



# Standard Guide for Alkaline Stabilization of Wastewater Treatment Plant Residuals<sup>1</sup>

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## 1. Scope

1.1 This document provides guidance for use of reactive alkaline materials (quicklime, hydrated lime, high lime fly ash, or other byproducts) for treating wastewater solids (biosolids) to reduce pathogen levels and achieve compliance with regulatory requirements. Federal (40 CFR, Part 503) regulations for use or disposal of biosolids became effective on March 22, 1993; refer to USEPA regulations and guidance documents for information on other treatment processes or for specific requirements for use or disposal of biosolids.

1.2 Additional requirements may be imposed by individual states, and these are available through state regulatory agencies that issue permits for treatment and use or disposal, or both, of biosolids.

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone

### 2.2 USEPA Publication:

Title 40, Code of Federal Regulations (CFR), Part 503, Standards for the Use or Disposal of Sewage Sludge; Final Rules, 58 FR 9248-9404<sup>3</sup>

## 3. Terminology

3.1 *Acronyms:acronyms*—these are defined by operating parameters (for example, time, temperature) whose values must be met in order for biosolids to be used in various ways as a nutrient source/soil conditioner. Ref. 40 CFR Part 257.

3.1.1 *PFRP*—Processes to Further Reduce Pathogens (equivalent to 503 Class A).

3.1.2 *PSRP*—Processes to Significantly Reduce Pathogens (equivalent to 503 Class B).

## 4. Significance and Use

4.1 Operators of power and other plants producing alkaline by-products and wastewater treatment plant operators needing to treat and manage wastewater solids will find this guide helpful in dealing with their materials.

4.2 This guide provides the tests, procedures, and parameters that should be considered to significantly reduce pathogens in wastewater treatment plant solids by the addition of manufactured or by-product alkaline materials (**1**).<sup>4</sup>

## 5. Alkaline Materials Characteristics

### 5.1 Chemical Composition:

Alkaline materials may be tested for Available Lime Index (ALI) in accordance with the optional chemical test of Table 1. Other chemical components, if required, may be determined in accordance with the appropriate procedure when requested by the purchaser.

### 5.2 Reactivity:

5.2.1 Alkaline materials should be tested for pH and heat of hydration (heat rise or slaking rate) in accordance with the recommended tests of Table 2.

### 5.3 Physical Characteristics:

5.3.1 Alkaline materials should be tested to determine the particle size in accordance with the recommended physical tests of Table 3.

## 6. Process Performance

### 6.1 PFRP (Class A) Alkaline Treatment of Biosolids:

6.1.1 *Mixing*—Thorough mixing of the biosolids and stabilization reagent must be provided to ensure uniform pH distribution and pathogen reduction throughout the biosolids mass (**2**). Effective mixing depends upon achieving the appropriate ratio of alkaline material to biosolids cake uniformly distributed throughout the treated biosolids.

6.1.1.1 Biosolids with a high moisture content will require less mixing energy than high-solids biosolids cake.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

<sup>4</sup> The boldface numbers in parentheses refer to the list of references at the end of this guide.

**TABLE 1 Optional Chemical Test**

Test Method	Component	Specification
C 25	Available Lime Index (ALI), %	<sup>A</sup>

<sup>A</sup> To be specified only as required by purchaser.

**TABLE 2 Recommended Reactivity Tests**

ASTM Test Method	Component	Specification
C 25	pH	≥ 12.0 <sup>A</sup>
C 110 <sup>B</sup>	Heat rise, C	<sup>C</sup>

<sup>A</sup> Based on 40 CFR Part 503 for pH >12 for 2 h or more.

<sup>B</sup> Modify Test Method C 110 to proportion alkaline reagent in lieu of quicklime. Alkaline material and water ratio may need to be modified to obtain measurable results. Any modification of Test Method C 110 must be clearly stated on the analysis report.

<sup>C</sup> To be specified only as required by purchaser.

**TABLE 3 Recommended Physical Test**

ASTM Test Method	Component	Specification
C 110	Amount retained on 600 μm (No. 30 mesh), %	<sup>A</sup>
C 110	Amount retained on 75 μm (No. 200 mesh), %	<sup>A</sup>

<sup>A</sup> To be specified only as required by purchaser.

6.1.1.2 Biosolids characteristics will determine the proper type of equipment or system required for adequate mixing. Incomplete mixing can cause odor release during product storage or application and may lead to failure to meet regulatory requirements for pathogen and vector control.

**6.1.2 Particle Size:**

6.1.2.1 Given an adequate moisture supply using alkaline agents (for example, CaO) with smaller particle sizes will facilitate rapid and efficient mixing of agents with biosolids and increase reaction rates and pH, resulting in higher temperatures and greater pathogen reduction.

