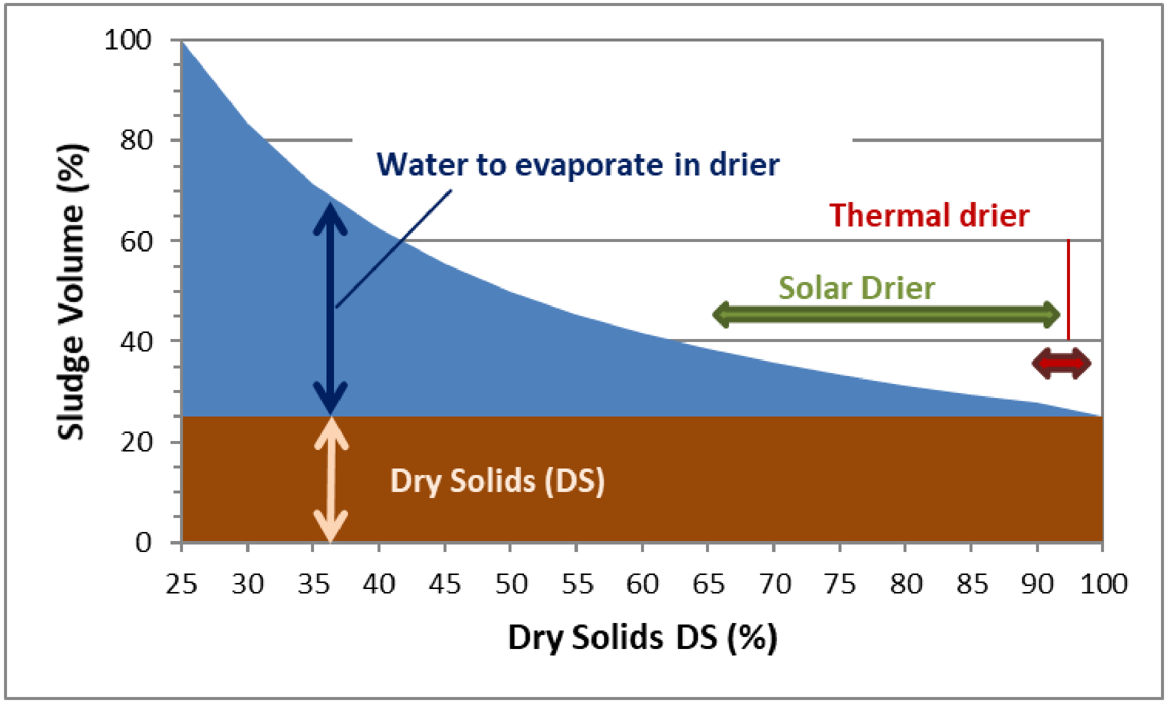
**Belt drier at Innsbruck WWTP (Austria)**





# 1. Sludge Treatment: Technologies & Trends

***Drying continued (2/3)***




***Potential for sludge volume reduction in driers***

(assuming that mechanically dewatered sludge with 25% DS equals 100% of initial volume)

**=> After drying only 20-40% of dewatered volume remain; 80-60% of volume are removed.**



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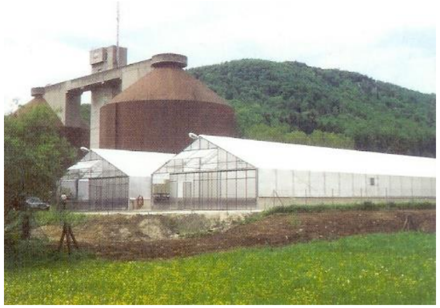
# 1. Sludge Treatment: Technologies & Trends

*Drying continued (3/3)*

|  |  |
|---|---|
| **Thermal drying** | **Solar drying** |
| Energy requirement ≈ 700-900 kWh/m3 water evaporated | Energy requirement ≈ 20-30 kWh/m3 water evaporated<br>(< 4% of thermal drying needs) |
| Typical output DS ≈ 85-95 % | Typical output DS ≈ 60-90 % |
| Low land requirement | Large land requirement |
| High-tech O&M, high OPEX | Simple O&M, low OPEX |
| High CAPEX | Medium CAPEX |



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# 1. Sludge Treatment: Technologies & Trends

## F. Incineration

### (i) Sludge Mono-Incineration

- Incinerators specifically designed for dewatered / dried sludge only.
- Typical capacity of such incinerators 10,000 - 100,000 tons DS/year.
- Gaining increased attention recently, since phosphorus recycling from ashes may offer interesting potential.

