SWIM-H2020 SM Regional Activities 14

Presented by:
MOHAMMD SUTARI, MEHSIP RESIDENT EXPERT-JORDAN

SWIM and Horizon 2020 SM REG-14: Refugee Emergency: Fast track project Design of wastewater
26 March 2018, Beirut, Lebanon

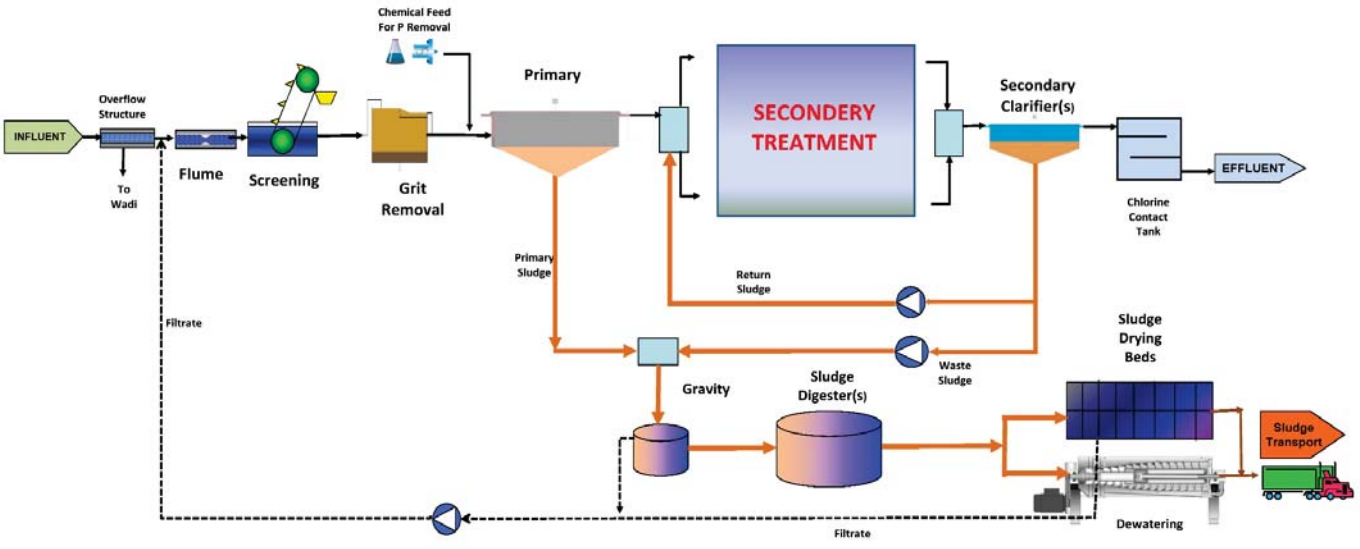
This Project is funded by the European Union

SLUDGE TREATMENT

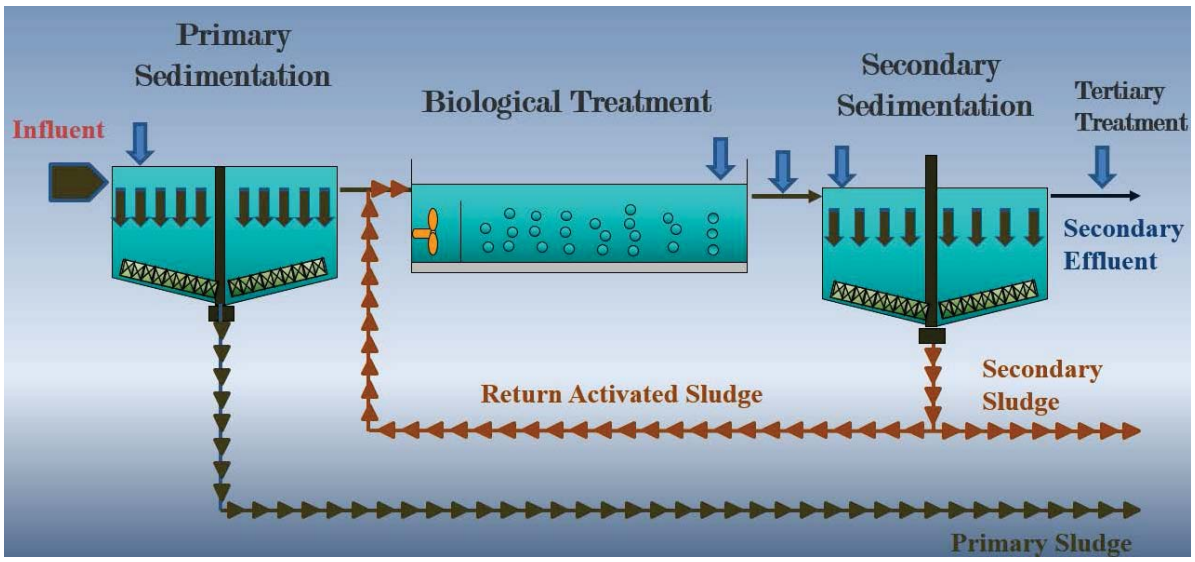
SLUDGE TREATMENT
CONTENTS

1. Volume mass relationship.
2. Regulations for solids reuse and disposal.
3. Bio-solids classifications.
4. Required treatment for class A & B solids
5. Criteria for meeting vector attraction requirements.
6. Sludge treatment requirements as per Jordanian standard.
7. Gravity Thickeners design parameters.
8. Sludge digestion
9. Dewatering.
10. Design Examples

WASTEWATER TREATMENT
SCHEMATIC PROCESS DIAGRAM



TYPES OF SLUDGE



GENERAL

- Definitions
  - Biosolids , organic wastewater product that remains after solids are stabilized that can be used beneficially.
  - The term Sludge is used only before beneficial use criteria have been achieved. It is used in conjunction with a process descriptor(primary sludge, waste sludge.
  - The term solids is used in case where it is uncertain whether beneficial use criteria have been met.
- Problems
  - Composed of the substances responsible for the offensive character of untreated wastewater.
  - Composed of organic matter which will decompose and become offensive.
- Sludge Treatment Objectives:
  - Reduce water and organic contents.
  - Render the solids suitable for reuse or final disposal.

