ALKALINE STABILIZATION

Lime stabilization process

- Lime addition is a chemical stabilization process that is very simple and low-cost
- Lime is added to prevent odor production and vector attraction
- The pH is raised to 12 or higher (minimum 2 hr at pH 12)
- High pH stops or substantially inhibits the microbial reactions and decomposition

- The lime-treated sludge readily dewaters with mechanical equipment, and is suitable for land application
- No direct reduction of organic matter takes place during lime treatment
- If pH drops below 11, biological decomposition will resume and produce odors
- The mass of dry biosolids is increased due to lime addition which increases the transportation and disposal costs

- The sludge does not decompose and create odors as long as the low pH is maintained
- Bacteria, viruses, protozoa, and other pathogens are inactivated or destroyed by lime addition
- Typically $Ca(OH)_2$ (hydrated lime) or CaO (quick lime) is used
- Fly ash, cement kiln dust, and carbide lime can also be used as a substitute

Table 3
Bacteria in Different Types of Biosolids

Sludge type	Bacterial density (number/100 mL)				
	Total coliform[a]	Fecal coliform[a]	Fecal *streptococci*	*Salmonella*	*Pseudomonas aeruginosa*
Raw					
Primary	2.9×10^9	8.3×10^8	3.9×10^7	62	195
Waste activated	8.3×10^8	2.7×10^7	1×10^7	6	5.5×10^3
Septage	2.9×10^8	1.5×10^7	6.7×10^5	6	754
Anaerobically digested					
Mixed primary and waste activated	2.8×10^7	1.5×10^6	2.7×10^5	6	42
Lime stabilized[b]					
Primary	1.2×10^5	5.9×10^3	1.6×10^4	<3	<3
Waste activated	2.2×10^5	1.6×10^4	6.8×10^3	<3	13
Septage	2.1×10^3	265	665	<3	<3
Anaerobically digested	18	18	8.6×10^3	<3	<3

Source: US EPA.
[a]Millipore filter technique used for waste-activated sludge and septage. MPN technique used for other sludges.
[b]To pH ≥ 12.0.

Advantages

- Lime treated sludge is suitable for a variety of uses
- Simple, low-tech, easy to construct
- Small foot print
- Flexible operation which can be easily started and stopped

Disadvantages

- The product is not good for all soil types
- Quantity of sludge is increased
- Potential for odor generation and pathogen regrowth remains
- Formation of ammonia and calcium phosphate reduce the N and P content of sludge

Process	Degree of attenuation		
	Pathogens	Putrefaction	Odor potential
Alkaline stabilization	Good	Fair	Fair
Anaerobic digestion	Fair	Good	Good
Aerobic digestion	Fair	Good	Good
Autothermal thermophilic digestion (ATAD)	Excellent	Good	Good
Composting	Fair	Good	Poor to fair
Composting (thermophilic)	Excellent	Good	Poor to fair

[a] Adapted, in part, from WEF (1998).

Relative degree of attenuation achieved with various sludge stabilization processes

Chemical reactions

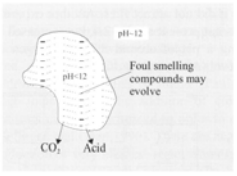
- $Ca^{2+} + 2HCO_3^- + CaO \rightarrow 2CaCO_3 + H_2O$
- $2PO_4^{3-} + 6H^+ + 3CaO \rightarrow Ca_3(PO_4)_2 + 3H_2O$
- $CO_2 + CaO \rightarrow CaCO_3$

Reactions with organic contaminants

- Acids: RCOOH + CaO→ RCOOCaOH
- Fats: Fat + $Ca(OH)_2 \rightarrow$ glycerol + fatty acids
- Hydrolysis of polymeric carbohydrates and proteins
- Hydrolysis of ammonia from amino acids

pH reduction

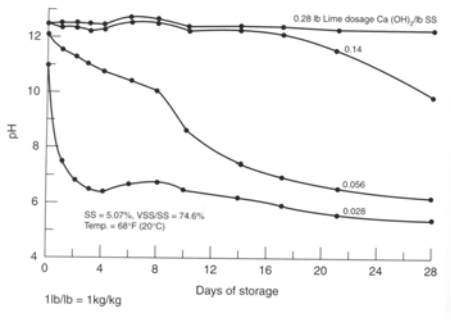
- If insufficient lime is added, the pH decreases as the reactions take place
- If biological activity is not sufficiently inhibited, carbon dioxide and organic acids will be produced and will react with lime
- Excess lime is required!