6.1.2.2 Since dusts are more easily generated from finely divided particles, precautions should be taken to prevent exposure to eyes and mucous membranes, which may result in irritation.

6.1.2.3 Reactivity and particle size also affect the rate of dust and mist emissions from reactors or mixing devices, or both. Particulate release may require scrubbing, water spray, or other emission controls on reactors or mixing devices for aesthetic reasons or to meet regulatory requirements.

6.1.2.4 Very small particle size may also lead to “air slaking” or recarbonation of active lime particles if the material is exposed to high humidity. Air slaked/recarbonated materials will not achieve the pH necessary to meet regulatory requirements.

**6.1.3 Reactivity (Heat and pH Elevation):**

6.1.3.1 Reactivity is dependent upon the interaction between the alkaline reagent and the material to be treated. Reactions occur as the alkaline material contacts the biosolids. The finer the alkaline product, the greater the potential for a more rapid pH/temperature elevation.

6.1.3.2 Reagent reactivity affects mixing time and dosage rate and must be considered in process design.

**6.1.4 Moisture Content:**

6.1.4.1 Adequate moisture must be present to react with the free CaO (as measured by Available Lime Index, ALI, as per

Test Methods C 25) to generate heat and elevate pH. Generally, dry biosolids cakes (18 to 30 %) require a more intimate mix to ensure proper penetration and reaction than is required by wet biosolids (less than 18 %).

6.1.4.2 The calcium oxide in the reagent must react with the moisture in biosolids (hydration) producing calcium hydroxide and heat. The moisture content in the biosolids mass must be sufficient to allow the hydration reaction to occur between the selected reagent (CaO concentration and fineness) and biosolids mass.

6.1.4.3 Biosolids cakes with a high moisture content will tend to react faster than biosolids with a low moisture content.

**6.1.5 Biosolids Type:**

6.1.5.1 Case-by-case alkaline material demand should be determined for each biosolids type through pilot testing using the actual biosolids cake and proposed reagents for each project. Develop process guidelines for alkaline additions by biosolids type and alkaline additive characteristics.

6.1.5.2 Biosolids with a high moisture content may require a higher dose ratio than drier dewatered biosolids cake when dosage ratios are expressed on a dry weight basis.

**6.1.6 Reaction Time and Curing Time:**

6.1.6.1 Heat will be generated as hydration of calcium oxide occurs. The reaction time will vary depending on reagent composition moisture content of the biosolids mass, and mixer efficiency.

6.1.6.2 Reaction times to effect pathogen reduction are established by applicable federal and state regulations. Reaction/cure times depend upon a number of variables and should be pilot-tested using the actual biosolids cake, alkaline admixture, mix unit, cure vessel, and testing protocol and acceptance criteria to assure compliance with regulatory standards.

6.1.6.3 For alkaline treatment processes, one of the three performance criteria is required:

(1) The time-temperature relation established in 40 CFR 503.32 (a) (3) (Alternative 1). Selected time-temperature values are as follows:

Biosolids	Temp, °C	50	55	60	65	70	75	80
Moisture >7 %	Time, hours	316	63	13	2.5	0.5	0.10	0.020
Moisture >7 %	Time, hours	120	24	4.8	0.95	0.19	0.04	0.008

(2) The pH-time, temperature-time, drying procedure in 40 CFR 503.32 (a) (4) (Alternative 2). Basically, the biosolids are held at a pH above 12 for 72 hours with a 12-hour period in which the temperature exceeds 52°C, followed by air drying to a solids content exceeding 50 %.

(3) Pasteurization (40 CFR 503, App. B, Part B—PFRP Option 7) in which the biosolids are maintained at a minimum temperature of 70°C for 30 minutes.

6.1.6.4 Ammonia or other odors released may require water spray, scrubbing, gas capture, or control of emission.

**6.1.7 Reaction/Cure Vessels or Containers:**

6.1.7.1 Consideration should be given to minimize heat losses through materials management, configuration, and materials of construction for processes that require extended curing times.

6.1.7.2 Proper temperatures can be maintained without an insulated vessel by adding adequate alkaline reagent to compensate for heat loss. However, some situations may benefit

from an insulated vessel to efficiently retain the heat to meet PFRP temperature requirements.

6.1.7.3 For processes using a windrow, at a minimum, the mixture should be at least 18 inches thick at all locations in the pile to ensure heat retention throughout the entire mass for the applicable curing time. Thin areas at the pile extremities should be avoided as they will not retain adequate heat and can lead to potential regrowth and recontamination of the entire mass.

