Wastewater Treatment SB1383 Compliance Characterization

Final Report

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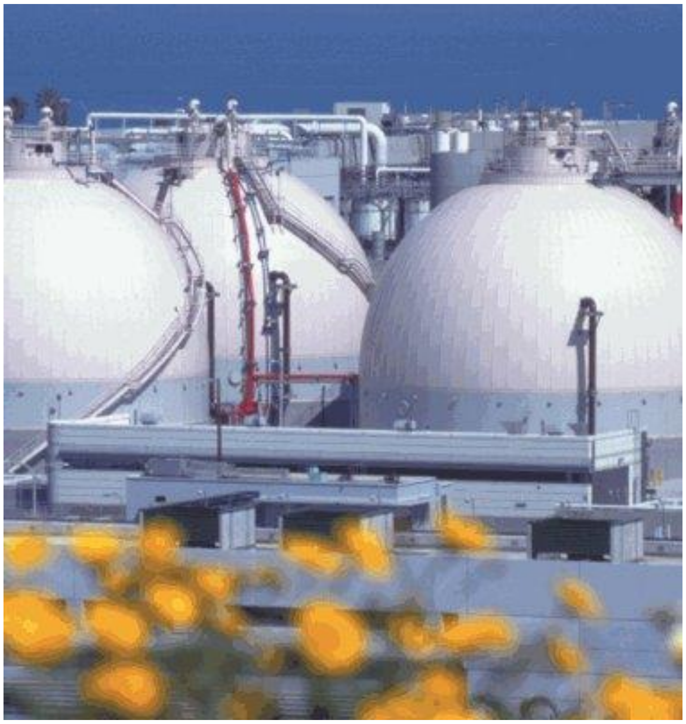

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Executive Summary

In collaboration with the CalNEXT program, designed and implemented by Energy Solutions and funded by California utility customers, Alternative Energy Systems Consulting (AESC) has performed a market characterization of the various California Senate Bill No. 1383 (SB1383) Landfill Diversion compliance solutions under consideration or are in planning by wastewater treatment facilities. The State's vast network of operating facilities within the investor-owned utilities (IOU) territories offer significant untapped potential for process-based energy savings and load optimization related to both existing operations, planned expansions, and capital investments as a result of these legislative changes. In this characterization effort, AESC has worked with industry partners and solutions providers to classify compliance strategies by plant size, treatment type, and other key drivers/limitations, and characterize each in terms of relative energy consumption, demand response (DR), and load management potential and fit, biogas generation/cogeneration impacts, carbon impacts, trucking/transportation impacts, creation of beneficial byproducts and other co-benefits.

The legislation governs the disposition of the approximately 675,000 dry metric tons (DMT) of biosolids developed annually targeting a reduction in short-lived climate pollutants (methane, hydrofluorocarbon) that are a byproduct of various disposal methodologies. Additionally, CalRecycle, in consultation with the California Air Resources Board (CARB), has established a statewide target for reducing and redirecting organic waste in landfills by approximately 27 million tons by 2025. This builds upon the existing US Environmental Protection Agency (EPA) Standards for the Use or Disposal of Sewage Sludge (Code of Federal Regulations Title 40, Part 503) which established the longstanding governance that the sector has operated under. Using a number of collaborative sources, the project team was able to inventory and classify the various biosolids management compliance strategies, including infrastructure improvements to enable enhanced treatment and process control, existing drying and caking strategies, regional solutions, and emerging technologies and strategies.

The study developed an understanding of the sources and characteristics of the solids under management at the facilities prior to individualized discussion of the common standard practice processing operations as it pertains to various process operations, including pumping systems, screening and grinding, degritting, blending and storage, conditioning and thickening, stabilization, dewatering, and final disposal. While there are several options for diverting organic materials from landfill disposal, it is expected that composting and anaerobic digestion facilities will manage the bulk of the materials, and market apportionment will grow in the coming years. The analysis of the waste sector, state government, and local government progress towards meeting the diversion goals indicates that organics recycling, and recovery infrastructure was growing but still needed significant expansion to provide the recycling capacity necessary to meet the disposal and methane reduction goals. To attain compliance in a more economical manner than traditional approaches, emerging technologies including vacuum filter presses, solar dryers, and advanced composting/pyrolysis have been explored for potential applications. These types of systems have benefits of energy efficiency, as well as non-energy benefits including reduced hauling costs, greenhouse gas emissions, operations and maintenance burden, and reliance on third-party sources amongst many others.

As it pertains to energy allocation, it is estimated that approximately 3,500 GWh of energy is used by the wastewater sector annually (approximately two percent of the total State's energy consumption), with an estimated existing burden of 525 GWh to solids handling and processing systems. In a survey of a number of facilities, a range of 13 to 60 percent of a total treatment facility's energy usage can be attributed to solids handling dependent upon configuration and technologies in place. In a case study of a medium-sized facility, a 90 percent reduction in energy consumption can be displaced with the utilization of an emerging technology, along with significant reductions in other ancillary operating costs. The market potential for similar optimization and displacement strategies is significant at an estimated 76.4 GWh/year and 454.6 GWh/year, respectively throughout the State.

To further substantiate the findings, a market survey of 31 facilities was conducted to better understand what the sites are currently doing to handle solids in their process, changes (if any) being made to maintain compliance with SB1383 requirements, impact (if any) these changes will have on process/energy footprint, technologies being explored to reduced process/energy impacts, and challenges being faced. Furthermore, quantitative data regarding production volumes, hauling and tipping costs, biosolids classification, solids characteristics, and disposal mileage were gathered for a number of facilities. A high percentage of sites (26 of 31) currently use mesophilic anaerobic digestion, with a number of facilities reporting use of more than one method including both on-site treatment and treatment that occurs after hauling to an offsite facility. As it pertains to dewatering technologies, the most common technology, likely due to the low operating cost, was belt filter presses (14 agencies), with centrifuges (nine agencies) and drying beds (six agencies) also being common. For final reuse and disposal, a majority of the dry solids developed are distributed as landfill alternative daily cover (ADC) (38 percent) and land application (30 percent), with 14 agencies utilizing the former and 16 the latter. Composting facilities have the longest one-way distance from facilities, at a median distance of 126 miles, with land application second at 112 miles due to the proximity of these facilities generally being located outside of populated areas where the treatment facilities are located. In response to readiness for SB1383, many agencies (17 of 31) are still planning for compliance or have in-progress efforts for compliance, while six have already completed preparations. Of those surveyed, seven already employ strategies that are in compliance with the legislation and are not impacted. Common trends include additional reliance on land application uses (11 agencies), or an increased diversion to third-party facilities for additional treatment (nine agencies).

Several market stakeholders are involved in preparations and implementation of SB1383, and a conceptual model for a decision support tool has been developed for use in navigating compliance and capital investment. The recommendation for agencies is to develop a comprehensive biosolids management plan that explores current and future requirements, in addition to implementing an energy management practice as part of the selection and operation of these facilities to maximize the operational benefits and limit exposure to volatile market conditions in the future. While SB1383 presents a challenge to the existing infrastructure, it also presents a unique opportunity for the wastewater sector to act as a resource in meeting the State's ambitious goals.

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Abbreviations and Acronyms

Acronym	Meaning
40 CFR Part 503	EPA Sludge Regulations
ADC	Alternative Daily Cover
AESC	Alternative Energy Systems Consulting
BNR	Biological Nutrient Removal
BOD	Biological Oxygen Demand
BTU	British Thermal Unit
CARB	California Air Resources Board
CASA	California Association of Sanitation Agencies
COGEN	Cogeneration Plant
CWEA	California Water Environment Association
DAC	Disadvantaged Communities
DMT	Dry Metric Tons
DR	Demand Response
EE	Energy Efficiency
EPA	Environmental Protection Agency
ET	Emerging Technology
GHG	Greenhouse Gas
HFC	Hydrofluorocarbon
IOU	Investor-Owned Utilities
MBR	Membrane Bioreactor
MBBR	Moving Bed Bioreactor

Acronym	Meaning
MGPD	Million Gallons per Day
MLSS	Mixed Liquor Suspended Solids
MSO	Molten Salt Oxidation
NPDES	National Pollutant Discharge Elimination System
O&M	Operation and Maintenance
OWM	Office of Wastewater Management
ODX	Oxidation Ditch
POTW	Publicly Owned Treatment Works
PG&E	Pacific Gas & Electric
PFOS/PFAS	Perfluorooctanesulfonic acid
PSI	Pound per Square Inch
RNG	Renewable Natural Gas
RP	Recycled Plant
SBR	Sequencing Batch Reactor
SB1383	Senate Bill 1383
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SRT	Solids Retention Time
SSDML	Sewage Sludge Digestion and Metal Leaching
SWRCB	State Water Resources Control Board
TPD	Ton per Day
VAR	Vector Attraction Reduction
VS	Volatile Solids

Acronym	Meaning
VSR	Volatile Solids Reduction
WAS	Wastewater Sludge
WEF	Water Environmental Federation
WERF	Water Environment Research Foundation
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant

Introduction

California has approximately 900 wastewater treatment plants (WWTP) within the investor-owned utilities (IOU) territories and offers utilities significant untapped potential for process-based energy savings and load optimization related to both existing operations, planned expansions, and capital investments. One key driver of near-term capital investments is related to California's Senate Bill No. 1383 (SB1383) Landfill Diversion legislation compliance. To limit short-lived climate pollutants, wastewater treatment plants in California will face restrictions in the final disposal of solids developed in the treatment process, mainly to anaerobic digestion and/or composting end-uses for land application in an effort to divert the landfill disposition of organics. California currently has 160 permitted composting facilities and more than a dozen anaerobic digestions facilities and with a pending compliance deadline, impacted plants are currently considering the costs and benefits of various compliance solutions, which can include investment in onsite biosolids[1] management technologies and strategies, and process changes required to achieve targeted levels of moisture content and treatment, as well as regional collaborative concepts. Each of these compliance solutions comes with significant energy, cost, carbon, and non-energy implications and trade-offs that are burdensome on plants, especially understaffed small, medium, and rural agencies, and those in disadvantaged communities.

Alternative Energy Systems Consulting (AESC) has performed a market characterization of the various SB1383 compliance solutions under consideration or are in planning by WWTPs in California of various sizes and operational characteristics. The project team has worked with industry partners and solutions providers to classify compliance strategies by plant size, treatment type, and other key drivers/limitations, and characterize each in terms of relative energy consumption, demand response (DR) and load management potential and fit, biogas generation/cogeneration impacts, carbon impacts, trucking/transportation impacts, creation of beneficial byproducts and other co-benefits.

Background

In California, the network of treatment facilities manages roughly four billion gallons of wastewater generated throughout the state each day, and process and dispose of approximately 675,000 dry metric tons (DMT) of biosolids annually. SB1383, signed into law in September 2016, aimed to develop and implement a comprehensive strategy to reduce emissions of short-lived climate pollutants to achieve a reduction in methane and hydrofluorocarbon (HFC) gases by 40 percent, and anthropogenic black carbon by 50 percent below 2013 levels by 2030. These pollutants have been identified as powerful climate forcers that have a dramatic and detrimental effect on air quality, public health, and climate change and many times more potent than that of carbon dioxide. Additionally, the bill established a statewide target for reducing organic waste in landfills, with the goal of a 50 percent reduction from the 2014 levels by 2020, and 75 percent by 2025. CalRecycle,

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[1] The term biosolids, as defined by the Water Environment Federation (WEF), refers to any sludge that has been stabilized to meet the criteria in the US Environmental Protection Agency's (EPA) 40 CFR 503 regulations, while the term sludge is only used before beneficial use criteria have been achieved.

in consultation with the California Air Resources Board (CARB), was tasked with developing regulations to meet these diversion requirements. CalRecycle estimates that approximately 27 million tons of organic material will need to be redirected from landfills by 2025, including edible food and approximately 18 million tons of organic waste that will need to be processed at compost, anaerobic digestion, chip-and-grind, or other processing facilities. CalRecycle, 2020)

Organic waste, as defined by SB1383, are solid wastes containing material originated from living organisms and their metabolic waste products including, but not limited to, food, green waste, paper products, biosolids, digestate, and sludges. CalRecycle estimates the State currently landfills approximately 20 to 23 million tons of organic waste annually, which accounts for roughly two-thirds of the State's overall waste stream and approximately 20 percent of the methane generated within the State. To meet the reduction goals set forth by SB1383, this disposal rate will need to be no more than 5.7 million tons by 2025, which will allow the avoidance of four million metric tons of CO_2 equivalent annually. In addition to the methane reduction potential, diverted disposal of organic wastes to beneficial reuses may demonstrate ancillary benefits of soil health, food security, climate stabilization, and is a critical tool in achieving California's goal for carbon neutrality by 2045.

In addition to SB1383, in 1993 the US Environmental Protection Agency (EPA) developed Standards for the Use or Disposal of Sewage Sludge (Code of Federal Regulations Title 40, Part 503), which establish pollutant limitations, operational standards for pathogen and vector attraction reduction, management practices, and other provisions intended to protect public health and the environment from any reasonably anticipated adverse conditions from potential waste constituents and pathogenic organisms. Building on this, in July 2004, the State Water Resources Control Board adopted Water Quality Order No. 2004-12-DWQ (General Order) and certified a supporting statewide Programmatic Environmental Impact Report (PEIR). The General Order incorporates the minimum standards established by the Part 503 Rule and expands upon them to fulfill obligations to the California Water Code. However, since California does not have delegated authority to implement the Part 503 Rule, the General Order does not replace the Part 503 Rule. The General Order also does not preempt or supersede the authority of local agencies to prohibit, restrict, or control the use of biosolids subject to their jurisdiction, as allowed by law. In general, the rule classifies biosolids into two categories: Class B and the higher-quality Class A. Though there are only two major classes in the policy, each has subclasses or "options" that are part of a more complicated matrix. A simplified version of this is found in Table 1 below. The main difference between Class A and Class B biosolids is that the former does not register any pathogens while complying with the most stringent limits for pollutants.