VOLUME-MASS RELATIONSHIP

$$V = \frac{M_S}{\rho_W \times S_{sl} \times P_S} \qquad V = \frac{M_S}{1000 \times P_S}$$

See example 14-4
M&E page 1493

Where:
V = volume of sludge,m3
M_S = mass of dry solids, kg
ρ_W = specific weight of water ,1000 kg/m3
S_{sl} = specific gravity of sludge
P_S = percent solids expressed as a decimal

Mass of Dry Solids kg/day	Volume at % Solids(m3/day)				
	0.60%	1%	2%	3%	20%
5000	833	500	250	167	25

REGULATIONS FOR SOLIDS REUSE & DISPOSAL

- U.S. Environmental Protection Agency issued 40 CFR Part 503 regulations in United States in 1993, which covers the followings:
  - Land application.
  - Surface disposal.
  - Pathogen and Vector Attraction reduction.
  - Incineration.

Vector attraction reduction decreases the potential for spreading infectious disease by vectors such as rodents, insects, and birds.

BIOSOLIDS CLASSIFICATIONS

Item	Class A	Class B
Definition	pathogens are reduced below current detectable levels	the pathogens are reduced to levels that are unlikely to pose a threat to public health and environment.
Criteria to be met	meet vector attraction requirements (38% in VS reduction)	meet vector attraction requirements (38% in VS reduction)
	A fecal coliform density of less than 1000 MPN/g total dry solids.[1]	meet fecal coliform limits less than $2X10^6$ MPN/g TS.
	Helminth limits of <1 viable ovum/4 g dry solids	treated by a process that reduces but doesn't eliminate pathogens(PSRP)
	Salmonella sp. Density of less than 3 MPN per 4 g of total dry solids.[1]	
Applications	May be sold or given a way without any pathogen-related restrictions.	subjecte to site restrictions that limit crop harvesting, animal grazing, and public access
	prepared for sale	Applied to agricultural land
	land application	disposed off in land fill
	home gardens	

1. It is not necessary to satify both fecal coliform and salomenallae criteria. Meeting the criteria of one is sufficient to satisfy part 503 rules

REQUIRED TREATMENT FOR CLASS A & B BIOSOLIDS

- Class A Processes to further reduce pathogens(PFRP)
  - Thermophilic Aerobic Digestion.
  - Alkaline Treatment.
  - Heat treatment.
  - Heat drying.
- Class B Processes to significantly reduce pathogens(PSRP)
  - Aerobic digestion
  - Air drying
  - Anaerobic digestion
  - Lime stabilization.
- VAR Requirements
  - Process to meet at least 38% reduction in volatile solids.

CRITERIA FOR MEETING VECTOR ATTRACTION REQUIREMENTS(40 CFR Part 503)

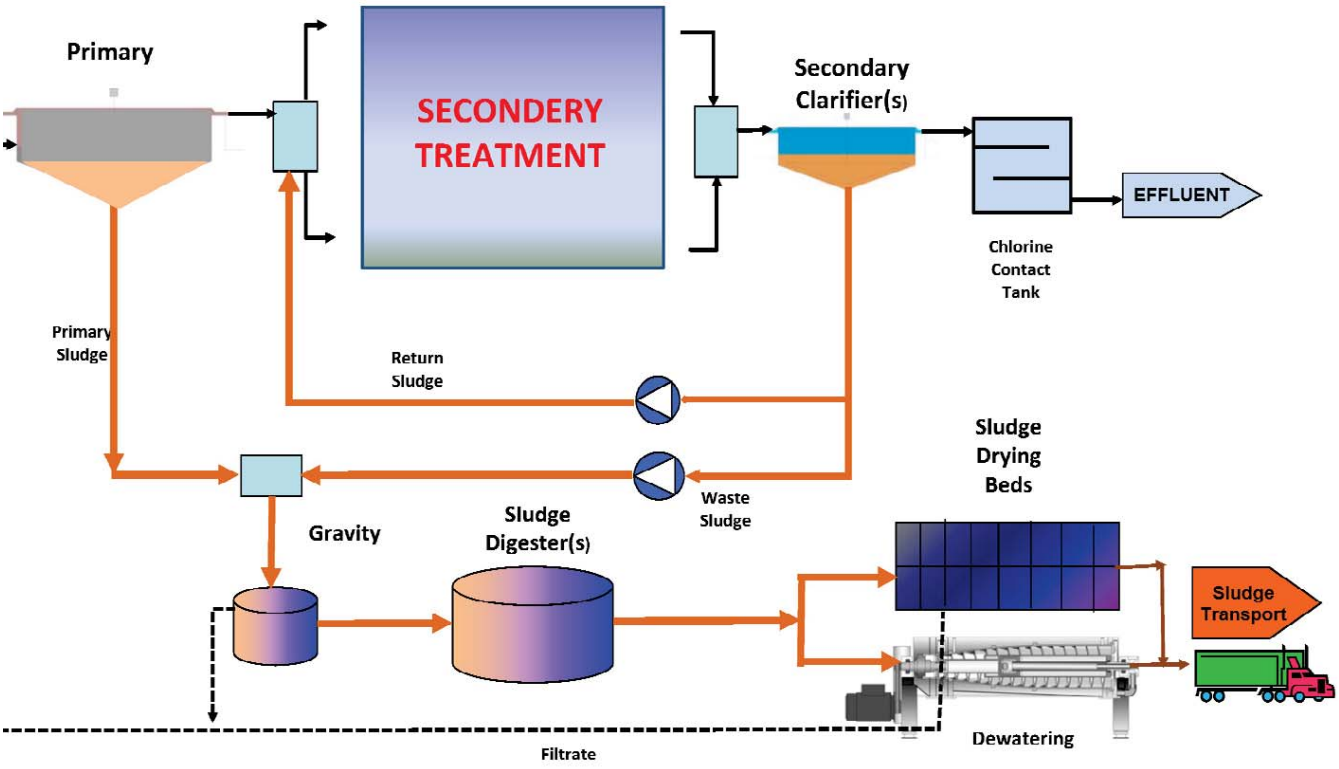
- A minimum of 38% reduction in volatile solids during biosolids treatment.
- Less than a specific oxygen uptake rate(SOUR) of 1.5 mg O2/h per gram of total sludge solids at 20^{o}C.