### (ii) Co-Incineration

- Sludge is incinerated in existing installations that were designed for other purposes, such as:
  - ✓ Cement kilns
  - ✓ Coal-fired power stations
  - ✓ Solid waste incinerators
- Dependent on status of existing installations more or less adjustments may be needed, particularly of exhaust gas filters.

# 2. Sludge Disposal/Reuse: Options & Trends

## A. Overview

Options for sludge disposal / reuse:

- **Sludge disposal in a sanitary landfill:**
  - ✓ Dumping together with municipal waste;
  - ✓ Use of sludge as greening cover of closed sections of landfill;
- **Sludge reuse in agriculture:**
  - ✓ Use for products, which are not directly consumed (grain, maize, etc);
  - ✓ Use for fruit trees;
  - ✓ Composting of sludge, and subsequent marketing of compost;
- **Sludge reuse in afforestation:**
  - ✓ For production of wood for construction, furniture, heating, etc;
- **Sludge reuse for land application:**
  - ✓ In abandoned mining areas;
  - ✓ For road embankments, etc;
- **Sludge reuse as a replacement of raw materials;**
  - ✓ For production of clay-based bricks or other materials;
- **Thermal reuse of sludge through incineration.**

# 2. Sludge Disposal/Reuse: Options & Trends

## B. Global Trends

Issues that shape global trends regarding sludge disposal/reuse:

- **Public opinion:**
  - ✓ Food safety: Increasing resistance towards food products where sewage sludge was involved in one way or another;
  - ✓ Environmental impacts: Effect of pollutants on environment?
  - ✓ Product safety: Are bricks / cement / etc, produced from sewage sludge, safe, or do they include dangerous compounds?

- **Legislation:**
  - ✓ Ever stricter regulations for sludge parameters in disposal/reuse;
  - ✓ Increasing range of parameters: hygiene, heavy metals, micro-pollutants;
  - ✓ Prohibition of disposal of organic matter on sanitary landfills;
  - ✓ Legal requirements for phosphorus recycling from sewage sludge (new!);

- **Commitment to reduce greenhouse gas emissions:**
  - ✓ Increasingly biogas production is maximized, to generate electric energy (considered to come from renewable source);

- **Sewage sludge as a resource:**
  - ✓ Sewage sludge as fertilizer (N,P);
  - ✓ Sewage sludge as source for energy production;
  - ✓ Sewage sludge as a resource for P recovery;



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# 2. Sludge Disposal/Reuse: Options & Trends

*Trends continued (2/6)*

## Issues that shape global trends regarding sludge disposal/reuse:

- **Technological developments:**
  - ✓ Increasing number of technologies on the market that facilitate sludge minimization;
  - ✓ Drying and incineration facilities for ever smaller installations;
  - ✓ Wide range of technologies for phosphorus recovery from sewage sludge, both from wet sludge and from sludge ashes;
  - ✓ Only sludge treatment that permits for flexible sludge disposal/reuse is "safe".

- **Quantities of sewage sludge:**
  - ✓ Where most sludge is being generated, also trends develop fastest:

| | EU | USA | China |
|---|---|---|---|
| tons DS/year | 11.5 million 1) | 7 million 2) | 6 million 4) |
| m3/year | 58 million 4) | 35 million 4) | 30 million 3) |

1) UBA (2012), 2) Ormeci (2014), WEF (2011), 3) see WB (2016), 4) based on average 20%DS