Table 1: Common Types of Sludge Disposal

	Class A	Class B
Subclasses	Exceptional Quality (EQ) Pollutant Concentration (PC) Cumulative Pollutant Loading Rate (CPLR) Annual Pollutant Loading Rate (APLR)	Pollutant Concentration (PC) Cumulative Pollutant Loading Rate (CPLR)
For Land Application		
Pathogen Reduction	Pathogen levels should be below detectable limits 24 hours after treatment or at the point of application Faecal Coliform: <1000 Most Probable Number (MPN)/g of dry solids (DS) Salmonella Sp.: <3 MPN/ 4g of dry solids (DS)	May contain pathogens up to certain levels. Animal grazing, crop harvesting, and public access are forbidden until environmental conditions have further reduced pathogens. Fecal Coliform: <2,000,000 MPN/g of dry solids (DS)
Pollutant Limits (Heavy Metals)	Should abide by limits for ten trace metals (varies per option/type): Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Molybdenum, Nickel, Selenium, and Zinc	
Vector Attraction Reduction	>38% volatile solids reduction should be observed* OR any 1 of 9 other options must be met (specified in the rule)	
Land Application Sites	EQ, APLR: allowed on all CPLR, PC: all except lawns and home gardens	All except lawns and home gardens
For Surface Disposal		
Pathogen Reduction	Must meet same Class A or Class B requirements as in Land Application OR have a daily cover over the active biosolids unit	
Pollutant Limits (Heavy Metals)	If no liner and leachate system: should abide by limits for three trace metals or approved site-specific limit (based on the distance of biosolids to site boundary): Arsenic, Chromium, and Nickel If with liner and leachate system: no limits Methane gas must be measured at site and site boundary	
Vector Attraction Reduction	>38% volatile solids reduction should be observed* OR any 1 of 6 other options must be met (specified in the rule)	
For Inceneration		
Pollutant Limits (Heavy Metals)	Should abide by limits for seven trace metals before incineration: Arsenic, Beryllium, Cadmium, Chromium, Lead, Mercury, and Nickel Should abide by limits for emissions (including total hydrocarbons or carbon monoxide)	
Other Requirements	EQ: None APLR: Labeling PC, CPLR: Management practices in the rule must be followed	Management practices and site restricitions in the rule must be followed.

Source: (Cambi)

Objectives

The SB1383 Compliance Characterization Report is designed to identify and characterize current practices and technologies utilized to stabilize, reuse, and dispose of wastewater biosolids in accordance with State and Federal regulations. The focus of this emerging technology study is on the impact of the SB1383 regulations as it pertains to the wastewater treatment sector, including the changes to disposal requirements, availability to supplement the State's available capacity for landfill diversion, emerging technologies, and impact to the energy profile of the sector.

This report will outline current practices and identify future solutions designed to meet California SB1383 that took effect in 2022 and Environmental Protection Agency (EPA) Part 503. The objectives of this study are the following:

- Survey current biosolids management practices in California's WWTPs and their energy implications related to SB1383 compliance.
- Characterize pre- and post- SB1383 biosolids management strategies by plant size, treatment type, and other operational characteristics.
- Propose an industry standard practice baseline for biosolids management under SB1383 compliance to help prioritize emerging technology focus areas, establish market size and energy savings potential, and inform future measure and workpaper development efforts.
- Compare SB1383 compliance solutions in terms of relative energy consumption, demand response (DR) and load management potential and fit, biogas generation/cogeneration impacts, carbon impacts, trucking/transportation impacts, creation of beneficial byproducts, and other co-benefits.
- Create an SB1383 compliance decision support tool for utility account representatives, consultants, and other industry stakeholders that will inform SB1383 compliance decisions.
- Characterize key drivers and market players that will inform final decisions.

Methodology & Approach

The team at AESC utilized extensive knowledge and hands-on experience in biosolids management to aid in the development of this characterization study. In addition, the team has researched trade sources, reviewed regulations, and interviewed wastewater treatment facility staff and manufacturers to understand and define the current state of biosolids management in the California utilities industry. Using these collaborative sources, the project team was able to inventory and classify the various biosolids management strategies available to various WWTPs to comply with SB1383, including infrastructure improvements to enable enhanced treatment and process control, existing drying and caking strategies, regional solutions, and emerging technologies and strategies. Based on the market stratification and initial treatment methodology characterization effort, the team developed a survey design and strategy to assess what WWTP are currently doing for biosolids management, what they are planning or contemplating to meet SB1383 compliance if they are not compliant, technologies and strategies in practice and available, and specific areas of concern as it pertains to compliance with the legislation.

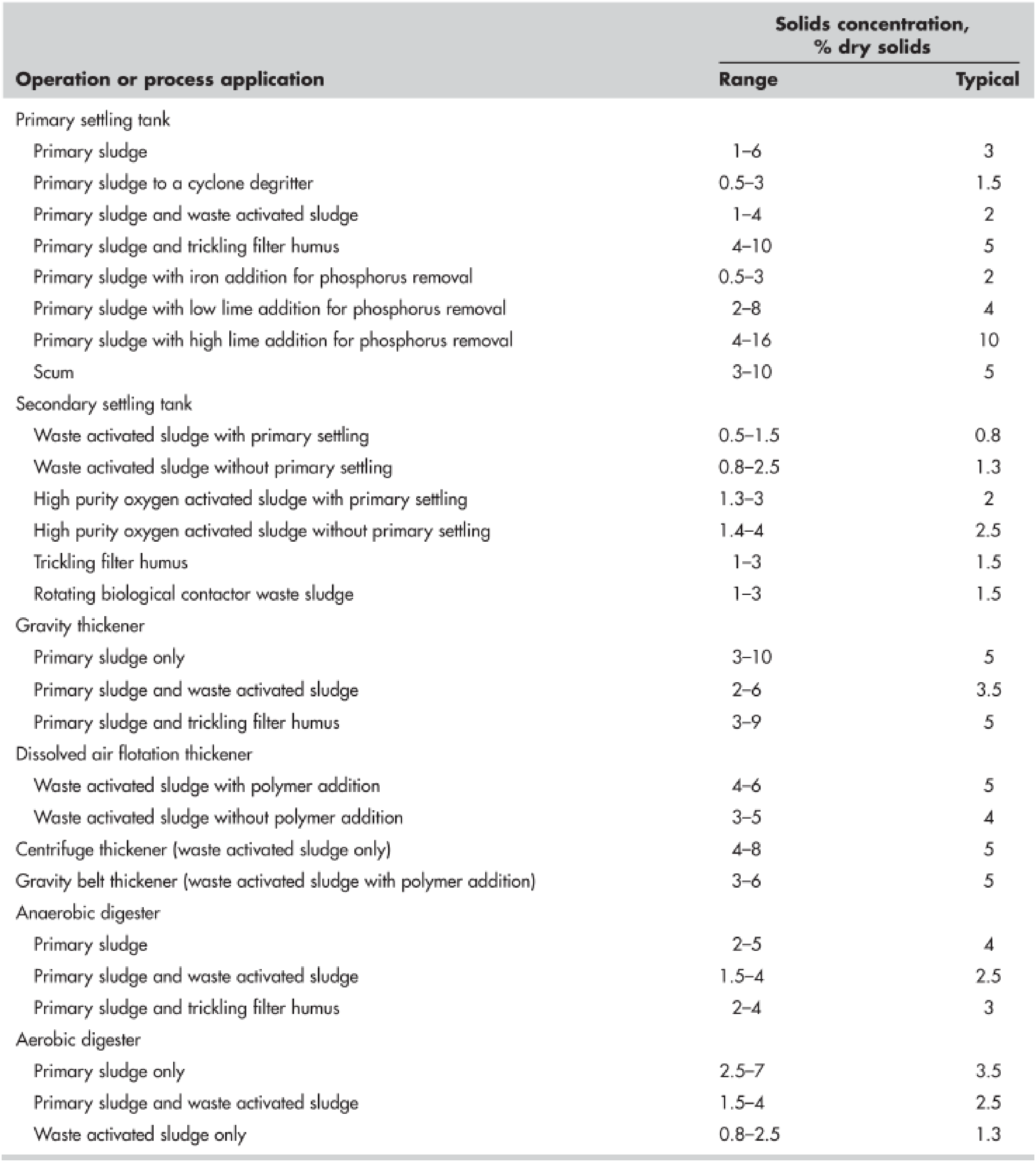
Findings

Process Overview

The handling of sludge and biosolids in the wastewater treatment process is a complex process that varies depending on the individual attributes and goals of the specific treatment facility. To further understand this, the study aimed to create a comprehensive account of the technology and treatment options available beginning at the source of the constituents, through the conveyance and processing, and final disposition of sludge and biosolids from WWTPs. The sections below summarize the existing biosolids management process in its current state.

Sources and Characteristics

The constituents removed and/or produced in treatment facilities include screenings, grit, scum, sludge, and biosolids. Of the constituents removed by treatment, sludge is by far the greatest in volume, and its processing, reuse, and disposition present a critical design requirement for WWTPs. The quantity and characteristics of the various sources vary significantly across the sector, with influences including the type of plant, method of operation, amount of aging, and the type of processing to which the sludge has been subjected. Examples of sources from common treatment processes include scum/grease, primary sludge, sludge from chemical precipitation, activated sludge, trickling filter sludge, aerobically digested biosolids, and anaerobically digested biosolids. The characteristics of various operations and process applications are provided in Figure 1 below, depicting changes in solids concentration (percent dry solids) and typical values found in the sector. These ranges and typical values are instrumental in the selection of processing operations as discussed in the proceeding sections to achieve the objectives of final disposal in accordance with relevant governing legislation.



Operation or process application	Solids concentration, % dry solids Range	Solids concentration, % dry solids Typical
Primary settling tank		
Primary sludge	1–6	3
Primary sludge to a cyclone degritter	0.5–3	1.5
Primary sludge and waste activated sludge	1–4	2
Primary sludge and trickling filter humus	4–10	5
Primary sludge with iron addition for phosphorus removal	0.5–3	2
Primary sludge with low lime addition for phosphorus removal	2–8	4
Primary sludge with high lime addition for phosphorus removal	4–16	10
Scum	3–10	5
Secondary settling tank		
Waste activated sludge with primary settling	0.5–1.5	0.8
Waste activated sludge without primary settling	0.8–2.5	1.3
High purity oxygen activated sludge with primary settling	1.3–3	2
High purity oxygen activated sludge without primary settling	1.4–4	2.5
Trickling filter humus	1–3	1.5
Rotating biological contactor waste sludge	1–3	1.5
Gravity thickener		
Primary sludge only	3–10	5
Primary sludge and waste activated sludge	2–6	3.5
Primary sludge and trickling filter humus	3–9	5
Dissolved air flotation thickener		
Waste activated sludge with polymer addition	4–6	5
Waste activated sludge without polymer addition	3–5	4
Centrifuge thickener (waste activated sludge only)	4–8	5
Gravity belt thickener (waste activated sludge with polymer addition)	3–6	5
Anaerobic digester		
Primary sludge	2–5	4
Primary sludge and waste activated sludge	1.5–4	2.5
Primary sludge and trickling filter humus	2–4	3
Aerobic digester		
Primary sludge only	2.5–7	3.5
Primary sludge and waste activated sludge	1.5–4	2.5
Waste activated sludge only	0.8–2.5	1.3

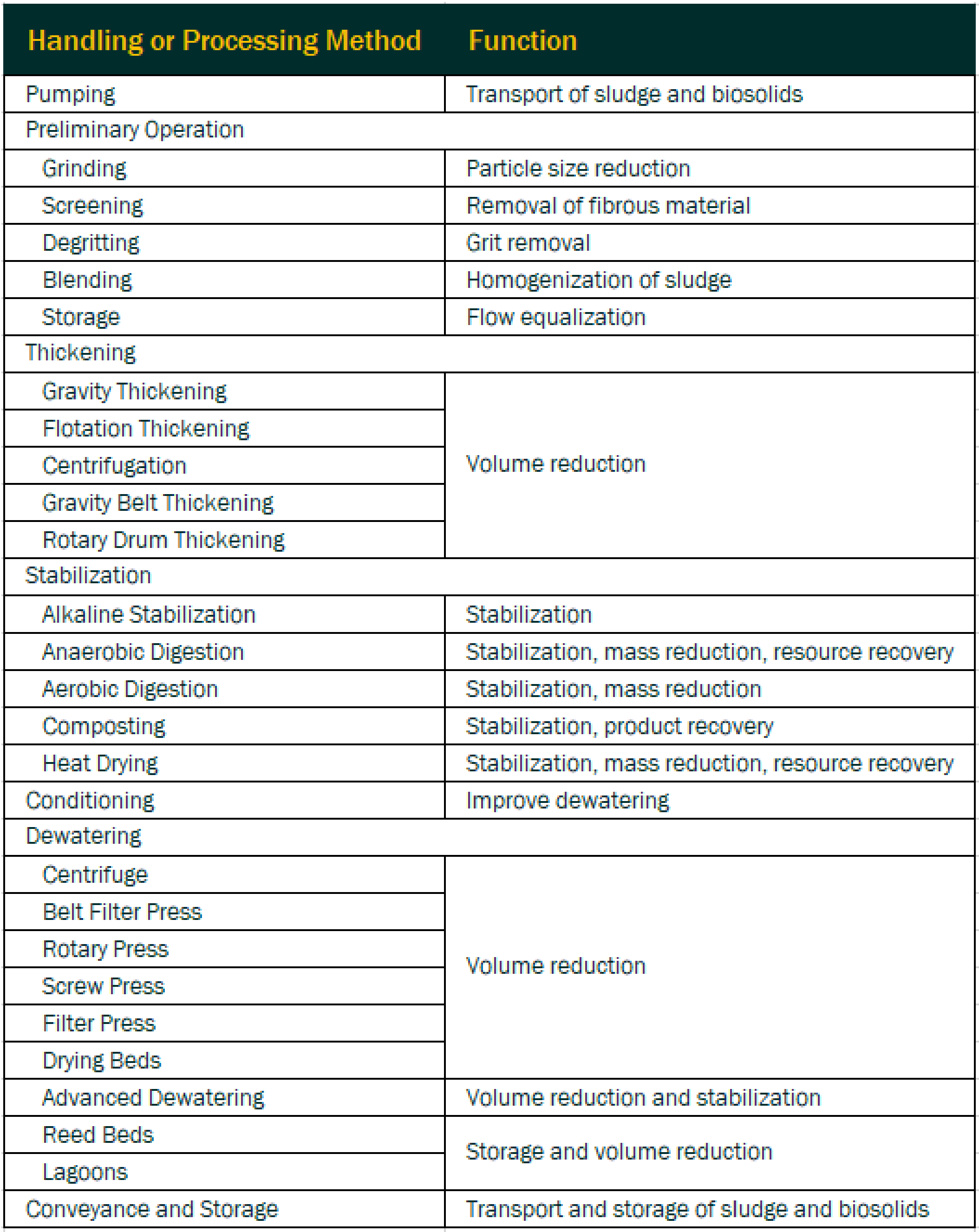
Figure 1: Characteristics of various operations and process applications at WWTPs

Source: (AECOM, 2014)

Sludge Processing Operations

The processing of sludge is often necessary to provide a relatively constant, homogenous feed to subsequent processing facilities, with various methods and functionality provided in Table 2: Handling or Process Method Functions below. An overview of the more common of these processes is provided in this section.

