SLUDGE TREATMENT AND DISPOSAL

Sludge treatment and disposal

- Sludge (residuals) generated from primary, secondary and tertiary treatment must be treated and properly disposed of
- The higher the degree of wastewater treatment, the larger the quantity of sludge to be treated and handled
- Sludge treatment and disposal constitute approximately 50% of the operating costs

Quantity and characteristics of sludge

- Approximately, 21 kg (47 lb) of dry sewage sludge per person is generated annually in North America
- Total solids and volatile solids contents, pH, nutrients, organic matter, pathogens, metals, organic chemicals and hazardous pollutants determine the characteristics of sludges

Primary sludge

- Sludge from primary settling tank contains from 3 to 7% solids which are approximately 60-80% organic
- Primary sludge solids are usually gray in color, slimy, fairly coarse, and with highly obnoxious odors
- Primary sludge is readily digested under suitable conditions

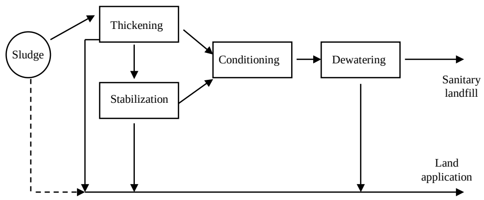
Secondary sludge

- Sludge from secondary settling tanks has commonly a brownish, flocculent appearance and an earthy odor
- Secondary sludge consists of mainly microorganisms (75-90% organic) and inert materials, and can be digested readily
- Waste activated sludge contains 0.5-2%, and trickling filter sludge contains 2-5% solids

Tertiary sludge

- The nature of the tertiary sludge depends on the unit processes
- Chemical sludge from phosphorus removal is difficult to handle and treat
- Tertiary sludge from biological processes is similar to waste activated sludge

Sludge processing alternatives



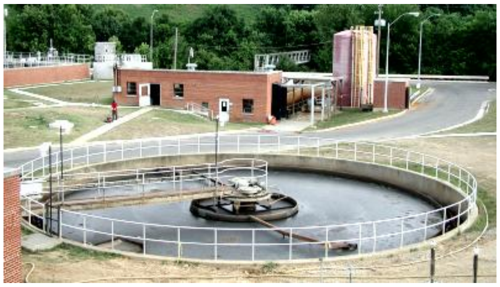
Sludge thickening

- Sludge thickening is used to remove water and increase the solids content
- If waste activated sludge with 0.6% solids is thickened to a content of 3% solids, a five-fold decrease in sludge volume is achieved
- Sludge thickening mainly involves physical processes such as gravity settling, flotation, centrifugation and gravity belts

Gravity thickening

- Gravity thickening uses gravity forces to separate solids from the sludge
- The equipment is similar in design to a conventional sedimentation basin
- A typical design is a circular tank with a side depth of 3-4 m and a floor sloping at 1:4 to 1:6

Gravity sludge thickener



www.roanokewpcp.info

Dissolved air flotation thickening

- The DAF thickener separates solids from the liquid phase in an upward direction by attaching fine air bubbles to particles
- The influent stream at the tank bottom is saturated with air, pressurized, then released to the inlet distributor
- DAF is used for light sludges such as activated sludge

DAF sludge thickener

www.roanokewpcp.info

Centrifuge thickening

- A centrifuge acts both to thicken and to dewater sludge
- The centrifuge process separates liquid and solids by the influence of centrifugal force which is typically 50 to 300 times that of gravity
- The solid bowl scroll centrifuge is the most widely used type

Gravity belt thickening

- GBT is effective for raw sludge and digested sludge with less than 2 percent solids content
- Conditioned sludge is distributed evenly across the width of a moving belt, the liquid drains through, and the solids are carried toward the discharge end

TABLE 11.2 - SLUDGE THICKENING METHODS AND PERFORMANCE WITH VARIOUS SLUDGE TYPES

THICKENING METHOD	SLUDGE TYPE	PERFORMANCE EXPECTED
Gravity	Raw Primary	Good, 8-10% Solids
	Raw Primary and Waste Activated	Poor, 5-8% Solids
	Waste Activated	Very Poor, 2-3% Solids (Better results reported for oxygen excess activated sludge)
	Digested Primary	Very Good, 8-14% Solids
	Digested Primary and Waste Activated	Poor, 6-9% Solids
Dissolved Air Flotation	Waste Activated (Not generally used for other sludge types)	Good, 4-6% Solids and ≥ 95% Solids Capture With Flotation Aids.
Centrifugation	Waste Activated	8-10% and 80-90% Solids Capture with Basket Centrifuges; 4-6% and 80-90% Solids Capture with Disc-nozzle Centrifuges; 5-8% and 70-90% Solids Capture with Solid Bowl Centrifuges