SLUDGE TREATMENT REQUIREMENTS AS PER JORDANIAN STANARD JS 1145:2006

Treatment Level	Applications	Treatment Requirements	Treatment Method	Minimum Retention Time (Days)	Minimum % Volatile solid Reduction
First Class (Class A)	Fertilizer for all applications Except for vegetables.	* Fecal coliform < 1000 MPN/g dry solids * Salmonella < 3 MPN/ g dry solids * Nematodes egg. <1 egg /4 gm dry solids * Viruses < 1 unit/4 gm dry solids	Composting	60	
			Heat Drying		
			Air Drying	45	
			Heated Aerobic Digestion @ 55-60 C.	10	38%
Second Class (Class B)	Soil Conditioning Disposal to landfill	* Fecal coliform < $2*10^{6}$ MPN/g dry solids	Aerobic Digestion @ air temperature	40	38%
			Anaerobic Digestion @ 37 C.	15	38%
			Anaerobic Digestion @ 24 C.	24	38%
Third Class	only Disposal to Solid Waste Sites.	Only dewatering	Thickening to 3% solids		

Jordanian Standard SludgeTreatment

SLUDGE MASS BALANCE



SLUDGE MASS BALANCE

Item	Total Solids (kg/day)	% Solids	Volume (m^3/day)
Primary Sludge	7,000	3%	233
Secondary Sludge	4,700	0.70%	671
Blended Thickener Influent	11,700	1.29%	905
Assumed % Solids lost out the thickener		5.00%	
Thickener Effluent	11,115	4.50%	247
Digester Effluent	7,297	2.95%	247
Assumed % Solids lost in dewatering		5.00%	
Dewatering Effluent	6,932	23%	30

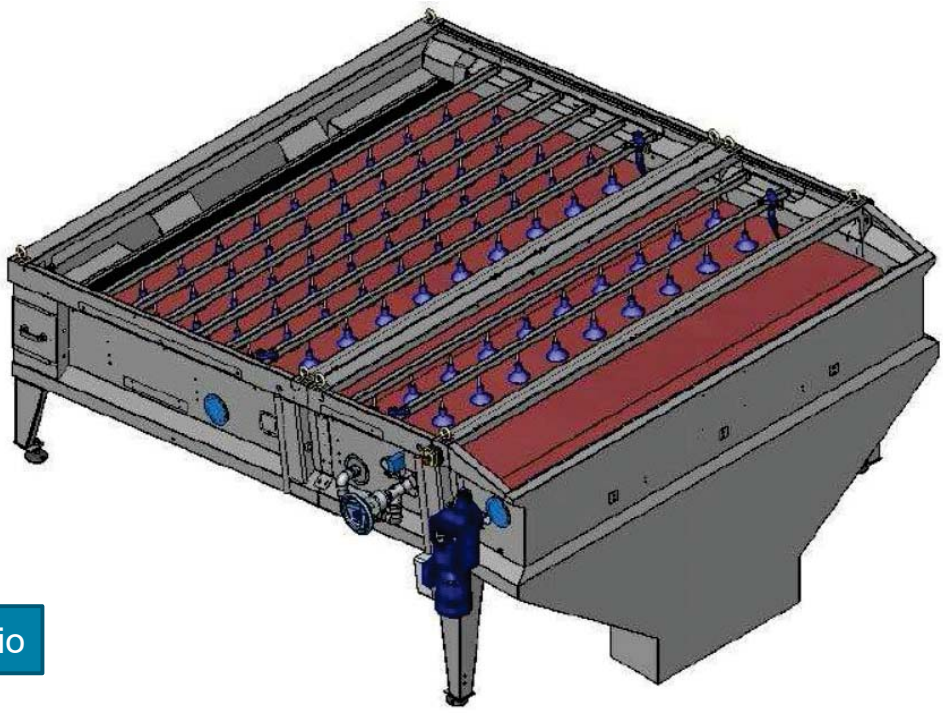
DESIGN PARAMETERS FOR GRAVITY THICKENERS

Sludge Type	%Solids concentration		Solids loading kg/m2.day
	Unthickened	Thickened	
Primary Sludge	2-6	5-10	100-150
Trickling-filter humus sludge	1-4	3-6	40-50
Air Activated Sludge	0.5-1.5	2-3	20-40
Extended Aeration Activated Sludge	0.2-1	2-3	25-40
Anaerobically digested primary sludge	8	12	120
Primary and trickling filter humus sludge	2-6	5-9	60-100
Primary and waste activated sludge	0.5-1.5	4-6	25-70
	2.5-4	4-7	40-80