Table 2: Handling or Process Method Functions

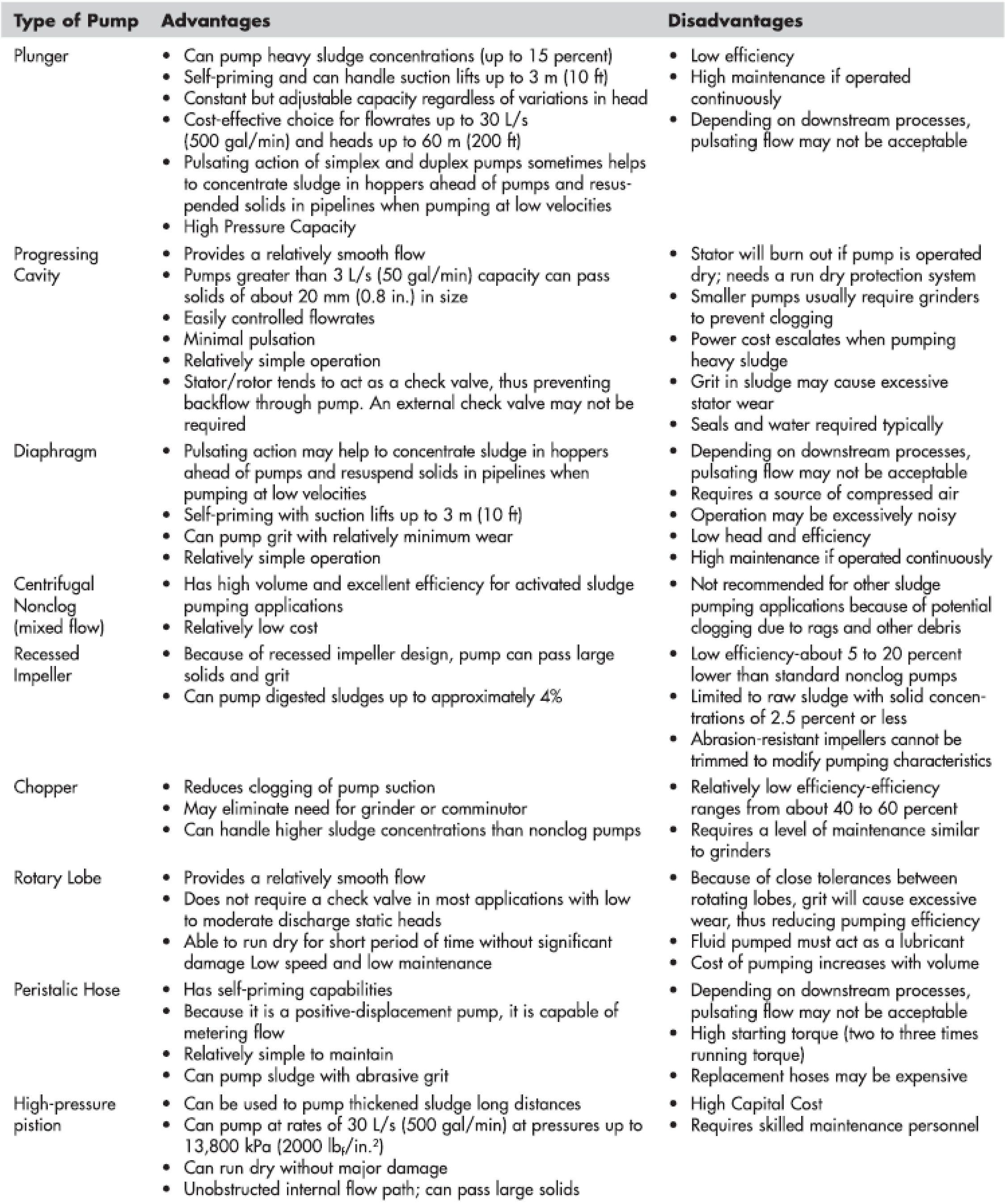


Handling or Processing Method	Function
Pumping	Transport of sludge and biosolids
Preliminary Operation	
Grinding	Particle size reduction
Screening	Removal of fibrous material
Degritting	Grit removal
Blending	Homogenization of sludge
Storage	Flow equalization
Thickening	
Gravity Thickening	Volume reduction
Flotation Thickening	
Centrifugation	
Gravity Belt Thickening	
Rotary Drum Thickening	
Stabilization	
Alkaline Stabilization	Stabilization
Anaerobic Digestion	Stabilization, mass reduction, resource recovery
Aerobic Digestion	Stabilization, mass reduction
Composting	Stabilization, product recovery
Heat Drying	Stabilization, mass reduction, resource recovery
Conditioning	Improve dewatering
Dewatering	
Centrifuge	Volume reduction
Belt Filter Press	
Rotary Press	
Screw Press	
Filter Press	
Drying Beds	
Advanced Dewatering	Volume reduction and stabilization
Reed Beds	Storage and volume reduction
Lagoons	
Conveyance and Storage	Transport and storage of sludge and biosolids

Source: (AECOM, 2014)

PUMPING

Sludge produced in the treatment facilities must be conveyed in various conditions from a more water-based slurry to a thick sludge. Many different pump types are used throughout the treatment process, each with their own advantages and disadvantages as outlined in Figure 2 below.



Type of Pump	Advantages	Disadvantages
Plunger	• Can pump heavy sludge concentrations (up to 15 percent) • Self-priming and can handle suction lifts up to 3 m (10 ft) • Constant but adjustable capacity regardless of variations in head • Cost-effective choice for flowrates up to 30 L/s (500 gal/min) and heads up to 60 m (200 ft) • Pulsating action of simplex and duplex pumps sometimes helps to concentrate sludge in hoppers ahead of pumps and resuspended solids in pipelines when pumping at low velocities • High Pressure Capacity	• Low efficiency • High maintenance if operated continuously • Depending on downstream processes, pulsating flow may not be acceptable
Progressing Cavity	• Provides a relatively smooth flow • Pumps greater than 3 L/s (50 gal/min) capacity can pass solids of about 20 mm (0.8 in.) in size • Easily controlled flowrates • Minimal pulsation • Relatively simple operation • Stator/rotor tends to act as a check valve, thus preventing backflow through pump. An external check valve may not be required	• Stator will burn out if pump is operated dry; needs a run dry protection system • Smaller pumps usually require grinders to prevent clogging • Power cost escalates when pumping heavy sludge • Grit in sludge may cause excessive stator wear • Seals and water required typically
Diaphragm	• Pulsating action may help to concentrate sludge in hoppers ahead of pumps and resuspend solids in pipelines when pumping at low velocities • Self-priming with suction lifts up to 3 m (10 ft) • Can pump grit with relatively minimum wear • Relatively simple operation	• Depending on downstream processes, pulsating flow may not be acceptable • Requires a source of compressed air • Operation may be excessively noisy • Low head and efficiency • High maintenance if operated continuously
Centrifugal Nonclog (mixed flow)	• Has high volume and excellent efficiency for activated sludge pumping applications • Relatively low cost	• Not recommended for other sludge pumping applications because of potential clogging due to rags and other debris
Recessed Impeller	• Because of recessed impeller design, pump can pass large solids and grit • Can pump digested sludges up to approximately 4%	• Low efficiency-about 5 to 20 percent lower than standard nonclog pumps • Limited to raw sludge with solid concentrations of 2.5 percent or less • Abrasion-resistant impellers cannot be trimmed to modify pumping characteristics
Chopper	• Reduces clogging of pump suction • May eliminate need for grinder or comminutor • Can handle higher sludge concentrations than nonclog pumps	• Relatively low efficiency-efficiency ranges from about 40 to 60 percent • Requires a level of maintenance similar to grinders
Rotary Lobe	• Provides a relatively smooth flow • Does not require a check valve in most applications with low to moderate discharge static heads • Able to run dry for short period of time without significant damage Low speed and low maintenance	• Because of close tolerances between rotating lobes, grit will cause excessive wear, thus reducing pumping efficiency • Fluid pumped must act as a lubricant • Cost of pumping increases with volume
Peristalic Hose	• Has self-priming capabilities • Because it is a positive-displacement pump, it is capable of metering flow • Relatively simple to maintain • Can pump sludge with abrasive grit	• Depending on downstream processes, pulsating flow may not be acceptable • High starting torque (two to three times running torque) • Replacement hoses may be expensive
High-pressure pistion	• Can be used to pump thickened sludge long distances • Can pump at rates of 30 L/s (500 gal/min) at pressures up to 13,800 kPa (2000 $\text{lb}_f/\text{in.}^2$) • Can run dry without major damage • Unobstructed internal flow path; can pass large solids	• High Capital Cost • Requires skilled maintenance personnel

Figure 2: Advantages and disadvantages of different types of pumps

Source: (AECOM, 2014)

SCREENING & GRINDING

Sludge grinding is the process of cutting or shearing larger material into small particles to prevent clogging or wrapping of rotating equipment. Utilization of grinders in the sludge treatment process is typically a low energy-intensive solution (<5-10HP) with benefits in the form of reduced equipment wear and operations and maintenance (O&M) costs associated with equipment upkeep. Furthermore, grinder pumps are a popular and efficient system designed to optimize grinding and pumping in collections systems, digester recirculation applications, return pumps, and similar applications. The grinder pump design utilizes a cutter blade to chop material as it passes through the system and the combination of grinding and pumping provides better pumping and energy efficiency by avoiding pump impeller fouling. The main grinder designs include:

- Twin-Shaft Grinders: Use intermeshing cutters on two counter-rotating shafts. Low-speed, high-torque gear driven. See Figure 3 below.
- Spherical (Hollow) Rotor: A single, rotating, hollow-centered, spherical rotor has cutting edges around its perimeter that intermesh with a stationary bar cage. Low-speed, high-torque, dual rotation.
- Rotate Plate and Knife: Solids pass through a perforated plate and are cut by a blade rotating at high speed. Best for light-duty applications.

Figure 3: Grinder

Source: (JWC Environmental, 2023)

Conversely, screening is also an important component of preliminary treatment in most wastewater treatment facilities. As raw sewage enters the facility it carries a large amount of solids including organic waste, inorganic waste, and anything disposed of into the sewer mains. The solids are uncontrolled and can cause major problems if allowed to enter the facility and are commonly removed from the waste stream by a headworks screen. There are several designs, styles, and technologies that remove solids from the waste stream, as well as levels of screening that can be achieved in the screening process. An example of this is depicted in Figure 4 below of a headworks screening system. The system is installed in the inlet channel of the facility and raw sewage passes through a series of vertical bars, perforated plates, or mesh wire screens. The system is designed to remove a certain size of solids and reduce BOD loading to the process.

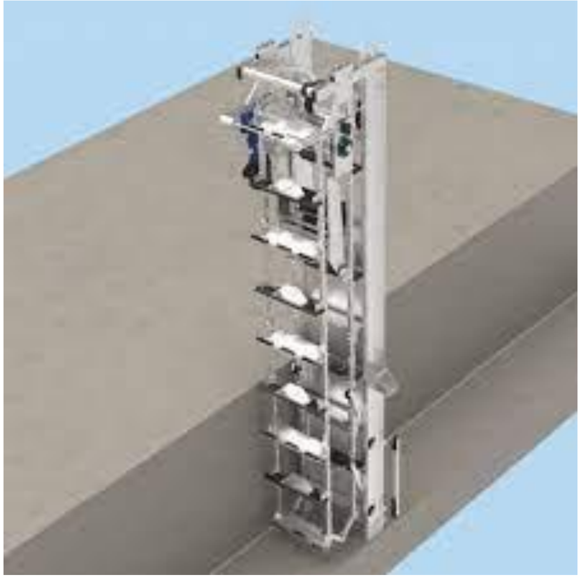


Figure 4: Headworks screening example

Source: (Parkson, 2017)

DEGRITTING

Removing grit is an important part of the overall treatment process at a wastewater treatment facility due to the abrasive nature of the material and the potential for downstream damage to pumps and valves, as well as deposits in pipelines and process vessels. The buildup of grit can also cause putrescible conditions that generate odors and can upset aerobic systems. Figure 5 below provides an overview of the common grit removal process flow from the separation of grit materials, washing, and dewatering along with products developed during the process. The separation of grit from wastewater is usually accomplished in separate grit chambers designed to physically separate heavy grit particles from lighter organic solids. Grit chambers are most often located after the bar screens and before the primary sedimentation tanks to prevent screening debris from impacting the operation and maintenance of the grit removal equipment. There are three general types of grit separation devices: horizontal-flow grit chambers, of either a rectangular or a square configuration, aerated grit chambers, or vortex grit chambers. As some of the heavier organic matter normally remains with the grit, washers are used to provide a second stage of volatile solids separation. Grit separated from the main wastewater flow is transported in a slurry to a washing process to remove organic material. The clean grit must then be dewatered to remove all free water prior to disposal to achieve clean, dry grit that is typically disposed of in landfills.

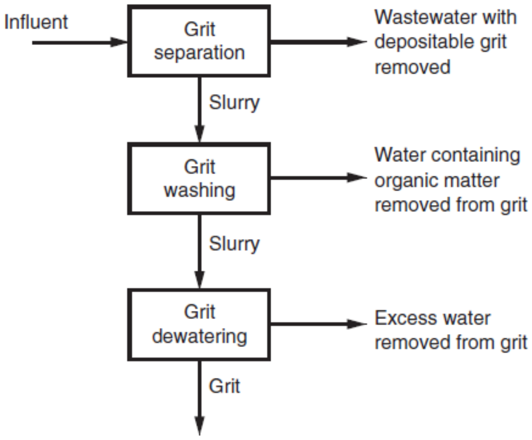


Figure 5: Degritting process flow

Source: (AECOM, 2014)

SLUDGE BLENDING & STORAGE

As previously discussed, sludge is generated in primary, secondary, and advanced wastewater treatment processes. Primary sludge consists of settleable solids carried in the raw wastewater, secondary sludge consists of biological solids as well as additional settleable solids, and sludge produced in the advanced wastewater processes may consist of biological and chemical solids. Sludge is blended in the process stream to produce a uniform mixture to downstream operations and processes. Sludge storage tanks are commonly used to fulfill this objective and aid in minimizing fluctuations in the rate of sludge and biosolids production and allow sludge to accumulate during periods when subsequent processing facilities are not operational (e.g., night shifts, weekends, and periods of equipment downtime). Short-term sludge and biosolids storage may be accomplished in settling or thickening tanks, while long-term storage may be accomplished in stabilization processes with long detention times (e.g., aerobic and anaerobic digestion, holding ponds, and lagoons). Supplemental aeration, mixing, ventilation, and odor control systems are often employed to prevent septicity and nuisance odors. Tanks that are not mixed or aerated can generate odors and cause an upset in the downstream processes. Figure 6 below provides an overview of a common application for blending and storage of sludge.