Source: Atlantic Canada Standards

Sludge stabilization

- The purposes of sludge stabilization are to reduce pathogens, eliminate odor causing materials, and to inhibit, reduce and eliminate the potential for putrefaction
- Stabilization processes include anaerobic digestion, aerobic digestion, lime stabilization and composting

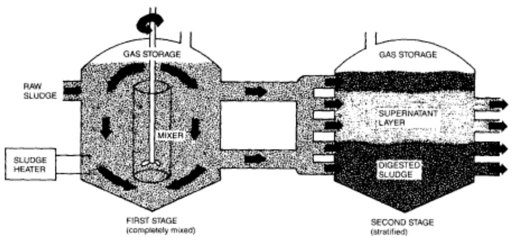
Anaerobic sludge digestion

- Anaerobic sludge digestion is the biochemical degradation of complex organic substances in the absence of free oxygen
- During anaerobic digestion, energy is released and much of the volatile organic matter is converted to methane, carbon dioxide, and water

Anaerobic digestion phases

- Anaerobic digestion involves three successive phases: hydrolysis, acid formation, and methane formation
- In the first phase, extracellular enzymes break down complex organic substances into soluble organic fatty acids, alcohols, carbon dioxide and ammonia

- In the second phase, acid forming bacteria convert the products of the first stage into short-chain organic acids such as acetic acid, propionic acid, other low molecular weight organic acids, carbon dioxide, and hydrogen
- The third phase, strictly anaerobic, involves two groups of methane forming bacteria (methanogens). First group: $C + H \rightarrow CH_4$, Second group: acetate $\rightarrow CH_4 + CO_2$ + other trace gases



High rate anaerobic digester

www.dep.state.pa.us

Anaerobic digestors

www.lenntech.com

Aerobic digestion

- Aerobic digestion is used to stabilize primary sludge and secondary sludge by long-term aeration
- The process converts organic sludge solids to carbon dioxide, ammonia, and water by aerobic bacteria with reduction of volatile solids, pathogens, and offensive odors

Lime stabilization

- Lime is added to sludge to raise the pH to 12 or higher for a minimum of 2 h contact
- The high alkaline environment inactivates biological growth and destroy pathogens
- The sludge does not putrefy, create odors, or pose a health hazards
- If pH drops below 11, renewed bacteria and pathogen growth can reoccur

Composting

- Composting is an aerobic biological decomposition of organic material to a stable end product at an elevated temperature
- Approximately 20-30 percent of volatile solids are converted to carbon dioxide and water at temperatures in the pasteurization range of 50-70%

Chemical conditioning

- Thickened and stabilized sludges still require some conditioning steps
- Chemical conditioning can reduce the 90-99 percent incoming sludge moisture content to 65-80 percent
- Lime, ferric chloride, alum and polymers are used as conditioners

TABLE 11.1 - SOME CHEMICAL CONDITIONING REQUIREMENTS			
SLUDGE	$FeCl_3$ (kg/tonne DRY SOLIDS)	$Ca(OH)_2$ (kg/tonne DRY SOLIDS)	POLYMERS (kg/tonne DRY SOLIDS)
RP	10 - 30	0 - 50	1.5 - 2.5
R(P + TF)	30 - 60	0 - 150	2 - 5
R(P + AS)	40 - 80	0 - 150	3 - 7.5
AS	60 - 100	50 - 1500	4 - 12.5
DP	20 - 30	30 - 80	1.5 - 4
D(P + TF)	40 - 80	50 - 150	3 - 7.5
D(P + AS)	60 - 100	50 - 150	3 - 10

KEY: R = RAW; P = PRIMARY; TF = TRICKLING FILTER; AS = ACTIVATED SLUDGE; D = DIGESTED

Source: Atlantic Canada Standards

Polymer

Mix sludge with polymer

Liquid/Solids separation

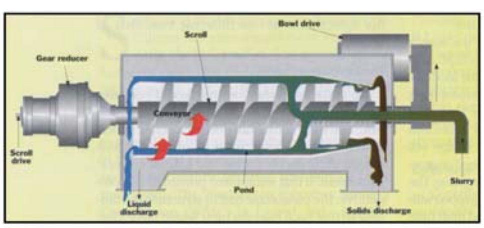
www.wwoa.org/public_ed

Sludge dewatering

- The primary objective of dewatering is to reduce sludge moisture
- Dewatering reduces the cost of sludge handling and disposal
- Sludge can be dewatered by slow natural evaporation or by mechanical devices such as vacuum filtration, pressure filtration, recessed plate filtration and centrifugation