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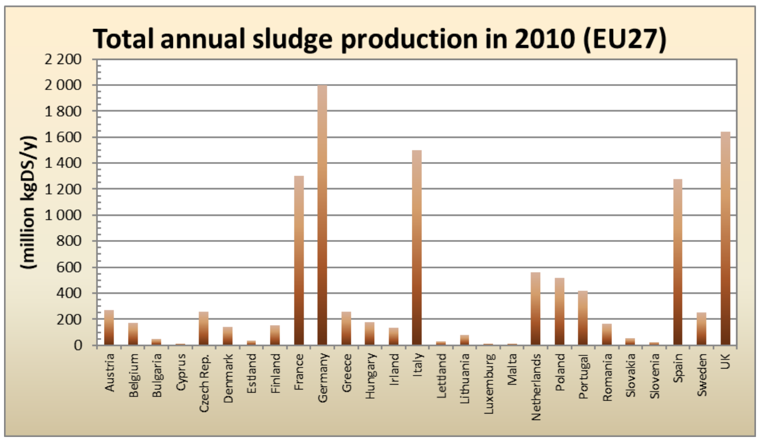
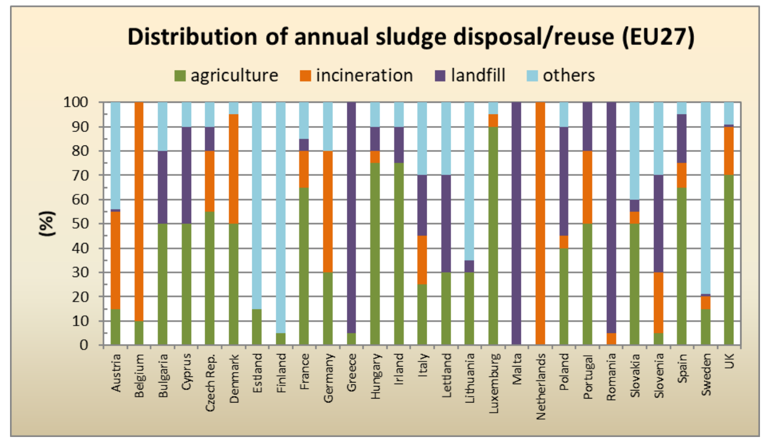
# 2. Sludge Disposal/Reuse: Options & Trends

## *Trends continued (3/6)*

## Exemplary developments:

### ❑ EUROPE:




- ✓ No uniform trend across **all countries**, but some tendencies are apparent:
  - Landfilling will be gradually phased out (legislation!), and it is mostly just the countries with low sludge production that currently still employ it on a larger scale.
  - Reuse in agriculture is decreasing.
  - Thermal reuse is increasing.
- ✓ Some features from **Germany,** the largest sludge producer, appear worth noting:
  - Total sludge volume has decreased by -17% from 2007 to 2017 due to focus on sludge minimization at WWTPs.
  - Sludge incineration has increased from 50% to 70% in same period.

# 2. Sludge Disposal/Reuse:  Options & Trends

***Trends continued (5/6)***

<u>Exemplary developments:</u>

- **<u>INDIA:</u>**
  - ✓ The legal signals in India are quite contradictive. The CPHEEO Manual (2013), which is strongly guiding the Indian sanitation sector, defines:
    - *"<u>Landfills are not usually recommended</u> for disposal of STP sludge. In case they are adopted, the above points should be considered."* (Those points define criteria typically associated with sanitary landfills.)
    - *"The use of <u>raw sludge</u> as a soil filler directly on land <u>for raising crops as a means of disposal is not desirable</u> since it is fraught with health hazards."* – Notwithstanding, subsequently the Manual continues with describing principles, which should be followed, whenever sludge is applied to soils.
    - Ministry of Environment, Forest and Climate Change, Notification: Solid Waste Management Rules (2016) defines *<u>quality criteria for compost</u>*.
  - ✓ "Recommendations and Guidelines" published mutually by 7 Indian Institutes of Technology (2010) only recommends thickening + dewatering, as well as generation of biogas in digesters, and <u>composting</u>.
  - ✓ In practice, this background **does not provide for clear guidance**, and **most sewage sludge is eventually disposed at sites of different quality standards**. – This actual status is equivalent to what was depicted on the previous page for China in the period between the years 2007 and 2010.