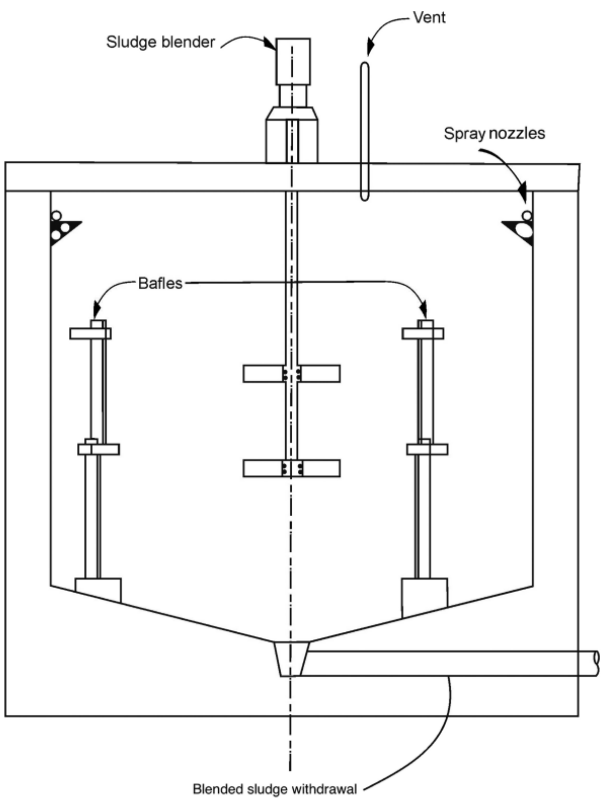


Figure 6: Example of sludge mixing and blending tank

Source: (Gurjar & Tyagi, 2017)

SLUDGE CONDITIONING & THICKENING

Sludge conditioning is the process of treating biosolids in preparation for thickening or removal of water with a primary goal to stabilize flocculation and coagulation. Technologies include heat, oxidation, chemical conditioning, freezing, electrical and ultrasonic treatment. Contaminants, including heavy metals, can interfere with conditioning and toxic substances should be identified prior to conditioning to avoid concentrating substances in the sludge.

Thermal conditioning occurs upstream of anaerobic digestion and is a high energy process that typically involves the operation of biogas, commercial gas, diesel fuel, and/or electricity fueled boilers to heat the sludge to the mesophilic temperature range. Sludge contains large volumes of cellular mass, and the biomass can contain water outside the cell wall, commonly referred to as bound water. Extreme heat and pressure can release the bound water and burst the cell wall to release the intercellular water. The net impact is a significant improvement in the dewaterability of the sludge.

Chemical conditioning involves dosing an iron or aluminum coagulant, ferric chloride, lime, and or organic polymer. The process for adequate chemical conditioning involves jar testing, trial and error, and proper chemical selection. A number of facilities experience changes in sludge quality throughout the year and must change chemical doses and chemical makeup to address the changing conditions. Selecting the best chemical involves trial and error and discipline to find the best combination of chemicals, application point, mixing, and conditioning to optimize the process. Chemical costs can be highly variable and budgeting for chemical costs can be challenging.

Thickening is the process of reducing water from biosolids by mechanical means with processes that include the following:

1. Co-settling Thickening: Primary clarifiers are often used to thicken sludge for downstream processing. To thicken the sludge, a sludge blanket must be created to consolidate the sludge without allowing the clarified water to be pulled through. Successful thickening of sludge in primary clarifiers has been achieved by a combination of the following: (1) using one clarifier in a bank of clarifiers for co-settling thickening; dilute sludge underflow (less than one percent solids) from the other clarifiers is discharged to the thickening clarifier, (2) maintaining the sludge inventory for about six to 12 hours, and (3) providing for the addition of coagulating chemicals such as polymer and ferric chloride to condition the sludge to enhance settling.
2. Gravity Thickening: Gravity thickening is one of the most common methods used and is accomplished in a tank similar in design to a conventional sedimentation tank. Normally, a circular tank is used, and dilute sludge is fed to a center feed well. The feed sludge is allowed to settle and compact, and the thickened sludge is withdrawn from the conical tank bottom.
3. Dissolved Air Flotation: In dissolved air flotation, air is introduced into a solution that is being held at an elevated pressure. A typical unit used for thickening waste activated sludge is shown in Figure 7 below. When the solution is depressurized, the dissolved air is released as finely divided bubbles carrying the sludge to the top, where it is removed.

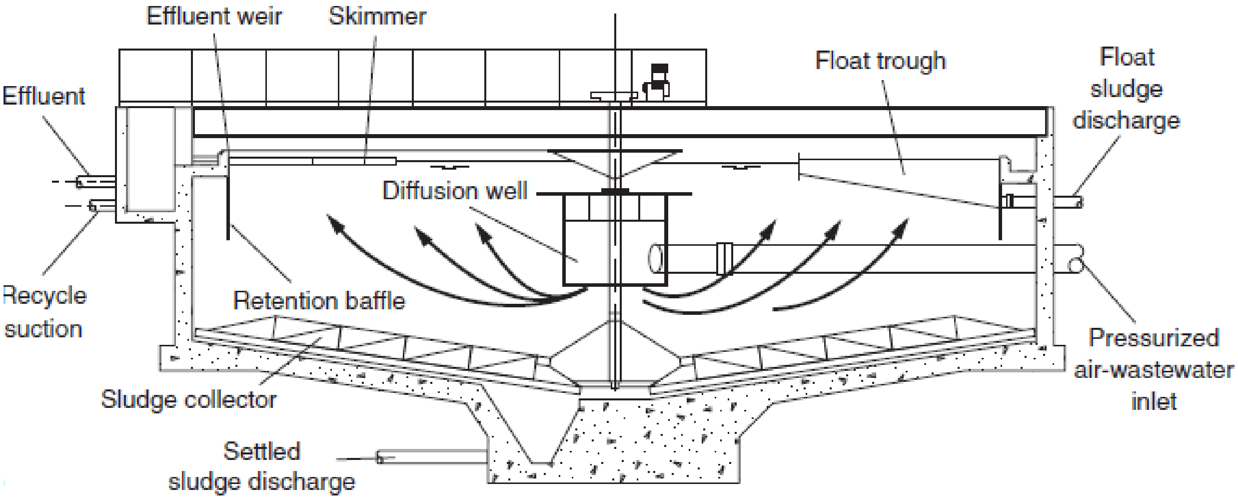


Figure 7: Typical dissolved air flotation thickener

Source: (AECOM, 2014)

4. Centrifugal Thickening: Centrifuges are used both to thicken and to dewater sludge, with thickening typically limited to waste activated sludge. Thickening by centrifugation involves the settling of sludge particles under the influence of centrifugal forces. The basic type of centrifuge used for sludge thickening is the solid bowl centrifuge, which consists of a long bowl, normally mounted horizontally, and tapered at one end. Sludge is introduced into the unit continuously, and the solids concentrate on the periphery. An internal helical scroll, spinning at a slightly different speed, moves the accumulated sludge toward the tapered end where additional solids concentration occurs, and the thickened sludge is discharged. See Figure 8 below.

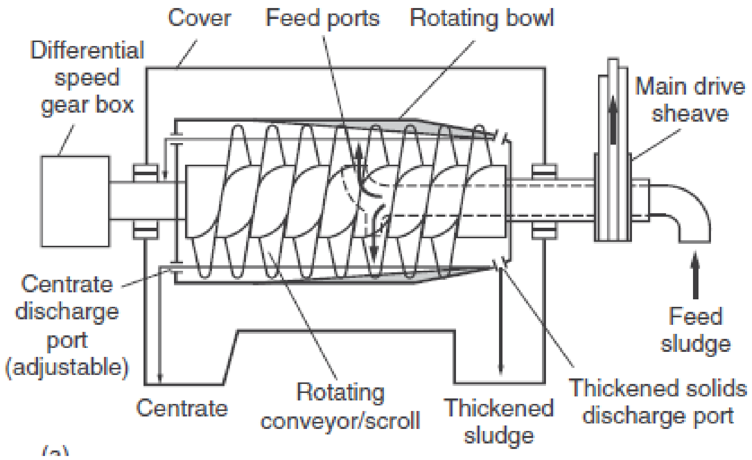


Figure 8: Typical centrifuge application

Source: (AECOM, 2014)

5. Gravity Belt Thickening: consists of a gravity belt that moves over rollers driven by a variable-speed drive unit. The sludge is conditioned with polymer and fed into a feed/distribution box at one end, where the sludge is distributed evenly across the width of the moving belt. The water drains through the belt as the concentrating sludge is carried toward the discharge end of the thickener. The sludge is ridged and furrowed by a series of plow blades placed along the travel of the belt, allowing the water released from the sludge to pass through the belt. After the thickened sludge is removed, the belt travels through a wash cycle. An overview of this process is provided in Figure 9 below.

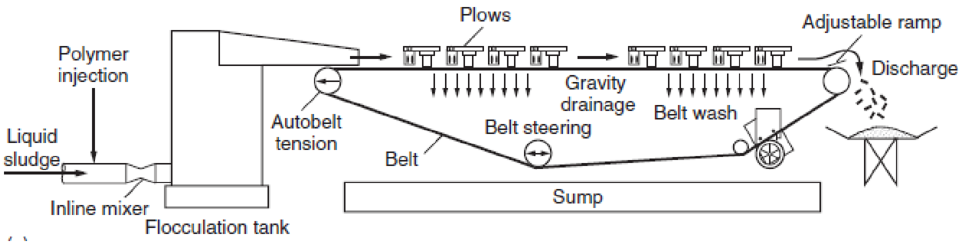


Figure 9: Typical belt filter press application

Source: (AECOM, 2014)

6. Rotary Drum Thickening: Consists of a conditioning system (including a polymer feed system) and rotating cylindrical screens. Polymer is mixed with dilute sludge in the mixing and conditioning drum. The conditioned sludge is then passed to rotating screen drums, which separate the flocculated solids from the water. Thickened sludge rolls out the end of the drums, while separated water decants through the screens.

STABILIZATION

Stabilization includes the processing of sludge to reduce pathogens, eliminate offensive odors, and inhibit, reduce, or eliminate the potential for putrefaction which occur when the microorganisms present are allowed to flourish in the organic fraction of the sludge. Stabilization is an energy and time intensive process that is used by most wastewater utilities for these principal health and aesthetic reasons, as well as volume reduction, production of usable gas (methane), and improved dewaterability. The type of system utilized in sludge stabilization is often based on final disposal objectives and region of the country.

Examples of stabilization processes include:

- Alkaline Stabilization: addition of an alkaline material, usually lime, to maintain a high pH level to affect the destruction of pathogenic organisms. This process results in a rich soil-like product with reduced pathogens, capable of producing a Class A product. A disadvantage is that the product mass is increased by the addition of the alkaline material.
- Anaerobic Digestion: the biological conversion of organic matter by fermentation in a heated reactor to produce methane gas and carbon dioxide in the absence of oxygen. Methane gas can be used beneficially for the generation of heat and/or electricity, with the resulting biosolids suitable for land application. The process requires skilled operation as it is susceptible to upsets and recovery is slow. See Figure 10 below for an example of a typical anaerobic digestion process.
- Aerobic Digestion: the biological conversion of organic matter in the presence of air (oxygen). This process is much simpler to operate than an anaerobic digester, but no usable gas is produced. This type of process is energy intensive because of the power requirement necessary for mixing and oxygen transfer.
- Autothermal Thermophilic Digestion: similar to aerobic digestion except higher amounts of oxygen are added to accelerate the conversion of organic matter, and the process operates at temperatures of 104-176°F. This process is capable of producing a Class A material; however, it requires skilled operators and is more energy intensive due to added oxygen requirements.
- Composting: biological conversion of solid organic matter in an enclosed reactor, windrows, or piles. This process requires the addition of a bulking agent to provide an environment suitable for biological activity, and the volume of compost produced is usually greater than the volume of wastewater sludge being composted. Composting is capable of producing Class A or Class B products; however, odor control is important to mitigate foul odors developed in this process.

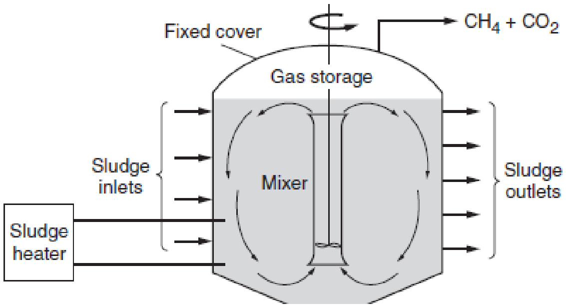


Figure 10: Example of anaerobic digestion stabilization process

Source: (AECOM, 2014)