DESIGN EXAMPLE FOR GRAVITY THICKENER

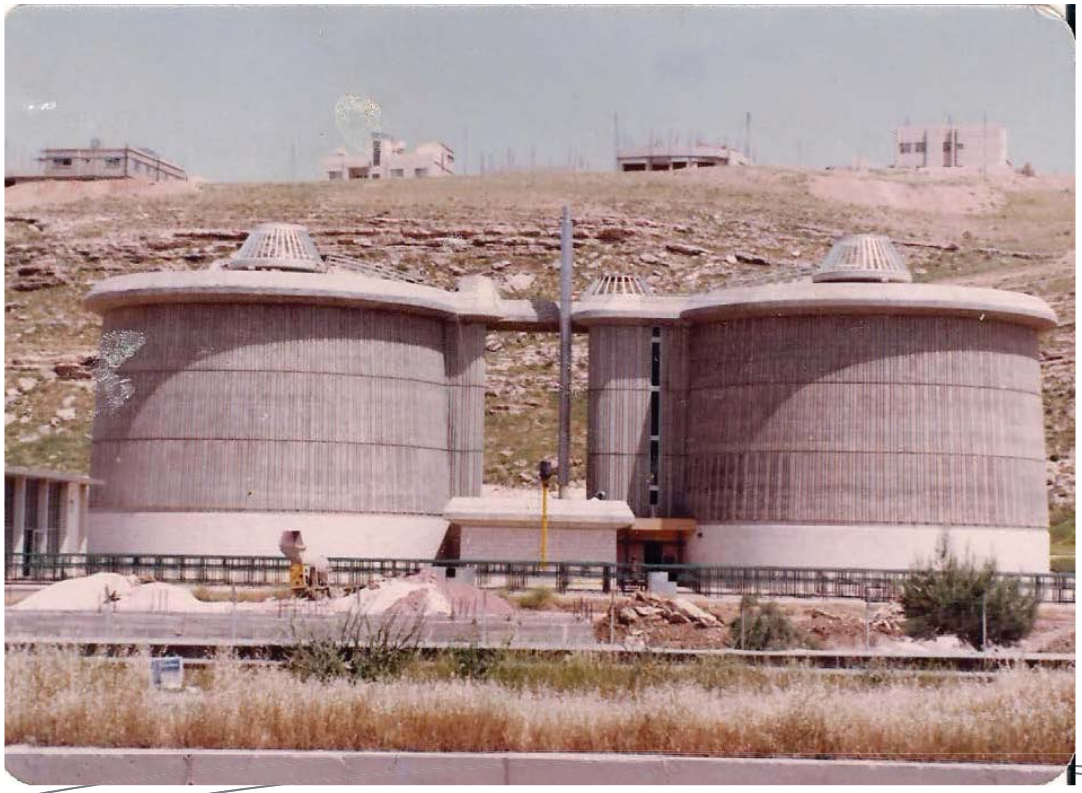
Item	Value	Unit
No. of Thickeners	**2**	
Total Sludge Flow to All Thickeners	**926**	**m^3/day**
Total Dry Solids to All Thickeners	**12000**	**kg/day**
Design Solids Loading Rate	**2.5**	**kg/m2.h**
Total Surface Area	**200**	**m^2**
Surface Area Each Thickener	**100**	**m^2**
Calculated Diameter	**11.3**	**m**
Used diameter	**11.5**	**m**
Used Total Surface Area	**208**	**m2**
Depth	**4**	**m**

MECHANICAL THICKENERS
GRAVITY BELT THICKENER

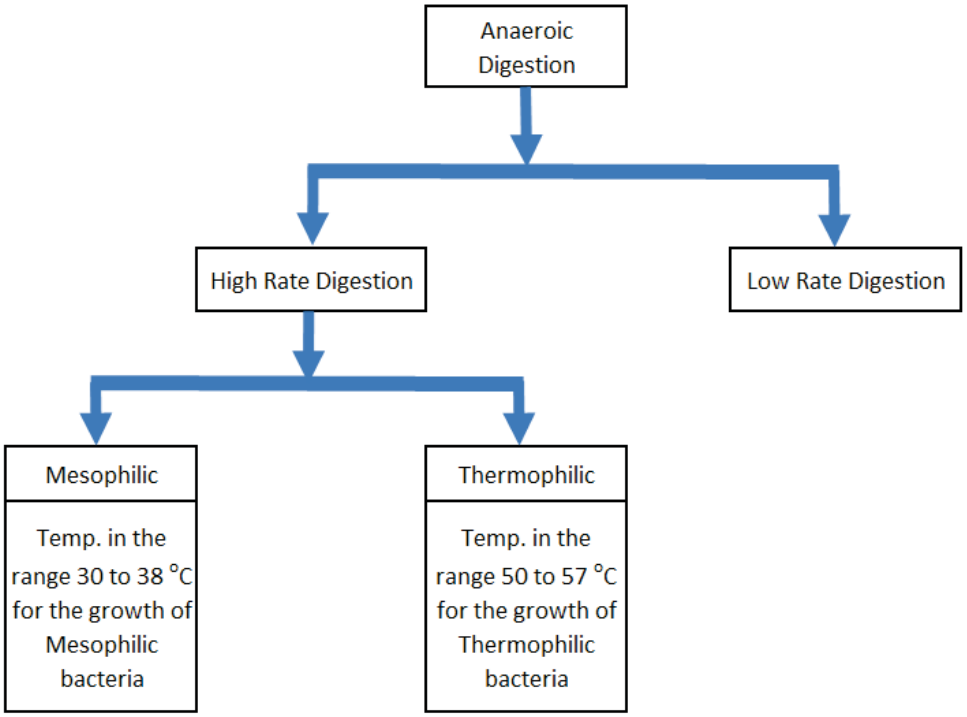


Vedio

SLUDGE DIGESTION



ANAEROBIC DIGESTION



DESIGN CRITERIA FOR MESOPHILIC ANAEROBIC SLUDGE DIGESTERS

Parameter	Units	Value
Solids loading rate	kg VSS/m3.d	1.6-4.8
Solids retention time	day	15-20

Estimating Volatile Solids Destruction

$$VS_D = 13.7 \times \ln(SRT) + 18.9$$

Digestion Time SRT days	% Volatile Solids Destruction
30	65
20	60
15	56

GAS PRODUCTION

- Production of biogas is a direct result of VS destruction.
- Typical values for gas production vary from 0.75 to 1.12 m3/kg of volatile solids destroyed.