Environment with very limited microbial growth

Unstable micro-environment with microbial growth

Figure 14.3. Proposed mechanism for reduction of pH at low doses of lime starting within the sludge. The pH drop spreads from the unstable micro-environment to the surroundines.



Source: US EPA

Heat generation

- Lime addition can cause substantial temperature increase in sludge
- Quicklime (CaO) reacts with water to form hydrated lime, and releases approximately 64 kJ/g.mole heat
- The reaction between quicklime and carbon dioxide releases approximately 180 kJ/g.mole heat as well

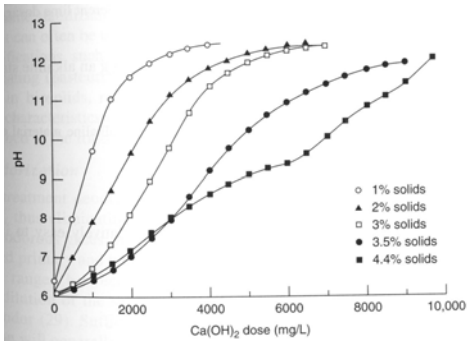
Design criteria

- Three fundamental design parameters: pH, contact time, and lime dosage
- The amount of lime required is determined by the type of biosolids, its chemical composition, and solids concentration
- Air emission control equipment to minimize odor and dust

Lime Doses Required to Keep pH More Than 11.0 At least 14 d

Type of sludge	Lime dose (lb $Ca(OH)_2$/lb suspended solids)
Primary sludge	0.10–0.15
Activated sludge	0.30–0.50
Septage	0.10–0.30
Alum-sludge[a]	0.40–0.60
Alum-sludge[a] plus primary sludge[b]	0.25–0.40
Iron-sludge[a]	0.35–0.60

Source: US EPA.
[a]Precipitation of primary treated effluent.
[b]Equal proportions by weight of each type of sludge.
1 lb/lb = 1 kg/kg.



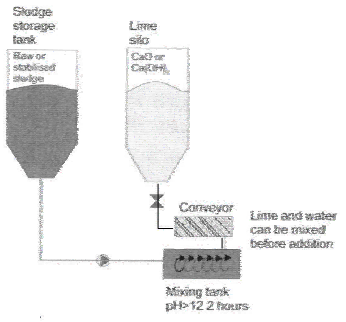
Source: US EPA

Application of alkaline stabilization processes

- Lime pretreatment – addition of lime to sludge prior to dewatering
- Lime posttreatment – addition of lime to sludge after dewatering
- Advanced alkaline stabilization technologies

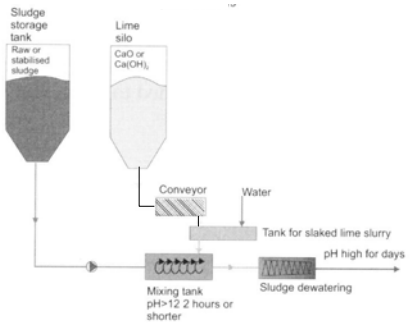
Lime pretreatment of liquid sludge

- Lime pretreatment of liquid sludge requires more lime per unit weight of sludge because of the chemical demand of the liquid
- Direct application of liquid sludge to land – OK for smaller plants
- Combining benefits of sludge conditioning and stabilization prior to dewatering – pressure type filter press should be used



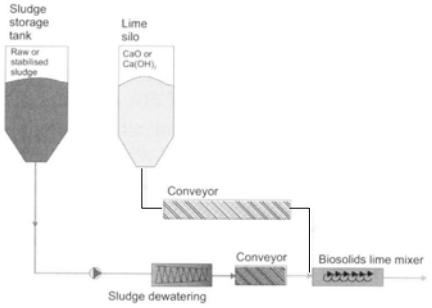
Lime addition to liquid sludge without dewatering (slurry-liming)

Andreasen, 2003



Lime addition prior to dewatering (pre-liming)

Andreasen, 2003



Lime addition to sludge cake (post-liming)

Andreasen, 2003

Contact time and dose

- The recommended design objective is to maintain the pH above 12 for about 2 h to ensure pathogen destruction
- As the percent solids concentration increases, the required lime dose increases
- The sludge must be treated with an excess of lime (x1.5) or disposed of before the pH drops significantly