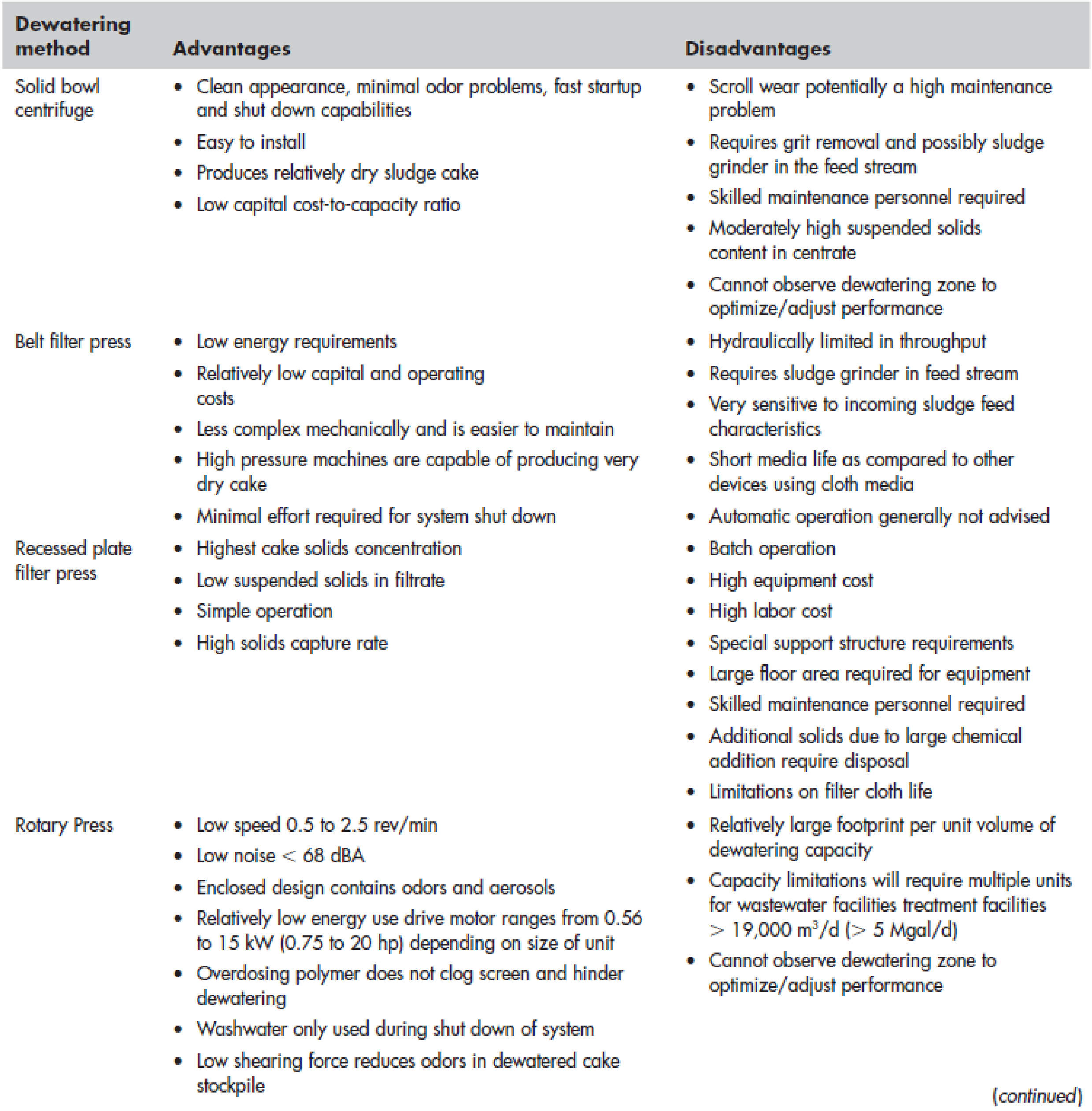
DEWATERING

Dewatering is used to separate the solid matter and water in the sludge or biosolids resulting in a high solids content stream referred to as “cake” and a liquid stream which contains fine, low-density solids and a high concentration of nutrients that is recycled to the treatment process (referred to as “side stream”). Increasing the solids content of sludge and biosolids is mainly practiced for one or more of the following objectives:

1. Reducing costs associated for trucking to the ultimate disposition site.
2. Ease the handling of sludge and biosolids using conventional shoveling, bucket/blade, and belt conveyance systems.
3. Required prior to incineration to increase the calorific value by removal of excess moisture.
4. Required before composting to reduce the requirements for supplemental building agents and amendments.
5. Required prior to thermal drying, as it is more cost-effective to remove the water mechanically compared to evaporating during drying.
6. Render biosolids odorless or non-putrescible.
7. Required prior to landfilling in monofils to reduce leachate production at the landfill site.

Dewatering of sludge can be achieved by several different methods, determined by the type of sludge or biosolids to be dewatered, characteristics of the dewatered product, downstream processing, ultimate disposition, and space constraints. Common technologies used for dewatering are provided in 3Table 3: Alternatives for Dewatering Technologies below, with advantages and disadvantages highlighted.

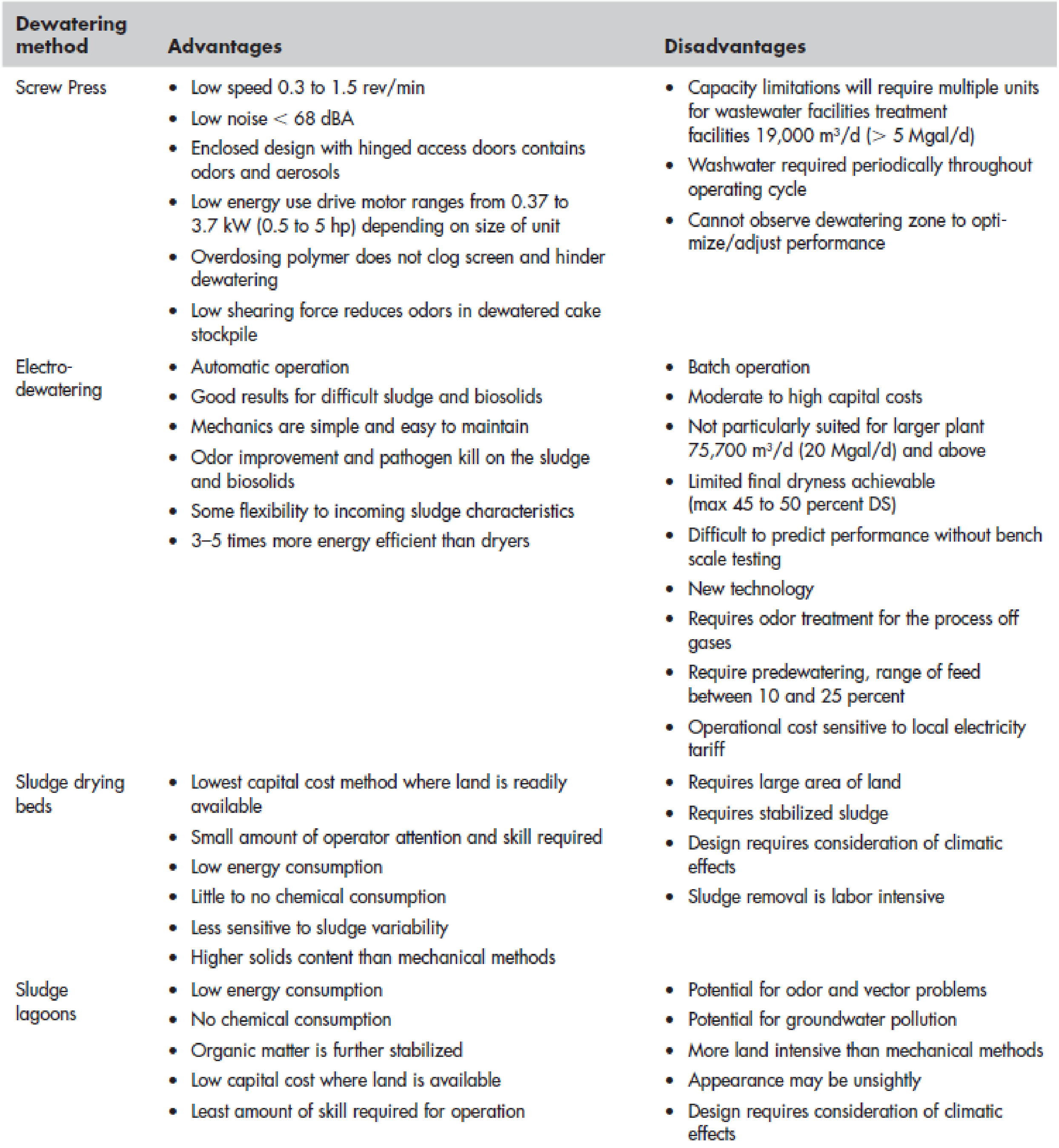
3Table 3: Alternatives for Dewatering Technologies



Dewatering method	Advantages	Disadvantages
Solid bowl centrifuge	• Clean appearance, minimal odor problems, fast startup and shut down capabilities • Easy to install • Produces relatively dry sludge cake • Low capital cost-to-capacity ratio	• Scroll wear potentially a high maintenance problem • Requires grit removal and possibly sludge grinder in the feed stream • Skilled maintenance personnel required • Moderately high suspended solids content in centrate • Cannot observe dewatering zone to optimize/adjust performance
Belt filter press	• Low energy requirements • Relatively low capital and operating costs • Less complex mechanically and is easier to maintain • High pressure machines are capable of producing very dry cake • Minimal effort required for system shut down	• Hydraulically limited in throughput • Requires sludge grinder in feed stream • Very sensitive to incoming sludge feed characteristics • Short media life as compared to other devices using cloth media • Automatic operation generally not advised
Recessed plate filter press	• Highest cake solids concentration • Low suspended solids in filtrate • Simple operation • High solids capture rate	• Batch operation • High equipment cost • High labor cost • Special support structure requirements • Large floor area required for equipment • Skilled maintenance personnel required • Additional solids due to large chemical addition require disposal • Limitations on filter cloth life
Rotary Press	• Low speed 0.5 to 2.5 rev/min • Low noise < 68 dBA • Enclosed design contains odors and aerosols • Relatively low energy use drive motor ranges from 0.56 to 15 kW (0.75 to 20 hp) depending on size of unit • Overdosing polymer does not clog screen and hinder dewatering • Washwater only used during shut down of system • Low shearing force reduces odors in dewatered cake stockpile	• Relatively large footprint per unit volume of dewatering capacity • Capacity limitations will require multiple units for wastewater facilities treatment facilities > 19,000 m^3/d (> 5 Mgal/d) • Cannot observe dewatering zone to optimize/adjust performance

(*continued*)

Source: (AECOM, 2014)



Dewatering method	Advantages	Disadvantages
Screw Press	• Low speed 0.3 to 1.5 rev/min • Low noise < 68 dBA • Enclosed design with hinged access doors contains odors and aerosols • Low energy use drive motor ranges from 0.37 to 3.7 kW (0.5 to 5 hp) depending on size of unit • Overdosing polymer does not clog screen and hinder dewatering • Low shearing force reduces odors in dewatered cake stockpile	• Capacity limitations will require multiple units for wastewater facilities treatment facilities 19,000 m³/d (> 5 Mgal/d) • Washwater required periodically throughout operating cycle • Cannot observe dewatering zone to optimize/adjust performance
Electro-dewatering	• Automatic operation • Good results for difficult sludge and biosolids • Mechanics are simple and easy to maintain • Odor improvement and pathogen kill on the sludge and biosolids • Some flexibility to incoming sludge characteristics • 3–5 times more energy efficient than dryers	• Batch operation • Moderate to high capital costs • Not particularly suited for larger plant 75,700 m³/d (20 Mgal/d) and above • Limited final dryness achievable (max 45 to 50 percent DS) • Difficult to predict performance without bench scale testing • New technology • Requires odor treatment for the process off gases • Require predewatering, range of feed between 10 and 25 percent • Operational cost sensitive to local electricity tariff
Sludge drying beds	• Lowest capital cost method where land is readily available • Small amount of operator attention and skill required • Low energy consumption • Little to no chemical consumption • Less sensitive to sludge variability • Higher solids content than mechanical methods	• Requires large area of land • Requires stabilized sludge • Design requires consideration of climatic effects • Sludge removal is labor intensive
Sludge lagoons	• Low energy consumption • No chemical consumption • Organic matter is further stabilized • Low capital cost where land is available • Least amount of skill required for operation	• Potential for odor and vector problems • Potential for groundwater pollution • More land intensive than mechanical methods • Appearance may be unsightly • Design requires consideration of climatic effects

Source: (AECOM, 2014)

FINAL DISPOSAL

Final disposal methods of biosolids for either beneficial or non-beneficial use is typically determined by availability, cost to transport materials, and governing regulations. Common practices include:

1. Land Application: Land application relates to biosolids reuse and includes all forms of applying bulk or bagged biosolids to land for beneficial uses at agronomic rates, i.e., rates designed to provide the amount of nitrogen needed by crop or vegetation while minimizing the amount that passes below the root zone.
2. Landfill Disposition: Includes disposition to monofils (sludge-only landfills) as well as sanitary landfills. The sanitary landfill method is most suitable if it is also used for disposal of other types of solid waste. In a true sanitary landfill, the waste is deposited in a designated area, compacted in place with a tractor or roller, and covered with a layer of clean soil. Biosolids can only be disposed of at permitted landfills and of the 128 permitted landfills located in California, 55 are permitted to accept biosolids for disposal with some landfills permitted for the disposal of biosolids not accepting biosolids on a routine basis. Alternatively, biosolids can be used as landfill alternative daily cover (ADC), which is used to cover and contain landfilled materials at the end of each day and is a critical part of vector control at landfills.
3. Incineration: Incineration involves the high-temperature burning of biosolids using a fuel supply such as natural gas or diesel fuel. The resultant ash is significantly lower in volume than the feedstock (biosolids) and thus higher in metals concentrations. The ash is typically landfilled. Incinerators require significant capital investment and have high operating costs. There are three operating facilities statewide, each with a very limited capacity relative to the total amount of biosolids produced statewide. Due to air quality regulations, permitting of additional facilities is not considered likely.
4. Composting: Biosolids can be composted using a bulking agent such as wood chips or co-composted with green materials. Producers who wish to compost either must contract with an existing permitted facility that has the capacity to accept additional material or put together the significant capital investment and operational outlay to fund the permitting, construction, and operation of a new facility.
5. Onsite Disposal: Surface disposal methods require large amounts of vacant land which is lined with an impermeable material prior to the implementation of disposal operations. Surface disposal is used on a limited basis by several wastewater treatment agencies and is not used on a widespread basis due to the dedicated land-area requirements.
6. Others: Include approaches to generate liquid fertilizer (Lystek) and biochar, typically employed as a district approach where a single facility receives biosolids from multiple surrounding agencies for processing at a single, third-party location. The Lystek Organic Materials Recovery Center (OMRC) located in Fairfield, California began processing biosolids to produce Class A-EQ liquid fertilizer in 2016 and has grown in popularity in the surrounding region.

A breakdown of the final disposal allocation for biosolids in California is shown in Figure 11 11below. Reuse via landfill ADC receives the largest amount of dry tonnage of biosolids in the region, followed by land application. Onsite disposal accounts for a large amount of wet tonnage, but a small amount of dry tonnage because of the low solids content. By number of agencies, land application is the most popular management strategy followed by landfill ADC. More agencies are expected to move away from landfill ADC and disposal in the future due to SB 1383 requirements, operating costs, haul costs, fuel costs, and sustainability challenges.