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# 2. Sludge Disposal/Reuse: Options & Trends

***Trends continued (6/6)***

**Exemplary developments:**

- BRAZIL:
  - ✓ Sludge disposal/reuse is not yet fully recognized as a major issue in Brazil. E.g., the latest "*Atlas esgoto*" by ANA (2017), Brazil's National Water Agency, which provides an excellent overview of wastewater treatment, does not even include a single para related to sewage sludge disposal/reuse!
  - ✓ Consequently, the situation is characterized by:
    - Sludge is typically disposed at landfills, or at dedicated sites at the WWTP.
    - Sometimes sludge is also reused in agriculture, however mostly just in rural environments.
    - Sludge incineration is not commonly employed.
    - Sludge digestion is popular (both via anaerobic wastewater technologies, and in anaerobic sludge digesters), and biogas use for generation of electric energy has become a trend in recent years, receiving a particular push by strongly increased power unit cost since about 2015. (Previously most of the biogas was simply flared.)

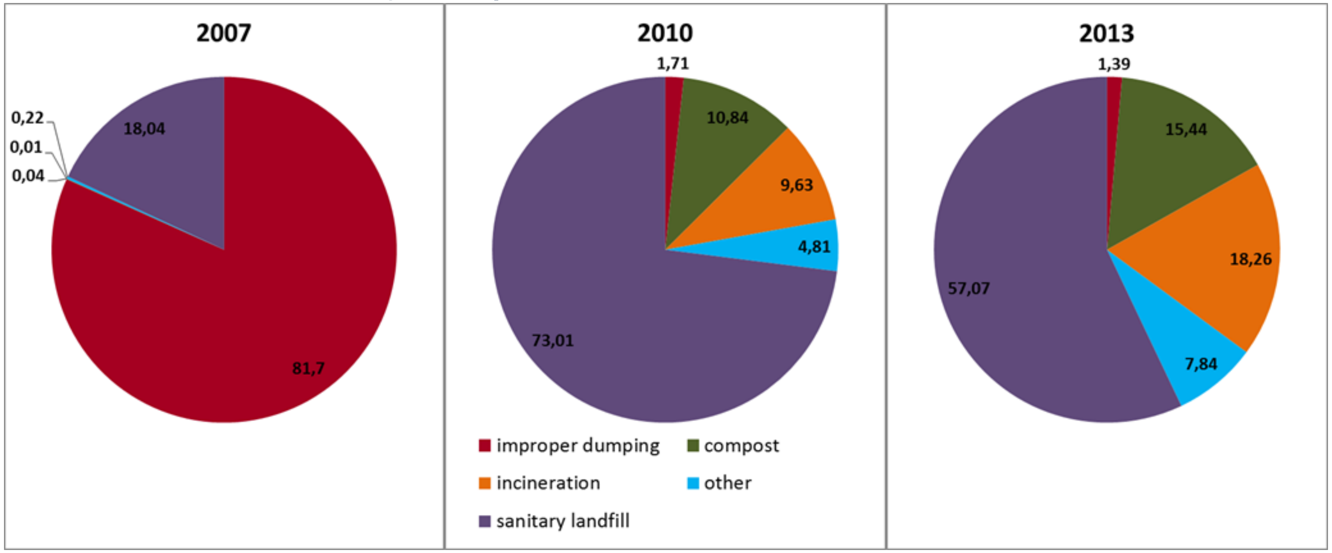
# 2. Sludge Disposal/Reuse: Options & Trends

*Trends continued (6/6)*

## Exemplary developments:

❑ **CHINA:**

*Distribution of sludge disposal / reuse in China in 2007, 2010, 2013*




**Source**: WRI (2016), using data from MOHURD and its own estimate

⇒ Within recent years a major shift has taken place from improper dumping to
- Sanitary landfill has become main way of disposal, and
- recently thermal reuse also gained increasing prominence.