6.1.8 *Process Testing Requirements:*

6.1.8.1 Process testing requirements vary with the specific alkaline process selected.

6.1.8.2 Temperature and pH measurements for the requisite time periods should be recorded to comply with pathogen reduction (and vector attraction reduction). Daily testing may include monitoring and documenting the elevated temperature and pH for a predetermined period of time (see 6.2.6 for details). Some methods also require documentation of reduced moisture content and mixing.

6.1.8.3 Procedures to monitor or collect samples for analysis are developed for each project based upon site-specific conditions considering the process selected, equipment utilized, volumes of materials to be processed, local state and federal regulatory requirements, and local conditions (3).

6.1.9 *Process Testing Schedule:*

6.1.9.1 Testing must be conducted in accordance with federal, state, and local regulations. Product testing, to meet end-use requirements, will be site-specific. Under 40 CFR Part 503 regulations, pathogen (salmonella, virus, protozoan, and helminth egg) or indicator organism testing and pollutant concentration (metals) testing requirements are:

Amount of Biosolids (dry metric tons/365 days)	Frequency
> 0 and < 290	Once per year
≥ 290 and < 1500	Once per quarter
≥ 1500 and < 15 000	Once per 60 days
≥ 15 000	Once per month

6.1.9.2 In addition, at a minimum, daily operating records should be maintained documenting compliance with applicable requirements (for example, process time/temperature, pH, solids concentrations, and fecal coliform levels) (4).

6.1.10 *Product Solids Content:*

6.1.10.1 Product utilization may be affected by solids content to aid in control of microbial regrowth during storage to minimize odor potential at application sites and during storage or to improve end-product marketability and physical handling characteristics.

6.1.11 *On-Site Storage:*

6.1.11.1 On-site storage may be required for a land application or marketing program of the tested product. Programs that produce an end-product for sale should consider on-site storage capacity to meet the seasonal fluctuations in market demand, the scheduling needs of the consumer, and production rates of the generator.

6.1.11.2 On-site storage may require odor control for end-products with high moisture content or a low alkaline reagent dosage rate.

6.2 *PSRP (Class B) Alkaline Treatment of Biosolids:*

6.2.1 *Mixing*—Thorough mixing of the biosolids and chemical reagent must be provided to ensure uniform pH distribution and pathogen reduction (2). Mechanical mixing to achieve a homogeneous blend of reagent throughout the biosolids mass depends upon a number of factors, including achieving the proper ratio of alkaline reagent to biosolids, and sufficient moisture to enable the reaction to occur.

6.2.1.1 Incomplete mixing or an inadequate reagent dosage rate can cause odor generation and release during product storage or application and failure to meet regulatory pathogen or vector control requirements.

6.2.2 *Alkaline Reagent Particle Size:*

6.2.2.1 Reactions occur as the alkaline reagents contact the moist biosolids particles. The rate of reaction of the alkaline reagent tends to increase with: (1) finer reagent particle size, and (2) increased free moisture content. Reagents with a finer (smaller) particle size distribution generally are more easily and uniformly blended into the biosolids.

6.2.2.2 When using an alkaline slurry, or treating liquid biosolids, particle size may not be as critical as long as sufficient mixing and reaction time are provided.

6.2.3 *Reactivity (pH elevation):*

6.2.3.1 Care must be taken to ensure moisture will not come into contact with the reagent prior to entering the mixer. Air slaking of the alkaline reagent can be a problem in long-term storage or pneumatic transfer systems. Guidance for proper storage of reactive alkaline materials can be found in Lime—Handling, Application and Storage, National Lime Association Bulletin 213.

6.2.3.2 Increasing the alkaline reagent oxide concentration may increase potential for reactivity.

6.2.4 *Moisture Content:*

6.2.4.1 Moisture content affects the pH by permitting the alkaline reagents to dissociate, releasing hydroxide ions, increasing the pH. As moisture increases, it is easier for the alkaline material to disperse, penetrate, react, and dissociate, thus generating hydroxide ions throughout the mixture.

6.2.4.2 Care should be exercised when working with biosolids cakes with greater than 30 % solids content to ensure a complete uniform reaction is achievable.

6.2.5 *Biosolids Type*—Biosolids characteristics will impact on the required dosage rates for specific alkaline reagents. Therefore, site-specific process guidelines should be developed through actual pilot studies for alkaline additions by biosolids type and alkaline additive characteristics. Liquid biosolids require less mixing energy to achieve a uniform distribution of alkaline reagent (and therefore uniform pH) throughout the mixture than do cake biosolids.