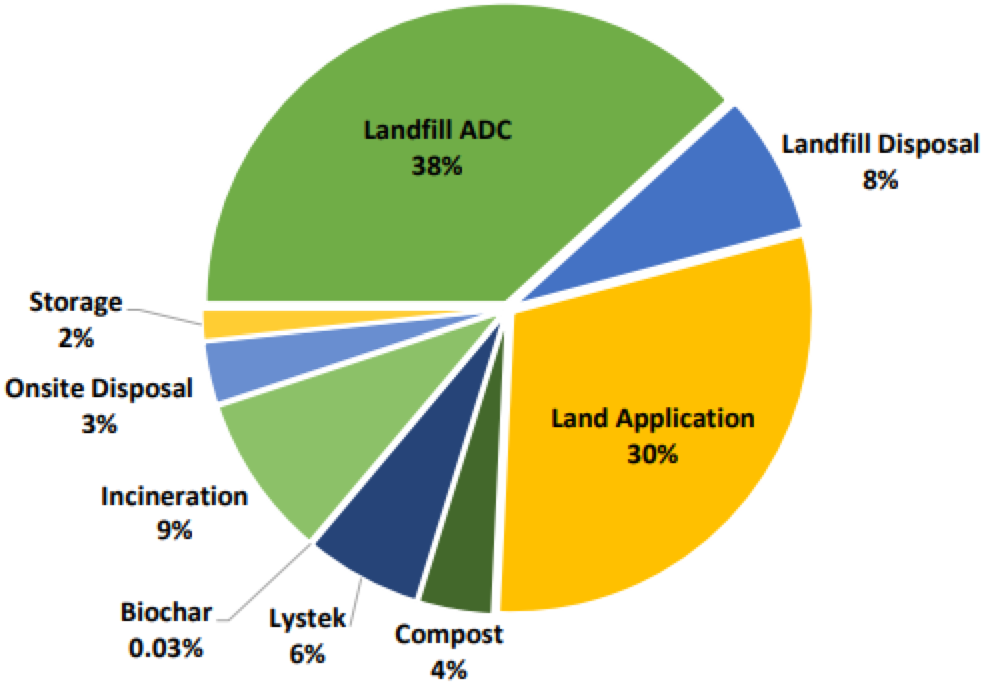


Figure 11 11: Biosolids use and disposal

Source: (Sustainable, 2021)

Existing SB1383 Compliant Technologies

While there are several options for diverting organic materials from landfill disposal, CalRecycle and Integrated Waste Management Consulting expect composting and anaerobic digestion facilities to manage the bulk of these materials. To reduce landfill disposal, the legislation further characterizes organic waste sent to facilities such as recycling centers, compostable material handling facilities, and biomass conversion facilities, provided that the organic waste is not subsequently disposed (Legislature, 2016). Below are examples of processes that are currently available to comply with SB1383. In 2020, CalRecycle conducted an analysis of the waste sector, state government, and local government progress toward meeting the 2020 and 2025 organic waste diversion goals. The high-level findings of the progress analysis indicated that organics recycling, and recovery infrastructure was growing, but still needed significant expansion to provide the recycling capacity necessary to meet the disposal and methane reduction goals. The available capacity expected in 2025 for predominant methods of diversion are provided in Table 4: Technologies below, which further demonstrates the State's need for additional capacity. (CalRecycle, 2020)

Table 4: Technologies

Technology	Estimated Anticipated Capacity, 2025 (tons)	Estimated Needed Capacity, 2025 (tons)	Difference (tons)
Compost	5.3	9.6	(4.3)
Anaerobic Digestion	1.0	2.7	(1.7)
Co-Digestion	0.21	2.4	(2.2)
Chipping & Grinding	3.5	3.3	0.2
Total	**10.0**	**18.0**	**(8.0)**

Source: (DaRosa, 2020)

Composting

Composting is the process of controlled aerobic decomposition of organic material. An estimated 6 million tons of organic waste was composted in 2017 with an existing capacity to compost an additional four million tons. Currently, there are approximately 180 compost facilities in California, many of which are small or operate under a tier that limits the type of feedstock they can accept (e.g., limited to agricultural materials). Since 2018, new and expanded compost facilities brought an additional 200,000 tons of annual capacity into operation statewide. Fourteen compost facilities are anticipated to begin operations for additional capacity of one million tons of organic waste recycling within the next few years. CalRecycle has awarded grants to 12 of these facilities. In March 2020, CalRecycle announced grant awards to an additional three compost facilities that are projected to add another 100,000 tons of capacity per year. (CalRecycle, 2020)

Stand-Alone Anaerobic Digestion

Anaerobic digestion is a biological process in which microorganisms break down biodegradable material in the absence of oxygen. It generates a solid material called biomass, as well as methane, carbon dioxide, and digestate as byproducts. A conventional anaerobic digester requires several ancillary systems. Prior to digestion, raw waste sludge is thickened, pumped to the digester for a minimum of 25 days, mixed and heated continuously, pumped to a break tank, mixed again, and finally pumped to dewatering equipment. Methane generated from this process, referred to as biomethane, can be used to produce electricity, heat, and low carbon transportation fuels, such as compressed renewable natural gas (RNG). CalRecycle estimates that approximately 350,000 tons of solid waste was recycled as fertilizer at stand-alone anaerobic digestion facilities in 2017 with a total capacity of approximately 400,000 tons. Since 2017, two facilities began operations with an estimated combined annual capacity of 90,000 tons and eight facilities are anticipated to begin operations with new or expanded capacity within the next few years, including three that received grants from CalRecycle. These facilities will bring an additional 850,000 tons of annual recycling capacity into operation within the next few years. Finally, in March 2020, CalRecycle announced grant awards to an additional three projects expected to add 300,000 tons of capacity per year. (CalRecycle, 2020)

Co-Digestion at Wastewater Treatment Plants

Co-digestion at WWTPs can help divert food and green waste from disposing in landfills, which contribute a significant volume of organic waste. California produces an estimated 5.5 million tons of food waste that is sent directly to landfills each year and it is one of the largest sources of methane gas emissions in the state. (Klerk, 2022). In 2017, approximately 26,000 tons of food waste were diverted from landfills and co-digested at three WWTPs. However, if fully utilized, these three facilities could manage an additional 74,000 tons of material. Six WWTPs are anticipated to start co-digesting food waste, which will bring an additional 140,000 tons of capacity online by 2025. The State Water Resources Control Board (SWRCB) estimates that California WWTPs have enough existing excess digester capacity to accommodate between 2.4 and 8.6 million tons of municipal food waste. This range reflects different assumptions regarding digester operating conditions, including system redundancy, varying retention times, and loading rates. Maximizing the use of excess capacity would require expanding the capacities of other key wastewater treatment components, such as biosolids dewatering, and biogas utilization systems. Using this existing infrastructure at WWTPs could reduce the number of new facilities that need to be built, and potentially significantly lower the capital investment needed to add new capacity.

Mandatory collection programs are critical for organics recycling and recovery infrastructure development and to help attract private investments. Facilities only expand when new collection programs are implemented or existing programs broaden, with a majority of facilities citing new processing contracts as a reason to enlarge their facility. The requirement in the SB 1383 regulations that jurisdictions implement mandatory organics collection programs for all organic waste generators is designed to facilitate organics processing infrastructure expansion and development. The collection of source-separated organic waste, and feedstock agreements between haulers and organic waste processing facilities, will help facilities justify the expenditures necessary to expand and develop additional capacity.

Emerging Technologies

Wastewater utilities are facing numerous challenges with rising chemical costs, unstable fuel prices, supply chain issues, labor shortages, and new and upcoming regulations such as SB1383 and polyfluoroalkyl substances (PFAS)[2] rules, which are not fully established yet. These new regulations and increasing costs are driving the demand for emerging technologies in the industry. However, the emerging technology adoption has been slow, with many technologies still being tested and piloted across California. As a result, most utilities are still processing wastewater sludge with out-of-date technologies that may not meet the new regulations in California. In addition, current technologies are high energy processes that require a significant footprint at the facility and disposal sites.

Thus, emerging technology is needed to increase capacity and to reduce energy impact. A number of new technologies are in the embryonic stage and pilot state of development. Some of the most

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[2] PFAS is a group of chemicals used in manufacturing of fluoropolymer coatings and products such as cleaners, leather, paper, textiles, fire-fighting foam and wire insulation. PFAS chemicals do not breakdown easily and can have significant health impacts to humans.

promising technologies that may address SB 1383, energy use, air emissions and PFOS/PFAS requirements include:

> Vacuum Filter Press Dryer: The technology uses a plate and frame press, vacuum and steam to dewater raw wastewater sludge to 95% dry solids. The system receives conditioned undigested waste sludge at three percent solids and in a single batch process delivers a dry material. The technology eliminates the requirement for digestion and saves a considerable amount of energy by displacing existing anaerobic digester ancillary equipment (when present) and conventional dewatering equipment. Greenhouse gas production is eliminated by the streamlined process and transportation, landfill fees and landfill utilization are dramatically reduced. Treatment of PFOS/PFAS is unknown at this time although this can be achieved in secondary processes if necessary.
>
> Solar Dryer: Concentrated solar thermal biosolids drying heats water to 121°C in parabolic trough collectors. The heated water is pumped through circulation pipes under the drying beds where waste sludge is distributed in a covered greenhouse. The system utilizes the energy from the sun and produces a 90 percent dry solids sludge. The system is somewhat passive and reduces the energy footprint, haul, and disposal costs of more conventional systems. Treatment of PFOS/PFAS is unknown at this time and will require further study.
>
> Advanced Composting/Pyrolysis: The advanced composting process is the first step in the process and can reduce volumes by 75 percent followed by the pyrolysis process that can take the dry solids content to 90 percent. The system can process green waste in combination with wastewater sludge and produce a biochar material that has secondary reuse qualities. Treatment of PFAS/PFOS is claimed to be achieved through the pyrolysis process and this could set this technology aside from other advanced technologies.

Energy Impacts

The energy requirements of wastewater treatment systems depend on the flowrate, the characteristics of the incoming raw wastewater, and the treatment process employed. Various types of electric motor-driven equipment are involved in these operations and processes including pumps, blowers, mixers, sludge collectors, and centrifuges. In conventional secondary treatment, most of the electricity is used for (1) biological treatment by either the activated sludge process that requires energy for aeration blowers or trickling filters that require energy for influent pumping and effluent recirculation; (2) pumping systems for the transfer of wastewater, liquid sludge, biosolids, and process water; and (3) equipment for the processing, dewatering, and drying of residuals and biosolids. Figure 1212 below represents end-use energy usages in a typical wastewater treatment facility.

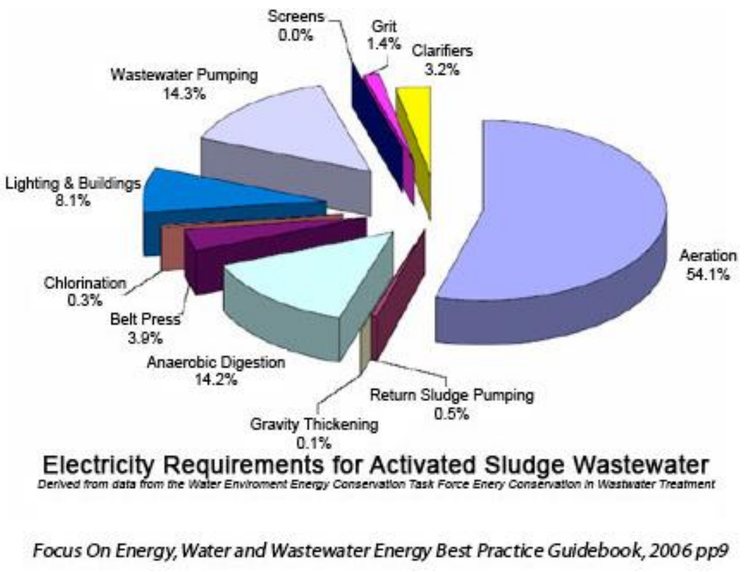

Figure 1212: Energy profile of sample sites

Source: (Focus on Energy, 2006, p. 9)

As it pertains to solids processing, common equipment requiring electric input include the aforementioned pumps, grinders, thickener drives, chemical feeders, mixers for digesters and blending tanks, aerators for aerobic digestors, dewatering technologies, and conveyance systems. Each of these have typical energy consumption requirements as outlined in Table 55 below. Ancillary equipment also commonly includes various odor control and air management systems due to the foul odors typically generated through this treatment process.

Table 55: Energy Consumption by WWT Process Technology

Technology	Energy Consumption (kWh/1,000 gal)
Sludge Pumping	0.003
Gravity Thickening	0.001-0.006
Aerobic Digestion	0.48-1.2
Mesophilic anaerobic digestion (primary plus waste activated sludge)	0.35-0.6
Mesophilic anaerobic digestion with thermal hydrolysis pretreatment (primary plus waste activated sludge)	0.58-0.6
Centrifuge	0.02-0.05
Belt Filter Press	0.002-0.005

Source: (AECOM, 2014)

Table 66 below demonstrates the energy allocation of the solids handling for sample sites surveyed as part of this study. As shown, the energy allocation fluctuates depending on volume (MGD) as well as technologies in place but generally accounts for approximately 15 to 20 percent of the total site usage. More energy intensive systems, such as autothermal thermophilic aerobic digestion systems require supplemental oxygen thus increasing the amount of energy spent on solids handling.

Table 66: Energy Analysis of Sample Sites

			Conditioning/Thickening/Dewatering						Stabilization			External Receiving		Cogeneration		
Capacity (MGD)	Solids Handling Energy (kWh/yr)	% of Total Site Usage	DAFT	Sludge Drying Beds/Lagoon	Rotary Drum Thickener	Screw Press	Belt Filter Press	Centrifuge	Anaerobic Digestion	Autothermal Thermophelic Aerobic Digestion	Multiple-Hearth Furnace	Food Waste Receiving	FOG Receiving	Heat Recovery	Energy Production	Steam Production
2.9	335,000	13%	X	X					X					X	X	
3.0	550,000	13%	X			X	X		X			X		X	X	
3.0	800,000	60%	X				X		X					X		
3.6	325,000	16%	X				X		X					X		
4.0	2,300,000	35%					X	X		X						
5.1	700,000	20%	X	X			X		X					X	X	
7.5	800,000	25%			X	X			X							
15.4	2,100,000	21%	X				X		X					X	X	
20.0	1,500,000	25%		X			X		X				X	X	X	
29.5	4,300,000	38%					X	X	X					X	X	
54.0	3,200,000	13%	X					X			X			X	X	X
80.0	7,800,000	15%	X				X	X	X				X	X	X	

Source: Project Team

Emerging technologies and proper energy management techniques can be employed to reduce the energy consumption for solids handling, as well as shifting the energy demand of the facility. Optimizing or displacing the need for tradiditonal stabilization practices such as digestion (anaerobic and aerobic) offers the most significant energy savings potential as these systems require substantial pumping, mixing, and air (aerobic systems). Emerging technologies that can be explored for this purpose include thermal vacuum drying, high-solids anaerobic digestion, compost drying and pyrolysis, as well as thermal hydrolysis, with each offering varying benefits of energy efficiency, reduced hauling costs, increased biogas generation, reduced footprint, etc. In an example of this, the replacement of the in-situ dewatering and stabilization practice at a 15.5 MGD facility with thermal vacuum drying technology offers the benefit of a reduction of approximately 550,000 kWh of energy (90 percent reduction), improved solids concentration to 95 percent, and reduction in hauling and chemical costs of approximately $250,000 annually.