Centrifuge

Operation of a centrifuge



Belt press filter

TABLE 11.10 - SLUDGE DEWATERING METHODS AND PERFORMANCE WITH VARIOUS SLUDGE TYPES

DEWATERING METHOD	SOLIDS CAPTURE (%)	SOLIDS CONCENTRATIONS NORMALLY ACHIEVED (1)	MEDIAN ENERGY REQUIRED (MJ/DRY TONNE) (2)
Vacuum Filter	90 - 95	Raw primary + was (10-25%) Digested primary + was (15-20%) Was (8-12%)	1080
Filter Press	90 - 95	Raw primary + was (30-50%) Digested primary + was (35-50%) Was (25-50%)	360
Centrifuge (Solid Bowl)	95 - 99	Raw or Digested primary + was (15-25%) Was (12-15%)	360
Belt Filter	85 - 95	Raw or Digested primary + was (14-25%) Was (10-15%)	130

1. INCLUDING CONDITIONING CHEMICALS, IF REQUIRED.
2. MJ/DRY TONNE - DENOTES MEGAJOULES PER DRY TONNE OF SLUDGE THROUGHOUT.

Source: Atlantic Canada Standards

Biosolids

- The end product of wastewater sludge treatment processes are referred to as “biosolids”
- The term “biosolids” has recently gained popularity as a synonym for sewage sludge because it perhaps has more reuse potential than the term “sludge”

www.ci.boulder.co.us

Use and disposal of biosolids

- The beneficial uses of biosolids include land application to agricultural lands or non-agricultural lands, and sales or give-away for use on home gardens
- Disposal methods include disposal in municipal landfills, surface disposal, and incineration

Incineration

Air pollution control system

Ash storage

Regulatory requirements

- USEPA “Part 503 Rule” was developed to protect public health and environment from any reasonably anticipated adverse effects of using or disposing of sewage sludge
- Atlantic Canada Standards and Guidelines for the Collection, Treatment and Disposal of Sanitary Sewage

Class A and B biosolids

- Class A requirement is to reduce the pathogens in biosolids to below detectable levels. Class A biosolids can be applied without any pathogen-related restrictions
- Class B requirements ensure that pathogens have been reduced to levels that are unlikely to pose a threat to public health and environment

Land application

- Microorganisms, heavy metals and toxic organic chemicals are major public health concerns
- The application rate of biosolids applied to agricultural land must be equal to or less than the “agronomic rate”
- Pollutant concentration limits, cumulative pollutant loading rate limits and annual pollutant loading rate limits must be met for heavy metals

General limitations

- Only stabilized sludge shall be surface applied
- Sludge should not be applied to land which is used for growing raw vegetables
- No sludge shall be applied on land if the soil pH is less than 6.0
- If there are known problems with persistent organic chemicals, sludge should first be analyzed

TABLE 11.13 - MINIMUM DISTANCE TO PHYSICAL FEATURES

TYPE OF FEATURE	MINIMUM SETBACK DISTANCE
Public Wells	150 m **
Private Wells	90 m **
Property Line	10 m *
Bedrock Outcrops	10 m *
Dwellings	90 m **
Uninhabited Buildings	30 m
Perennial Water Bodies & Watercourses	90 m
Intermittent Water Bodies & Watercourses	60 m
Swales and Man-Made Drainage Ditches	15 m
Primary & Secondary Roads	30 m *
Unimproved Dirt Roads	10 m *

NOTE: * 100 m setback required for spray irrigation areas
** 300 m setback required for storage lagoons and spray irrigation areas

Source: Atlantic Canada Standards

Sludge application rates

- Nitrogen restrictions
- Phosphorus restrictions
- Additive metal loading restrictions
- Maximum acceptable concentrations in soil

TABLE 11.15 – CRITERIA FOR METAL CONTENT IN SOILS

METAL	MAXIMUM ACCEPTABLE METAL ADDITION TO SOIL (kg/ha)	MAXIMUM ACCEPTABLE METAL CONTENT IN SLUDGED SOILS (µg/g)
As	14	14
Cd	1.6	1.6
Co	30	20
Cr	210	120
Cu	150	100
Hg	0.8	0.5
Mo	4	4
Ni	32	32
Pb	90	60
Se	2.4	1.6
Zn	330	220

Liquid biosolids application

lamar.colostate.edu

Solid biosolids application

lamar.colostate.edu

Source

- Water and Wastewater Calculations Manual, Suhandar Lin
- Wastewater Engineering, Metcalf & Eddy
- Water Supply and Pollution Control, Viessman and Hammer
- Atlantic Canada Standards and Guidelines Manual