EXAMPLE ANAEROBIC SLUDGE DIGESTION

Anaerobic Digesters		
Volume thick. Sludge	m3/day	2936
Assumed Thick. Sludge Solids	%	5
Total Dry Solids	Kg TSS/day	146,782
VSS/TSS		0.75
Total Volatile Suspended Solids	Kg VSS/day	110,087
Process Temp.	°C	35
Overall Digestion time(SRT)	days	20
Total Volume	m3	58,720
No. of Digestors	no	4
Volume of one sludge digetsor	m3	14,680
Diameter	m	30
Surface Area one digestor	m2	706.5
Depth of conical section	m	3
Height	m	19.8
Volume Digested Sludge	m3	2936
Organic Solid Load	Kg VSS/day	110,087
% Volatile solids degraded		50%
Amount Volatile solids degraded	Kg TSS/day	55,043
Total DS quantity out	Kg TSS/day	91,739
% Solids Digested Sludge	%	3.12%
Gas Production		
Min Gas Production	l/kg org.DS	500
Amount Gas Production	m3/day	27,522
Required Gas Storage volume	m3	10,000
No. of gas Holders		2
Each Gas Holder Volume	m3	5,000
Gas Holder Diameter	m	20
Gas Holder Height	m	16
Energy Content of Gas	kWh/m3	6.5
Total Energy	kWh/d	178,891

Anaerobic Digesters

AEROBIC SLUDGE DIGESTION

- Similar to activated sludge process.
- As the supply of available substrate(food) is depleted, the microorganisms begin to consume their own protoplasm to obtain energy for cell maintenance reactions(endogenous phase).
- Cell tissue is oxidized aerobically to CO2, water, and ammonia.
- 75-80% of the cell tissue can be oxidized.
- Ammonia is subsequently oxidized to nitrate as digestion proceeds.
- Nonbiodegradable volatile suspended solids will remain in final product from aerobic digestion.

AEROBIC SLUDGE DIGESTION ADVANTAGES & DISADVANTAGES

- Advantages
  - Easy operation.
  - Low capital cost
- Disadvantages
  - High power cost.
  - Methane gas is not recovered.
  - Effected by temperature.
  - Poor mechanical dewatering for digested sludge.

GENERAL DESIGN PARAMETERS FOR AEROBIC DIGESTERS

- Temperature
  - The design should provide for the necessary degree of sludge stabilization at the lowest expected liquid operating temperature.
  - The design should provide the maximum oxygen requirements at the maximum expected liquid operating temperature.
- Volatile Solids Reduction
  - The major objective of aerobic digestion is to reduce the mass of the solids for disposal.
  - The reduction takes place only with the biodegradable contents of the sludge.
  - Volatile solids reduction ranging from 35 to 50% are achievable by aerobic digestion.
- Detention Time(SRT)
  - Solid destruction is function of temperature and detention time.

DESIGN CRITERIA FOR AEROBIC DIGESTERS

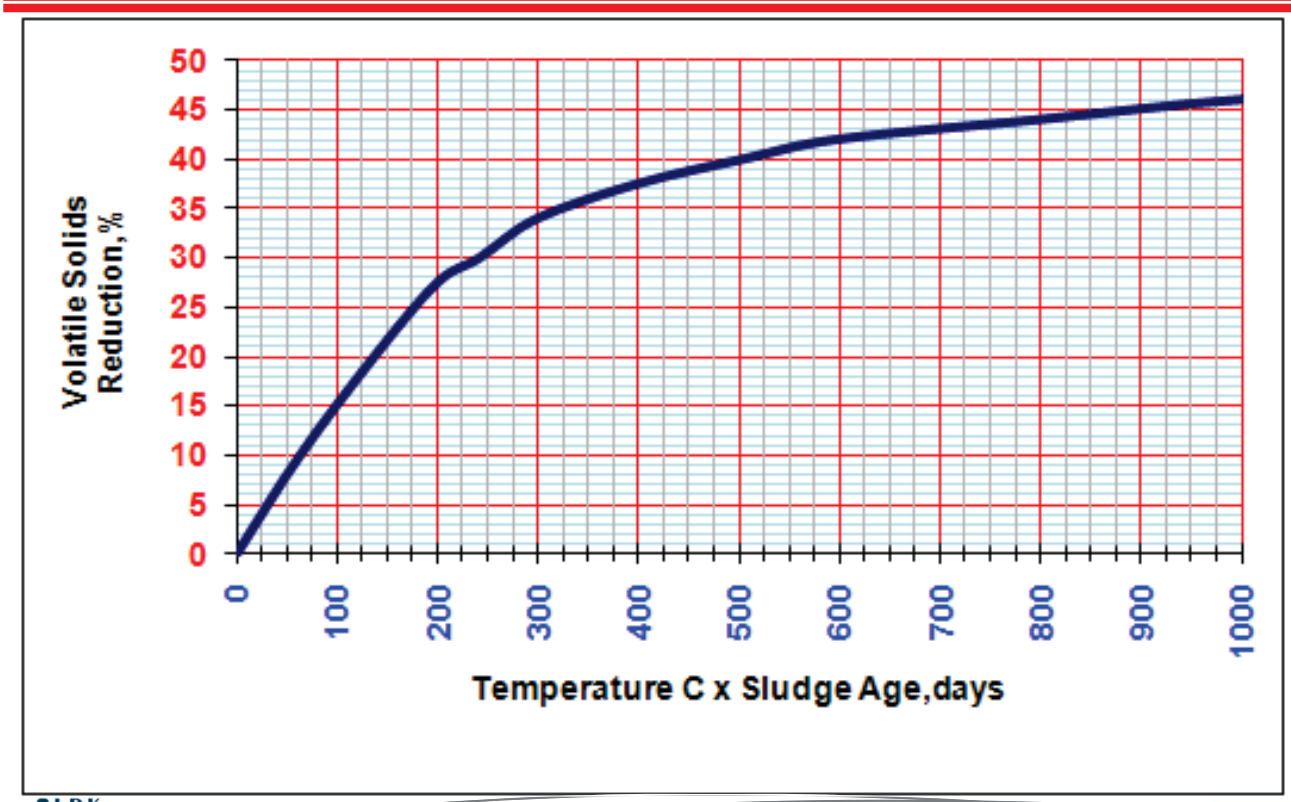
Parameter		Value	Unit
SRT[1]	@ 20 °C	40	day
	@ 15 °C	60	
Volatile solids loading		1.6-4.8	kg/m3.d
Oxygen Requirements	Cell tissue	2.3	kg O2/kg VSS Destroyed
	BOD in primary sludge	1.6-1.9	
Energy for Mixing	Mechanical aerators	20-40	kW/1000 m3
	Diffused air mixing	0.02-0.04	m3/m3.min
Residual DO in the liquid		1-2	mg/l
Reduction of Volatile suspended solids		38-50	%