Throughout the State, it is estimated that approximately 3,500 GWh of energy is used by the wastewater sector annually (approximately two percent of the total State's energy consumption), with an estimated existing burden of 525 GWh to solids handling. The optimization of these systems or displacement of traditional stabilization technologies has the potential to reduce this consumption significantly as demonstrated in

Table 77 below. It should be noted that the displacement of stabilization processes comes with the reduced value of cogeneration through the beneficial reuse of biogas, which is currently employed at approximately 151 facilities in California.

Table 77: Stabilization Process Energy Consumption

Process	Energy Consumption (GWh/yr)	Optimization Potential (GWh/yr)	Displacement Potential (GWh/yr)
Conveyance	2.3	0.3	-
Conditioning	2.7	0.4	-
Stabilization	490.3	73.5	441.2
Dewatering	14.9	2.2	13.4

Source: (Council, 2019)

Market Survey

In the state of California, there are approximately 250 wastewater treatment facilities that are considered “major” facilities, classified as having a daily average design flow of more than one million gallons per day. Data on the use and disposal of the solids produced by smaller facilities (<1 mgd) are generally lacking; however, most of these facilities only manage solids every five to 25 years, storing them for long periods of time in lagoons or similar applications. Thus, the major treatment facilities generally account for approximately 97percent of the total solids produced and reported in the State.

A market survey was conducted in February 2023 and was designed to better understand the current practices and challenges that utilities are currently facing. The survey aimed to understand what the sites are currently doing to handle solids in their process, changes (if any) being made to maintain compliance with 1383 requirements, impact (if any) these changes will have on process/energy footprint, technologies being explored to reduced process/energy impacts, and challenges being faced. Furthermore, quantitative data regarding production volumes, hauling and tipping costs, biosolids classification, solids characteristics, and disposal mileage were gathered for a number of facilities. The survey results represent 31 facilities operating in the State with varying daily average flows and treatment designs.

A high percentage of sites (26 of 31) currently use mesophilic anaerobic digestion, with a number of facilities reporting use of more than one method including both on-site treatment and treatment that occurs after hauling to an offsite facility as shown in Figure 13:13below. The primary use of anaerobic digestion as the principal method for stabilization is in line with the State apportionment based on 2018 data, which quantified approximately 615,000 of the 715,500, or roughly 90 percent, of the solids disposed of were treated via this method. This is due to the ancillary benefits of this processing method, which includes the beneficial reuse of biogas for heating and electric generation. Of the facilities, seven produce Class A solids, 23 produce Class B solids, with a single site incinerating solids, representing approximately 65,000 dry tons, 75,000 dry tons, and 20,000 dry tons, respectively.

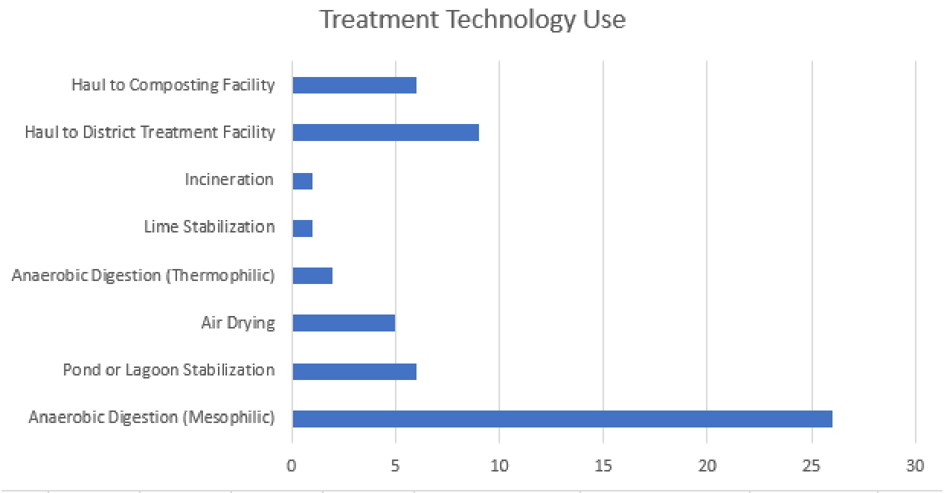

Figure 13:13 Treatment technology use for survey respondents

Source: (Agencies, 2021)

For dewatering, the sites use one or more technologies including belt filter presses, centrifuge, drying bed, screw press, rotary fan press, and storage lagoons. The most common technology, likely due to the low operating cost, was belt filter presses (14 agencies), with centrifuges (nine agencies) and drying beds (six agencies) also being common. These technologies were able to achieve high performance with regards to reducing the water volume, achieving median solids concentrations of 23 percent, 24 percent, and 64 percent, respectively as shown in **Error! Reference source not found.** b elow.

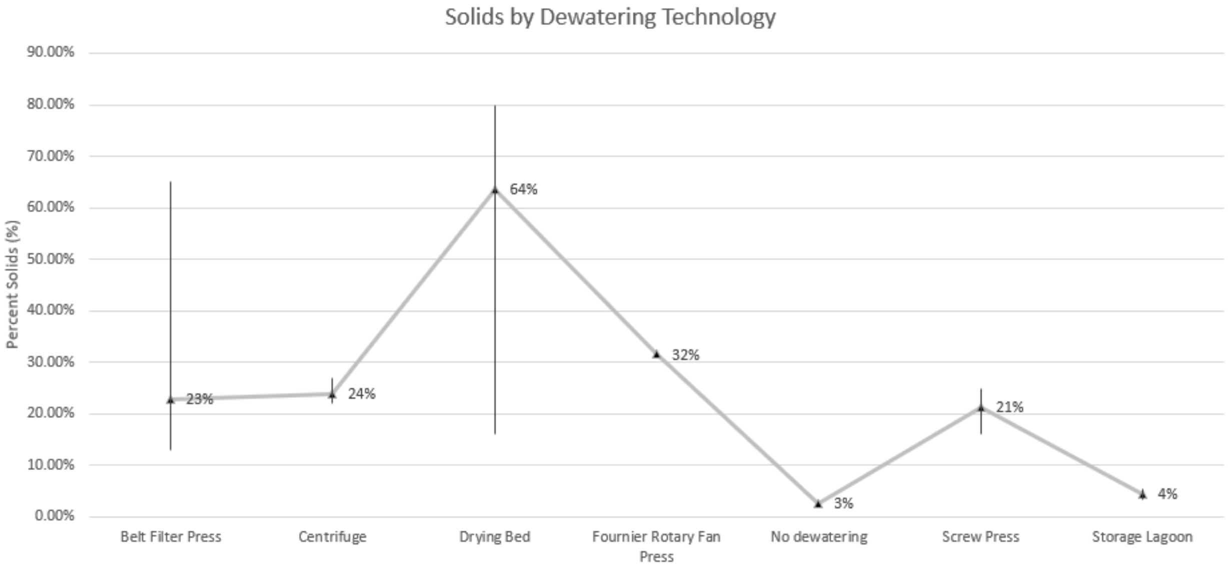

Figure 1414: Percent solids by dewatering technology

Source: (Agencies, 2021)

For final reuse and disposal, a majority of the dry solids developed are distributed as landfill ADC (38%) and land application (30 percent), with 14 agencies utilizing the former and 16 the latter. Conversely, the trends since 2015 demonstrate a reduction in sites disposing as landfill ADC, with an increase in land application and district approaches (Lystek) as shown in Figure 1515 and Figure 1616 below. The Lystek facility began processing biosolids in 2016 and produces Class A-EQ liquid fertilizer for use in land applications. The trend in reduction of landfilled biosolids and increase in beneficial reuse applications is expected to continue as a result of SB1383 requirements.

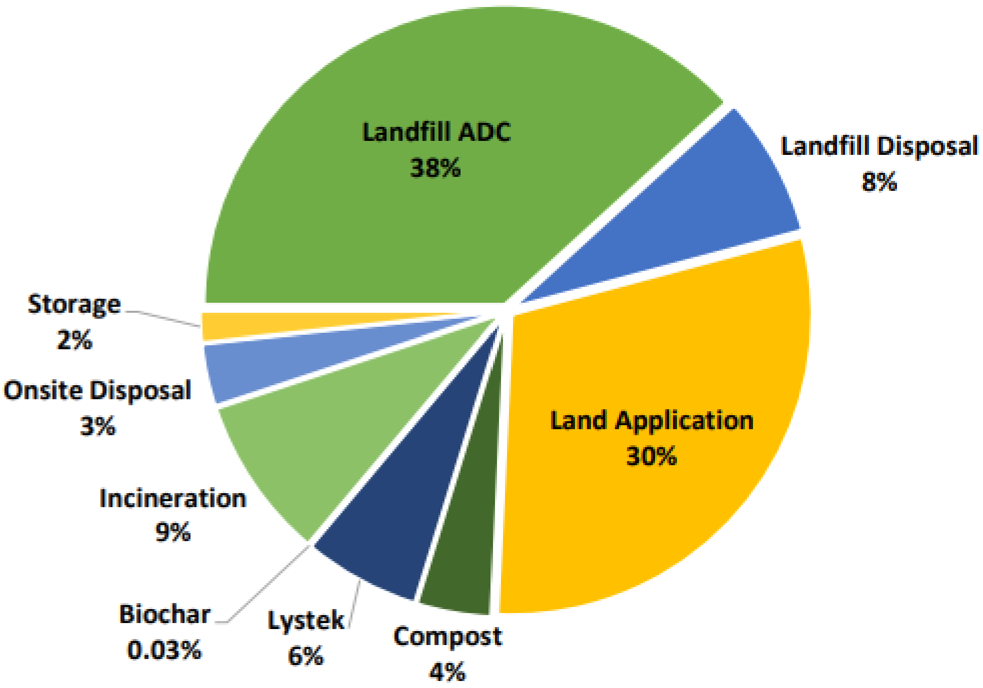

Figure 1515: Relative dry tonnage of biosolids per reuse and disposal method

Source: (Agencies, 2021)

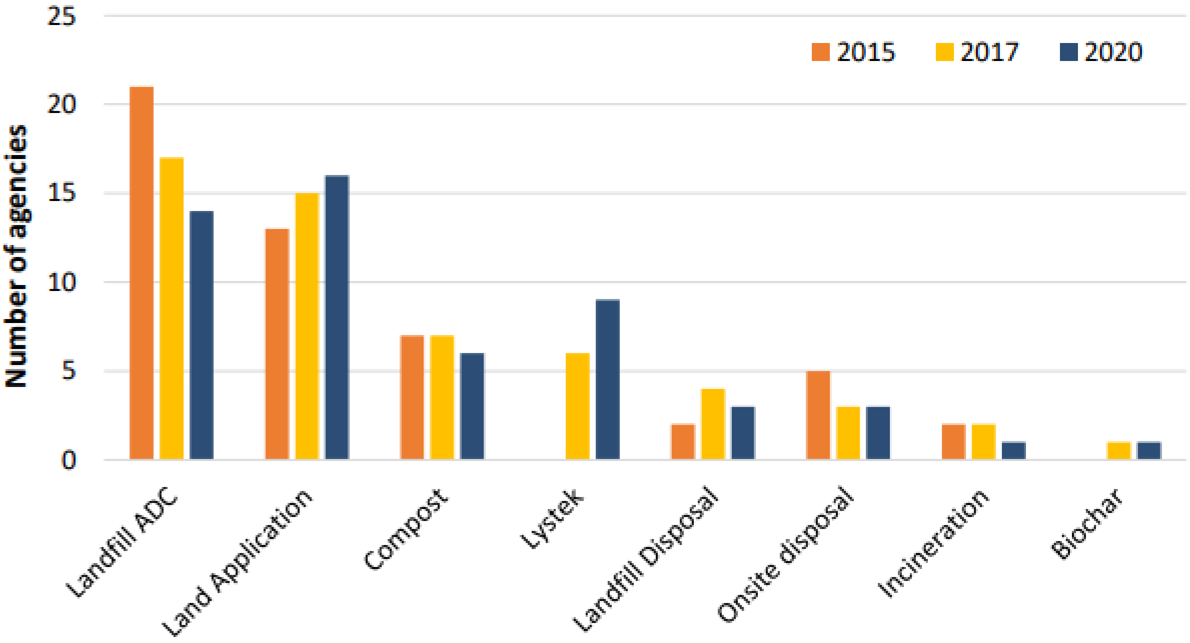

Figure 1616: Number of agencies for sample sites

Source: (Agencies, 2021)

To further quantify these end-use sources, the one-way hauling distances and associated hauling and tipping costs per ton were gathered. Composting facilities have the longest one-way distance from facilities, at a median distance of 126 miles, with land application second at 112 miles due to the proximity of these facilities generally being located outside of populated areas where the treatment facilities are located. See Figure 1717 below. Throughout the State, approximately 50% of the biosolids that were applied to land, not counting composted biosolids, were applied to farms in the Central Valley and 21 percent were land applied in Arizona. Similarly, many of the composting facilities are also located in the Central Valley, thus increasing the hauling distances for this end-use. For the 23 agencies that reported costs, the annual cost for solids disposal is approximately $19M and has increased by approximately 12 percent over the last three years. The use of onsite disposal is the lowest cost option for facilities employing this strategy, with large ranges in others such as landfill ADC (median: $65/ton) and land application (median: $52/ton), see Figure 1818 below. Both latter methods have increased substantially over the past three years, or approximately 36 percent and 64percent, respectively.