# 3. Trend in the Sector

Wa… to
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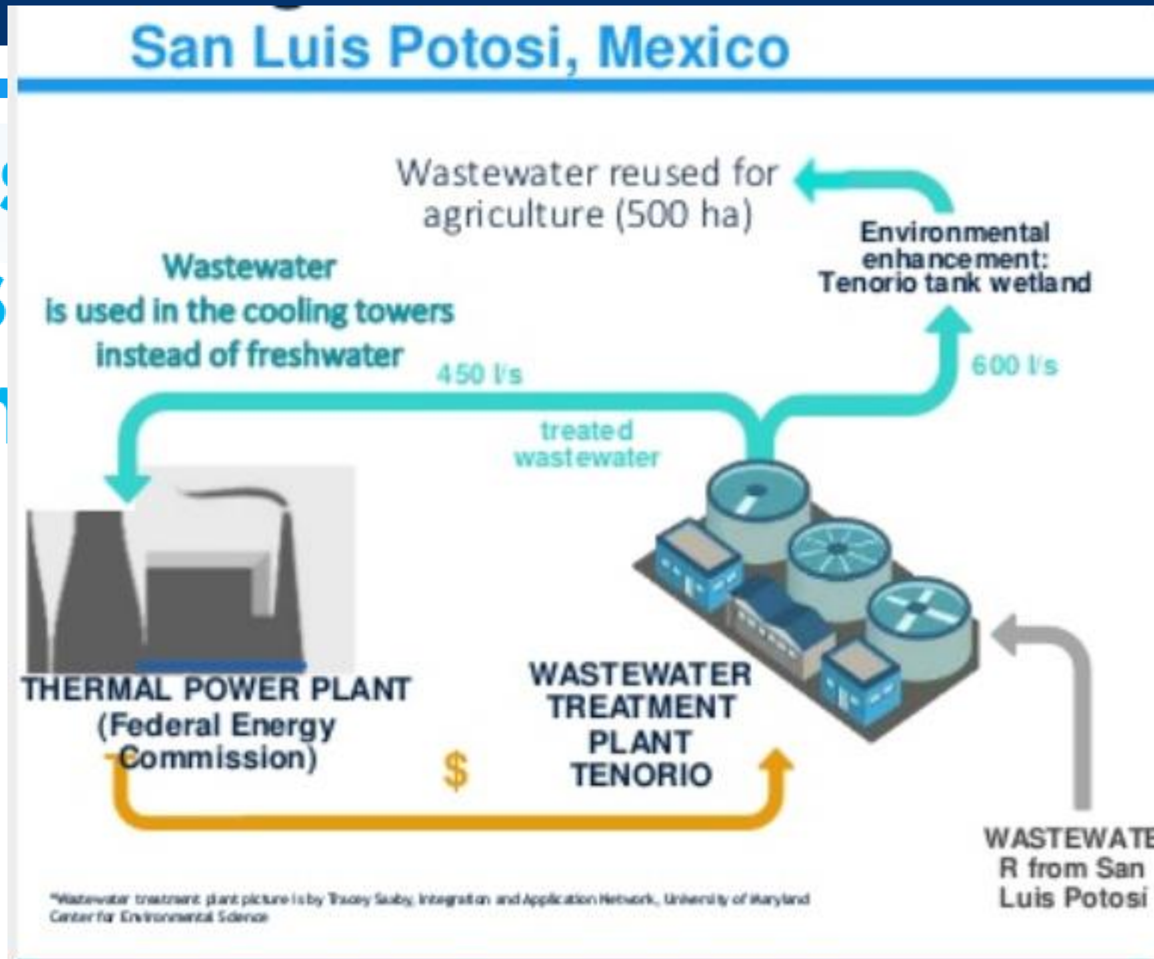


Source Norhan Sadik, WCEF, 2019



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# 4. Conclusions for Lebanon

1. A clear-cut sludge treatment technology and thereupon based disposal/reuse strategy should be considered an indispensable, integral part of any WWTP project.

2. Lebanese legal regulations for all sorts of sludge disposal/reuse should be checked, if they meet international standards, and if they are appropriate for actual conditions. Legal revisions/adjustments may be needed.

3. Investigate and analyze the existing potential for sludge reuse.

4. Promote:
   a. Measures to minimize sludge volume, such as anaerobic sludge digesters, and solar sludge drying.
   b. Measures to generate and utilize biogas for power generation.
   c. Regional co-operation in sludge management should be assisted, since economy of scale can help in bringing down sludge disposal/reuse cost.

# Thank You !

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