1. To meet pathogen reduction requirements(PSRP) of 40 CFR Part 503 regulations.

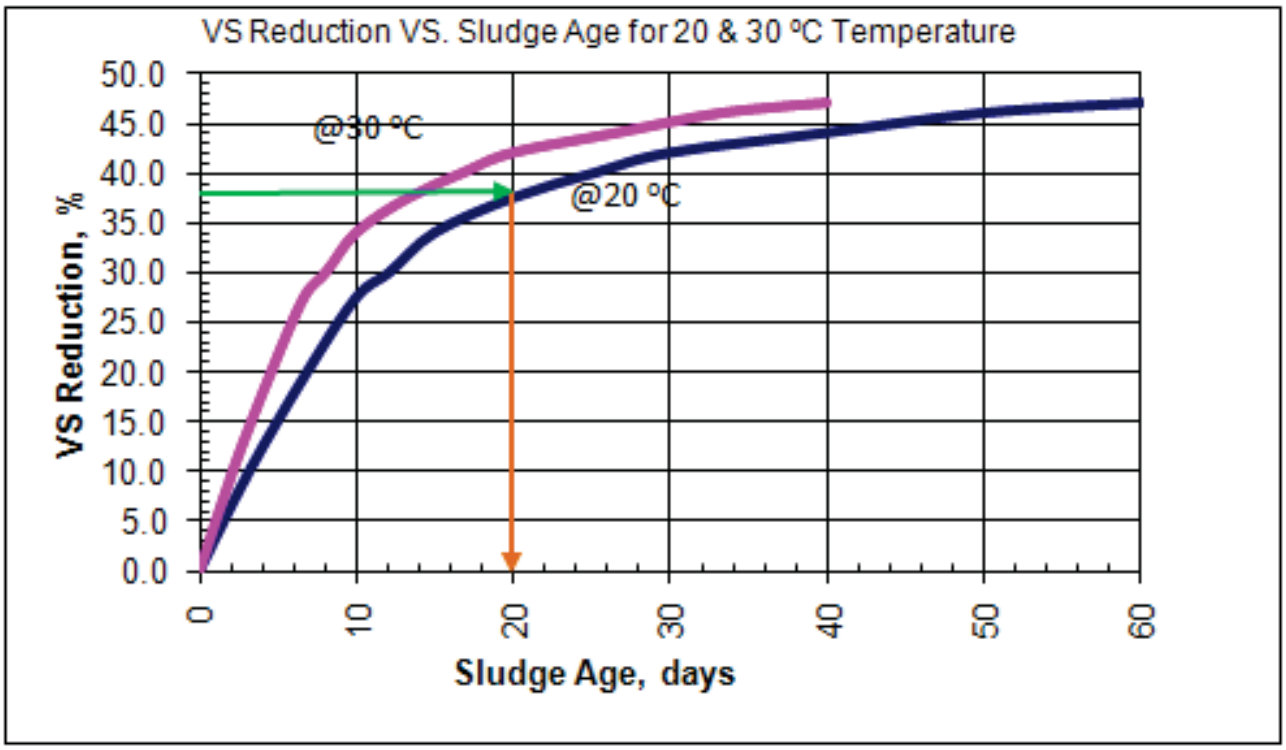
SRT & SLUDGE TREATMENT

- SRT is selected based on the following treatment requirements/Objectives:
  - ❑ Wastewater Treatment without Nitrification (Carbonaceous BOD removal only).
  - ❑ Wastewater Treatment with Nitrification.
  - ❑ Wastewater Treatment with Nitrification & Denitrification
  - ❑ Wastewater Treatment with Nitrification, Denitrification and sludge stabilization.