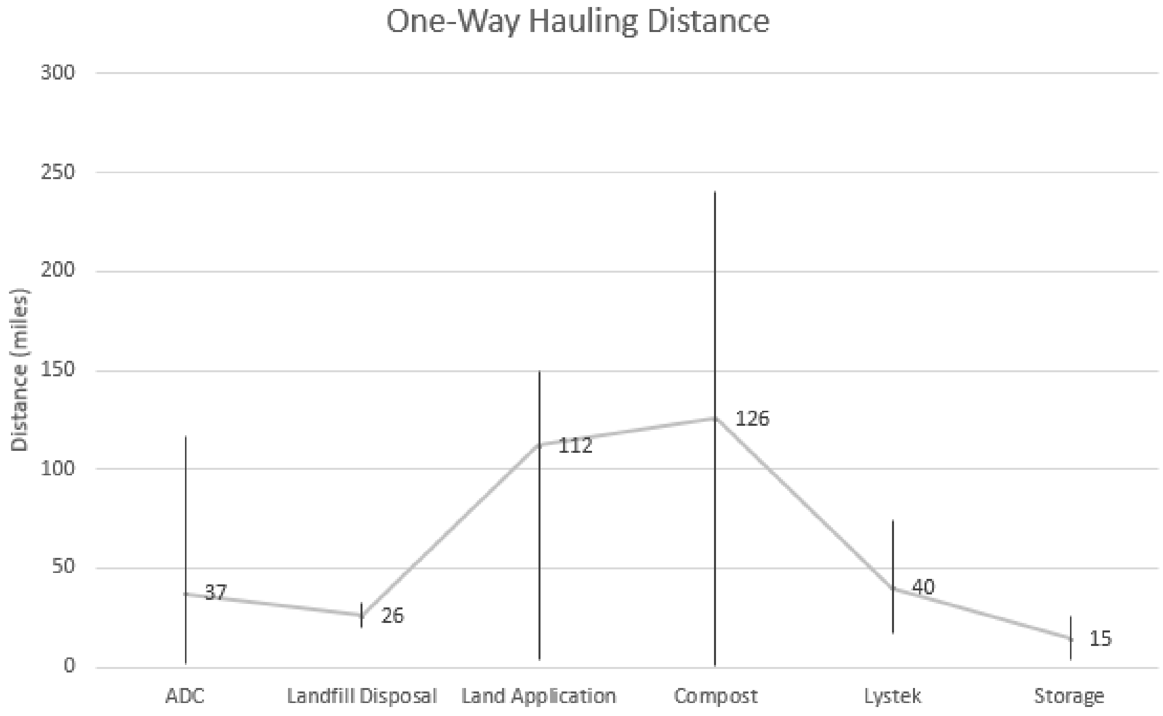

Figure 1717: One-Way hauling distance for sample sites

Source: (Agencies, 2021)

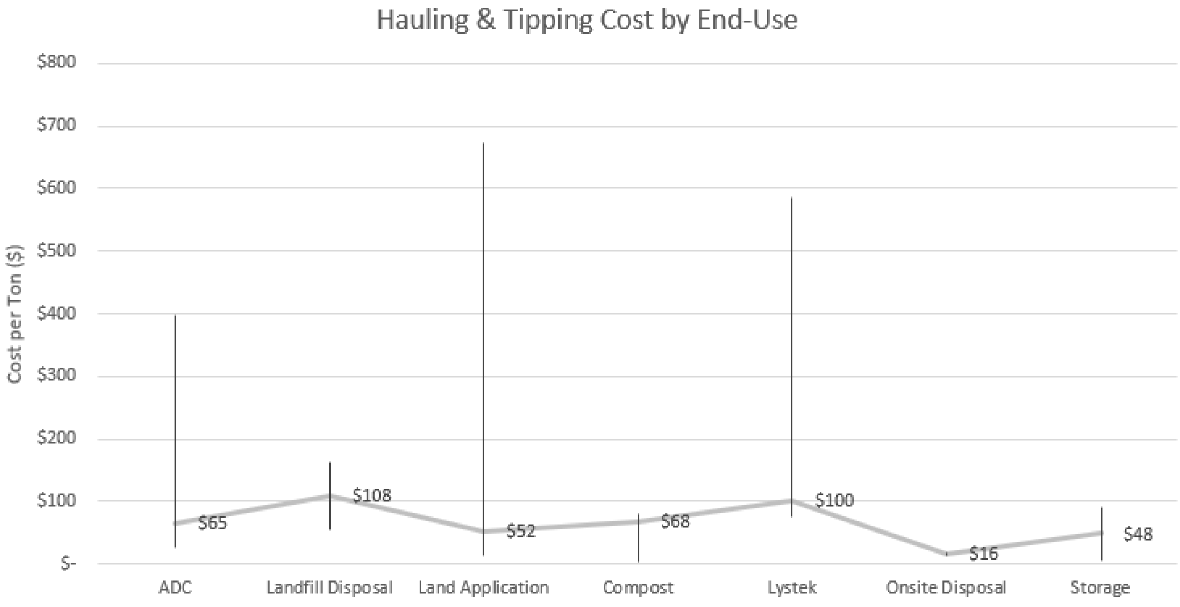

Figure 1818: Hauling and tipping cost by end-use

Source: (Agencies, 2021)

In response to readiness for SB1383, many agencies (17 of 31) are still planning for compliance or have in-progress efforts for compliance, while six have already completed preparations. Of those surveyed, seven already employ strategies that are in compliance with the legislation and are not impacted. Common trends include additional reliance on land application uses (11 agencies), or an increased diversion to third-party facilities for additional treatment (nine agencies). A small allocation of facilities are planning improvements to the treatment technology onsite (four agencies), as well as added digester capacity for organic co-digestion (four agencies), see Figure 1919. Some of the common challenges being faced include securing sustainable use and disposal options, rising costs, and hauling distances to the various compliant end-uses. Other uncertainties such as limitations on future land application, odor concerns from the public, and PFAS and microplastic regulations are also influencing the decision-making process.

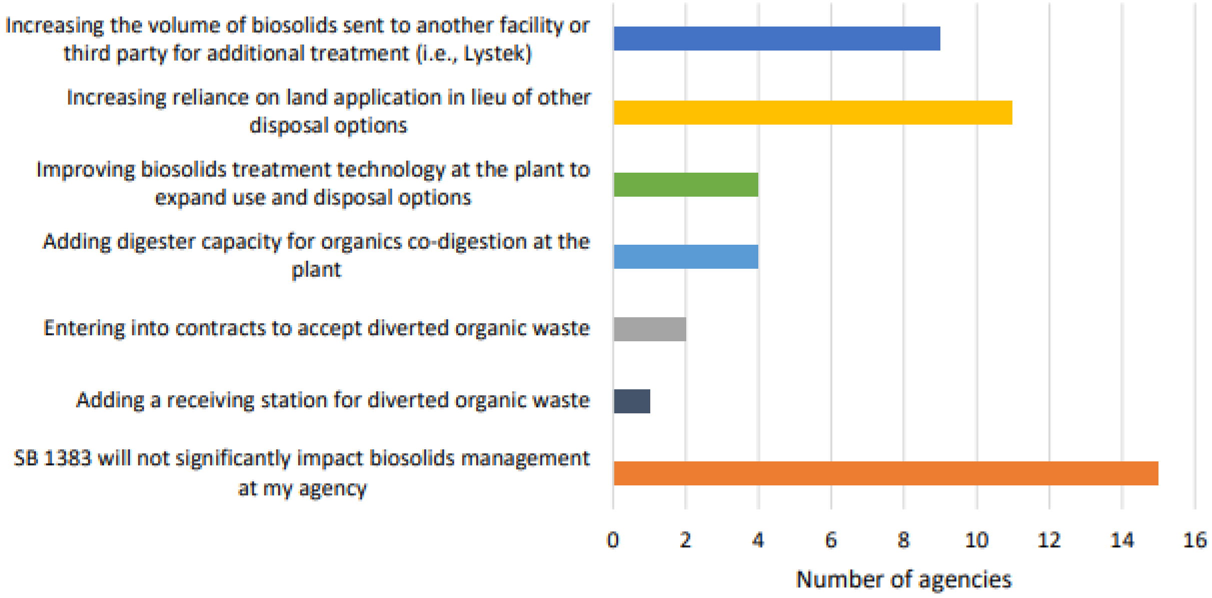

Figure 1919: Agency plans for responding to SB 1383

Source: (Agencies, 2021)

SB1383 Compliance Decision Support Tool

SB1383 will have significant impacts across a broad range of stakeholders. New regulations will impact decisions associated with modifications to infrastructure, planning, technology evaluation, procurement, design, new and innovative technology, market conditions, downstream impacts to landfills, transportation, agriculture, suppliers, and stakeholders. Making the best decision can be difficult in an environment where one decision impacts other important parts of the business. For example, compliance with SB1383 does not consider compliance with future evolving regulations such as PFOS/PFAS rules being considered by EPA. Some technologies that appear to be a good solution for SB1383 compliance may not produce a product that is compliant with pending rules. Understanding the problem and challenges is a first step in developing and utilizing a decision support tool. The process may involve consultants, regulators, and stakeholders to fully understand the implications of making the best decisions. Stakeholders should perform decision support exercises utilizing a decision support tool to fully evaluate risk and make the best decisions on SB1383 compliance. Additional drivers involve funding for new technologies, supply chain issues, sustainability, footprint and integration into the existing facility, proof of concept, operator buy-in, cascading challenges, and secondary and tertiary contractual business impacts.

There are a number of innovative technologies that have the potential to comply with SB1383, pending PFOS/PFAS regulations and save significant energy while reducing air emissions. The technologies explored in this report have the potential to reduce emissions, as well as ease the generation and combustion of greenhouse gases associated with current practices. Development of energy management plans, demand response plans, or energy action plans and decision support tools can provide a guide to facilities designed to meet the regulatory requirements while reducing costs. A number of market stakeholders are involved in preparations and implementation of SB1383 and include local governments, public and private utilities, key decision makers including councils, mayors, facilities management, third parties, industrial food plants, food service, contractors, private biosolids processing companies, farmers dependent on current biosolids resources, consulting firms providing decision support, design firms, equipment manufacturers, regulators, politicians, finance organizations and federal agencies involved in regulating and providing financial assistance to the industry. See Figure 2020 below for a decision support tool conceptual process.

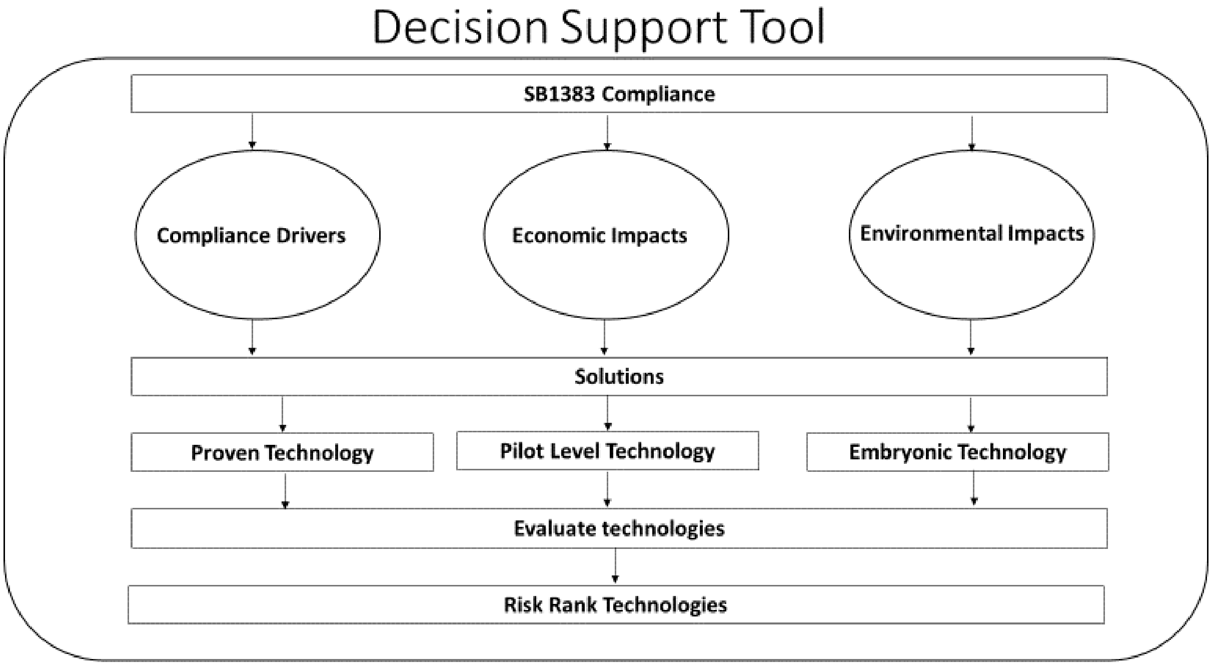

Figure 2020: Decision support tool concept

Source: Project Team

Recommendations

As discussed, utilities are facing numerous challenges with new regulations, rising costs, aging infrastructure, sustainability, workforce challenges, disposal challenges, and energy demands. Capital costs are a major challenge for utilities to retool their systems in order to meet these challenges. Beneficial reuse of biosolids is a popular value-added disposal method, although the impacts from rising haul costs and new regulations may make reuse uneconomical. New innovative technologies are designed to address the challenges of biosolids disposal and offer additional benefits that reduce volumes, lower transportation and disposal costs, and streamline the processes currently used to treat sludge. It is recommended that agencies consider the development of a long-term plan for biosolids treatment and disposal, which addresses current and future regulatory requirements and markets. An alternatives analysis and selection of the most beneficial technology for the facility should be conducted (e.g. operating costs, space constraints, forecasted changes in service populations, etc.) and the plan should evaluate the entire suite of benefits for the technology selected. For example, emerging technologies may allow a utility to displace existing aerobic and anaerobic digestion and all the ancillary equipment used to operate the system, with benefits that include:

- Significantly reduce energy consumption
- Reduced volumes and associated hauling and tipping costs
- Higher dry solids content compared to conventional averages
- Reduction/elimination of greenhouse gas generation of onsite systems and transportation components
- Reduced O&M costs
- Generating a reusable product that can be more easily used in the local community.

Furthermore, agencies should investigate the development of an energy management plan to provide real-time visualization of unit process energy use, demand charges, brownout conditions, and anything that impacts energy use and manage energy use in a similar manner to process control. Making good control decisions requires an in-depth understanding of the process and adding the energy element is a key part of the process. As wastewater treatment facilities have numerous electrical systems that operate continuously, agencies should work towards development of a demand response plan as part of the comprehensive energy management plan. These types of strategies often require instrumentation, with costs that can be lessened by supplemental funding provided by electric utilities.

Agencies should also consider the environmental and economic impacts of generating biogas as part of the sludge conditioning process, with some new technologies offering systems that do not generate GHGs and appear to comply with the SB1383 requirements. A growing number of agencies have invested in waste-to-energy systems that utilize biogas as a fuel source to generate electricity, which has a number of positive attributes, although the total cost of anaerobic digestion, biogas conditioning, gas storage, turbine/reciprocating driven generator O&M, support services, and infrastructure demands make these systems very expensive to own and operate. Further study is recommended to take into account these additional burdens on a site-by-site basis.

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