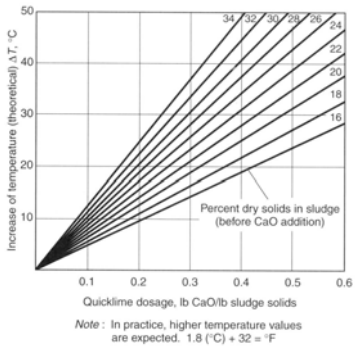
Type of sludge	Solids concentration, %		Lime dosage[b] lb $Ca(OH)_2$/ton dry solids		g $Ca(OH)_2$/kg dry solids	
	Range	Average	Range	Average	Range	Average
Primary	3–6	4.3	120–340	240	60–170	120
Waste activated	1–1.5	1.3	420–860	600	210–430	300
Anaerobically digested mixed	6–7	5.5	280–500	380	140–250	190
Septage	1–4.5	2.7	180–1020	400	90–510	200

[a] Adapted from WEF (1995a).
[b] Amount of $Ca(OH)_2$ required to maintain a pH of 12 for 30 min.

Typical lime doses for pretreatment sludge stabilization

Lime posttreatment

- Hydrated lime or quicklime is mixed with dewatered sludge to raise the pH of the mixture. A pugmill, paddle mixer, or screw conveyor can be used.
- Quicklime is preferred because the temperature of the mixture goes above 50 C which is sufficient to inactivate worm eggs



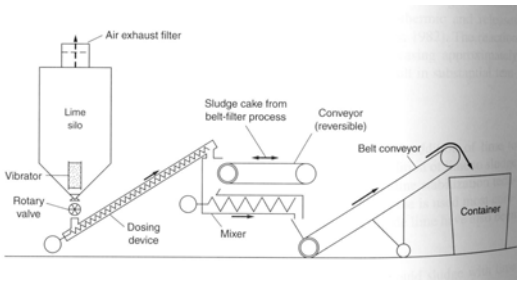
Theoretical temperature increase in postlime stabilized sludge using quicklime (Roediger, 1987)

Advantages of lime posttreatment

- Dry lime can be used
- No special requirements for dewatering
- Scaling problems and maintenance problems are eliminated
- The resulting mixture has a crumbly texture, and can be stored for long periods
- It can also be easily land applied using a conventional manure spreader

Disadvantages of lime posttreatment

- Lime posttreatment of anaerobic digested sludge release odorous gases
- Trimethyl amine causes typical fishy odor in low concentrations and an ammonia like odor in higher concentrations
- Odor control might be required
- Adequate mixing might be difficult to achieve



Typical lime posttreatment system (From Roediger Pittsburgh)

Advanced alkaline stabilization techniques

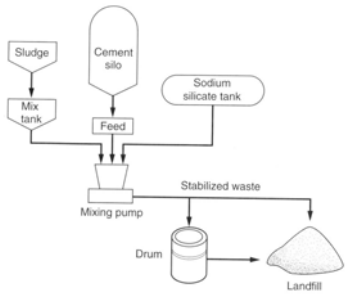
- Advanced alkaline stabilization techniques use materials other than lime
- Dewatered sludge is required
- Most of the technologies rely on additives, such as cement kiln dust, lime kiln dust, or fly ash
- The most common modifications include the addition of other chemicals, a higher chemical dose, and supplemental drying

Pasteurization

- Pasteurization may be accomplished by the exothermic reaction of quicklime with water to achieve a process temperature of 70 C and maintain it for more than 30 min.
- Pasteurization reaction must be carefully controlled and monitored to meet the regulatory criteria
- The process produces a soil like material that is not subject to liquefaction under mechanical stress

Chemical stabilization/fixation technologies

- Typically involve the addition of pozzolanic materials to dewatered sludge cake
- Chemical fixation/solidification processes have also been applied for industrial sludges
- The addition of pozzolanic materials produces a soil-like material of approx. 35 to 50 percent solids content



Schematic diagram of a chemical fixation system (US EPA, 1989)

Source

- Wastewater Engineering Treatment and Reuse - Metcalf and Eddy 2003
- Sludge into Biosolids - Spinosa and Vesilind
- Biosolids Treatment Processes – Wang, Shammas, and Hung