VOLATILE SOLIDS REDUCTION IN AEROBIC DIGESTER AS A FUNCTION OF TEMPERATURE AND SRT



VOLATILE SOLIDS REDUCTION IN AEROBIC DIGESTER AS A FUNCTION OF TEMPERATURE AND SRT



EXAMPLE AEROBIC SLUDGE DIGESTION

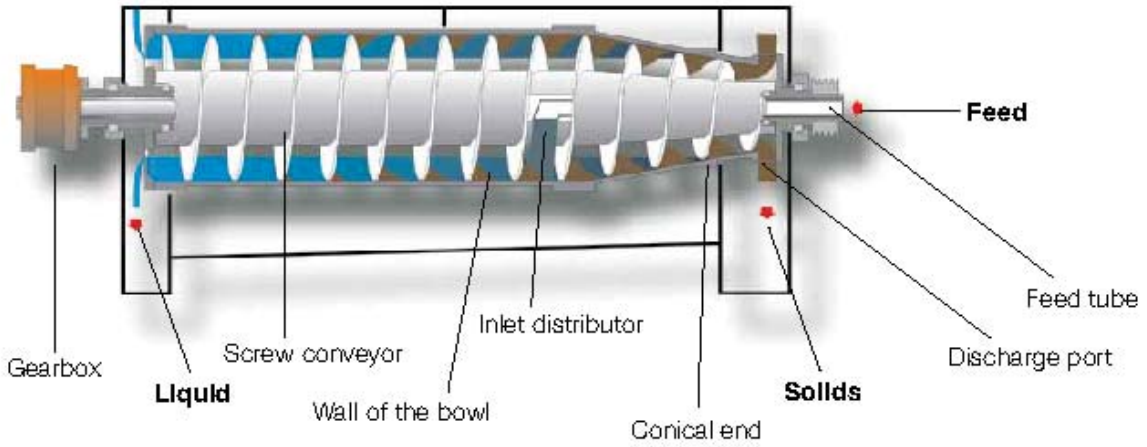
Aerobic Sludge Digesters			
Item	Unit	Value	Notes
Total Dry Solids	Kg TSS/day	11,115	mass balance
Dry Solids in Primary Sludge	Kg TSS/day	6,650	mass balance
Dry Solids in Secondary Sludge	Kg TSS/day	4,465	mass balance
Volume Thickened Sludge	m3/day	247	mass balance
Incoming Sludge Solids contents	%	4.50	mass balance
VSS/TSS ratio for Primary Sludge		92%	mass balance
VSS/TSS ratio for Secondary Sludge		88%	
VSS in Primary Sludge	Kg VSS/day	6118	
VSS in Secondary Sludge	Kg VSS/day	3929	
Total Volatile Suspended Solids	Kg VSS/day	10,047	
Inert Solids to Digester	Kg TSS/day	1,068	
Process Temperature	°C	20	
Hydraulic Detention Time/SRT	days	20.00	MOP 8
Total Digester Volume Required	m3	4,940	
No. of Digesters	no	2	
Volume of one sludge digester	m3	2,470	
Sludge Effective Depth	m	5.50	
Surface Area Each Digester	m2	449	
Diameter(If circular)	m	23.9	
Width(If rectangular)	m	20.0	
Length(If rectangular)	m	22.5	
Volume Digested Sludge	m3	247	
Organic Solid Load	Kg VSS/day	10,047	
Calculated volatile solids loading	Kg VSS/m3.day	2.0	
Average % Volatile solids degraded		38%	
Amount Volatile solids degraded	Kg VSS/day	3,818	
Total Dry Solids quantity out of Digester	Kg TSS/day	7,297	
Calculated % Solids Digested Sludge	%	2.95	
Calculated Average SRT taking degraded volatile solids	days	25	
% Volatile solids degraded in Summer(@30 °C)	%	42%	MOP 8
VSS degraded in Primary solids	Kg VSS/day	2,570	
VSS degraded in Secondary Solids	Kg VSS/day	1,650	
Total Volatile solids degraded in Summer	Kg VSS/day	4,220	

Aerobic Digester Design

SLUDGE DEWATERING

- Reduction of the moisture contents of sludge and biosolids:
  - Reduction of transport cost.
  - Easy to handle dewatered sludge.
- Dewatering Methods
  - Mechanical dewatering.
    - Centrifuges.
    - Belt-filter press.
  - Sludge drying beds.
    - Sand bottom.
    - Paved bottom.