6.2.6 *Reaction Time:*

6.2.6.1 For dry reagents, after uniform mixing with biosolids is complete, the alkaline metal oxides must hydrate to hydroxides and penetrate the biosolids mass. The presence of hydroxides will increase biosolids pH.

6.2.6.2 When working with biosolids cake with low moisture content or reagents with low reactivity due to particle size or oxide content, longer curing time (contact period) may be required to allow the hydration reaction to occur.

6.2.6.3 At elevated pH values, ammonia compounds in the biosolids or water dissociate to release ammonia gas (NH<sub>3</sub>). The biosolids may exhibit a transient pH of 12 or more due to unreleased ammonia in the form of unstable ammonium hydroxide (NH<sub>4</sub>OH). Once the NH<sub>4</sub>OH dissociates and the ammonia dissipates, the pH may fall. Therefore, the amounts of reagent added should take this factor into account and not be based on the short-term NH<sub>4</sub>OH effect on pH. The strong odor of ammonia release is a signal to be alert to this process occurring.

6.2.7 *Process Testing Requirements*—pH > 12 for two hours.

6.2.7.1 When testing a liquid/solid mixture with a system designed for liquids (pH probe), care must be taken to keep flow of sample moving across the pH probe surface for accuracy. Clean the electrode frequently, paying particular attention to the reference electrode junction. Bits of adherent biosolids or alkaline agent can strongly alter the measured pH, resulting in erroneous values not representative of the entire mass of material. pH measurements should be made at 25°C, or corrected for sample temperature differences as shown in Table 4, which demonstrates the temperature/pH relationship as the measured pH approaches the regulatory limit.

NOTE 1—At high pH (above 11), temperature has a significant effect on pH readings. Therefore, at high pH levels, the reading must be corrected to 25°C, standard temperature. Table 4 and following examples may be useful for a better understanding.

NOTE 2—pH meters often have temperature correction controls. These controls correct for probe temperature and conductivity only. Changes in the concentration of the test sample due to solubility that changes with temperature are not compensated by these controls. For example, at 30°C:

$$\text{Correction Factor (CF)} = 0.03 \text{ pH units} \times (T_{\text{meas}} - 25^\circ\text{C})$$

$$\text{CF} = 0.03 \times (30 - 25); \text{CF} = 0.03 \times 5$$

$$\text{CF} = + 0.15$$

$$\text{Actual pH} = \text{Measured pH} \pm \text{the Correction Factor}$$

$$\text{Actual pH} = 12.304 + 0.15 = 12.454$$

6.2.7.2 pH—Calibrate routinely with laboratory-grade standards developed for high pH monitoring.

6.2.8 *On-Site Storage:*

6.2.8.1 PSRP (Class B) biosolids have regulatory restrictions preventing application of material to a site during inclement weather, standing water, ice- or snow-covered fields.

6.2.8.2 On-site storage should be considered to hold biosolids, unless backup options are available when application sites cannot be used. Storage design must address regulatory con-

cerns for runoff or leachate and local site-specific concerns for odor. Storage capacity should be consider worst-case weather conditions.

6.2.8.3 Microbial recontamination and regrowth is possible at pH < 10, with concomitant odor potential.

7. End Use Criteria

7.1 *Matrix of Product Factors:*

7.1.1 Table 5 addresses various factors that influence specific product criteria for alkaline-treated biosolids. The relative importance of these criteria will depend on the type of product and its intended use; for example, for agricultural liming material, CaCO<sub>3</sub> equivalency and friability for handling will be important, along with metal levels, which must meet Table 3 of EPA’s 503 Rule for a product to be sold or distributed.

EPA 40 CFR Part 503.13 (13 (Table 3)  
Metal Concentration Limits

Metal	Pollutant Concentrations (mg/kg)
Arsenic	41
Cadmium	39
Copper	1,500
Lead	300
Mercury	17
Molybdenum	75 <sup>A</sup>
Nickel	420
Selenium	100
Zinc	2,800

<sup>A</sup> This is the ceiling concentration for Molybdenum. EPA is still developing a pollutant concentration value.

8. Federal Regulations

8.1 *Introduction:*

8.1.1 *Pathogen reduction*—Alkaline materials reduce pathogens in municipal wastewater solids by creating a series of stresses on the microbial population in the solids. The addition of an alkaline material raises the pH of the mixture to levels that are toxic to some microbes, resulting in their reduction or elimination (5). The exothermic reaction of quicklime with water also releases heat (often intense) and the resultant temperature rise helps inactivate pathogens. Hydration of alkaline oxide materials helps dry the biosolids, further stressing the microorganisms.