DECANTERS/CENTRIFUGES



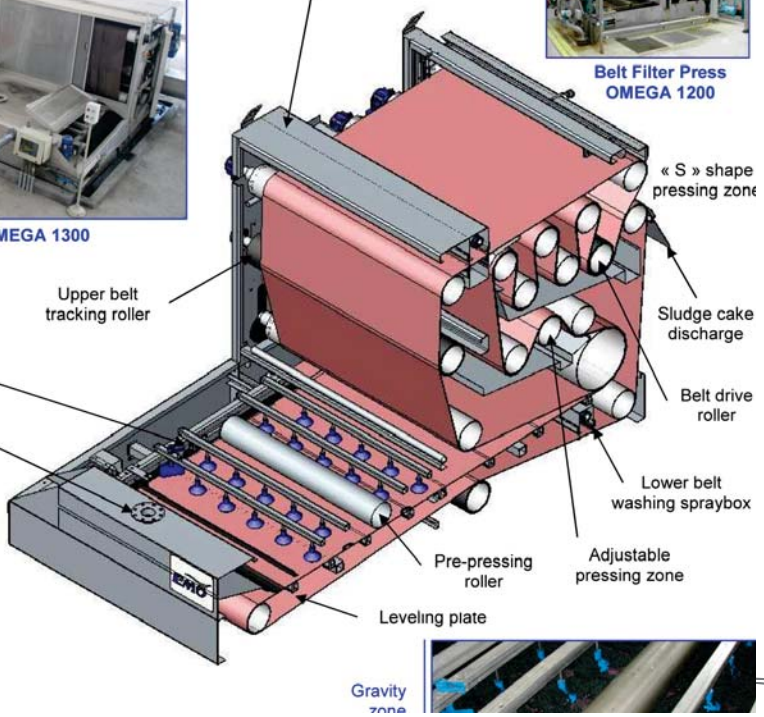
Vedio

BELT FILTER PRESS

Belt Filter Press OMEGA 1300

Belt Filter Press OMEGA 1200

Ultrasonic sensors for belt tracking



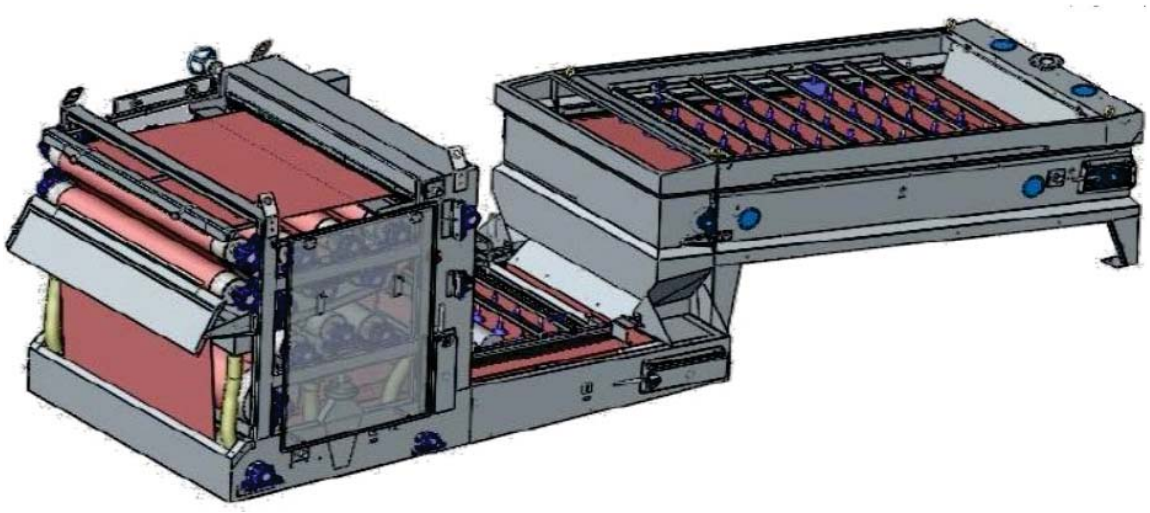
Vedio

EXAMPLE MECHANICAL SLUDGE DEWATERING

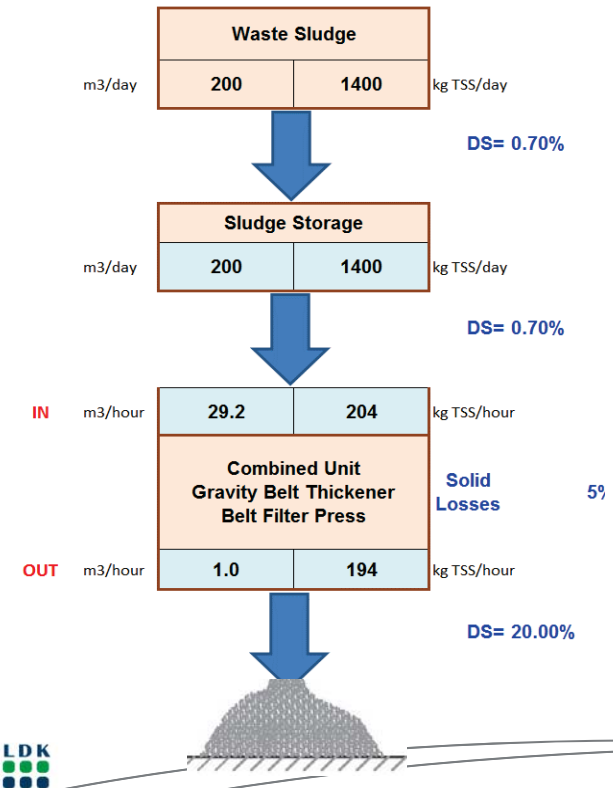
Mechanical Sludge Dewatering			
Item	Unit	Value	Notes
Percentage sludge transferred to Mechanical Dewatering		100%	
Sludge Feed Solids Contents	%	2.95	mass balance
Amount of Solids feed	Kg SS/day	7,297	mass balance
Assumed % Solids lost with centrate	%	5%	mass balance
Amount solids out	Kg SS/day	6,932	
Quantity of Sludge Transported to Mech. Dewatering	m3/day	247	mass balance
Volume of digested sludge	m3	247	
Type of Feed Sludge Feed pumps	Progressive Cavity		
No. of duty pumps	No.	2	
No. of standby pumps	No.	1	
Days of operation per week	days/week	6	
No. of operating hours per day	hours/day	6	
Capacity each pump	m3/hour	24.0	
Assumed Solid Contents for Output Sludge	%	23%	
Quantity of dewatered Sludge based on 36 hrs operation per week	m3/day	35	
	m3/hour	5.9	
Days of operation per week	days/week	6	
No. of operating hours per day	hours/day	6	
Capacity of all dewatering units	m3/hour	48	
No. of duty Centrifuges	No	2	
No. of standby Centrifuges	No	0	
Hydraulic capacity Each	m3/hour	24	
Main Drive size for Centrifuge	Kw	??	
Back Drive size for Centrifuge	Kw	??	
Solids Loading each machine	Kg DS/h	709	
Screw conveyor capacity each machine	m3/hour	2.9	
Average Polyelectrolyte Consumption	kg/ton of DS	4	
Required Polyelectrolyte quantity	Kg/day	29	

Mechanical Dewatering

COMBINED DEWATERING UNIT
GRAVITY BELT THICKENER+BELT FILTER PRESS



DEWATERING CALCULATIONS FOR COMBINED UNITS



Combined Unit

EXAMPLE SLUDGE DRYING BEDS

Sludge Drying Beds			
Total Wet Quantity of Digested Sludge	m3	247	
Percentage sludge transferred to Mechanical Dewatering		0%	
Percentage sludge transferred to Drying Beds(SDBs)		100%	
Quantity of Sludge Transported to SDBs	m3/day	247	
Initial Sludge Solids Contents	%	2.95	
Amount of solids	Kg TSS/day	7297	
Assumed Solids Contents of dried sludge		45%	WEF Manual of Practice No. 8 Page 24-74
Average Drying Time	days	21	
Assumed sludge thickness	m	0.30	
Total Area required	m2	17315	
Calculated Solids Loading	Kg/m2.a	154	
Average quantity of dried Sludge	m3/day	16	

SWIM-H2020 SM

For further information

Website

www.swim-h2020.eu E: info@swim-h2020.eu

LinkedIn Page

SWIM-H2020 SM LinkedIn

Facebook Page

SWIM-H2020 SM Facebook

SWIM and Horizon 2020 Support Mechanism

Working for a Sustainable Mediterranean, Caring for our Future

Thank you for your attention.

This Project is funded by the European Union