8.2 *Class A Pathogen Reduction:*

8.2.1 All 40 CFR Part 503 Class A alternatives must meet the following criteria:

8.2.1.1 Either the density of fecal coliform in the biosolids must be less than 1000 most probable numbers (MPN) per gram total solids (dry-weight basis), or the density of *Salmonella* sp. bacteria in the biosolids must be less than 3 MPN per 4 g of total solids (dry-weight basis).

8.2.1.2 Either of these requirements must be met at one of the following times: (1) when the biosolids are used or disposed; (2) when the biosolids are prepared for sale or give-away in a bag or other container for land application; or (3) when the biosolids or derived materials are prepared to meet the requirements of CFR 503 (6).

8.2.1.3 Vector attraction reduction must take place before or at the same time as pathogen reduction except when the pH

TABLE 4 pH Temperature Correction Factors at Varying Temperatures from Standard

Temperature Measured, ° C	pH Meter Reading	Correction Factor (CF), +/-	
30	12.304	+ 0.15	
29	12.334	+ 0.12	
28	12.364	+ 0.09	
27	12.394	+ 0.06	
26	12.424	+ 0.03	
25	12.454	0.00	12.454 <sup>A</sup>
24	12.484	- 0.03	
23	12.514	- 0.06	
22	12.544	- 0.09	
21	12.574	- 0.12	
20	12.604	- 0.15	

<sup>A</sup> pH of a saturated lime solution at 25°C.



**TABLE 5 Matrix of Product Factors**

End-Use Criterion	Related Process Parameter			
	Input Biosolids	Alkaline Additive	Process Heat	Other Parameters
Percent solids	Percent solids	Percent solids	Heat of hydration and evaporative heat loss	
Friability/particle size/plasticity	Percent solids	Amount added		Percent solids of final mix; bulking agent; type and amount of mixing
Nutrient content	Nutrient content	Amount added (dilution)		Amount of ammonia driven off; amount of "mineralization" of nitrogen in chemical reaction; nutrient content of bulking agent
Organic matter content	Percent volatile solids	Amount added (dilution)	Loss of volatile organics	"Mineralization" of organic content in chemical reaction; organic content of bulking agent
Metals content	Metals content	Metals content		Metals content of bulking agent
Liming potential	CaCO <sub>3</sub> equivalency	Ca content Mg content		Ca, Mg content of bulking agent
pH level and duration	pH, percent solids, ammonia and alkaline metals content, buffering capacity	CaO Ca(OH) <sub>2</sub>		Final pH of product; granularity or plasticity of end-product (permeability to air and water allowing reaction to product carbonate)
Pathogen reduction		pH 12 (CaO and Ca(OH) <sub>2</sub> content)	Heat level and duration	Dryness of end-product; chemical destruction of pathogens
Odor potential	Percent ammonia, percent volatile solids, digestion process, polymer type and content	pH-driven ammonia release; neutralization of malodorous organics	Volatilization of organics	Thoroughness of mix; odor stripping during process
Bearing strength	Non-volatile solids	Material available for forming carbonates; silicates; aluminates; aluminoferrites	Vaporization of water	Time since product was made; CO <sub>2</sub> reaction producing carbonates; characteristics of bulk agent(s)
Permeability		Cementitious compounds		Time since product was made; CO <sub>2</sub> process producing carbonates; plasticity/friability of bulking agent; characteristics of bulking agents; density

adjustment, percent solids vector attraction, injection, or incorporation options are met for vector attraction reduction.

### 8.3 Alkaline Processes for Meeting Class A Pathogen Reduction Requirements:

8.3.1 Alternative for Meeting Class A: Biosolids Treated in a High Temperature Process (through Chemically Produced Heat).

8.3.1.1 The time-temperature relation established in 40 CFR 503.32(a)(3) (Alternative 1). (See 6.1.6 for time-temperature examples.)

8.3.2 Alternative 2 for Meeting Class A: Biosolids Treated in a High pH-High Temperature-Air Drying Process 40 CFR 503.32(a)(4).

8.3.2.1 Elevating the pH to greater than 12 (measured at 25°C) for 72 h or longer,

8.3.2.2 Maintaining the temperature above 52°C for at least 12 h during the period that the pH is greater than 12,

8.3.2.3 Air-drying to over 50 % solids after the 72-h period of elevated pH, and

8.3.2.4 Meeting all the requirements in 6.2.

8.3.3 Alternative 5 for Meeting Class A: Treated in a PFRP (Pasteurization) Process Listed in 40 CFR 503, App. B, Part B-Option 7

8.3.3.1 Combined with an Alkaline Method of Vector Attraction Reduction 40 CFR 503.33(b)(6), raise the temperature to  $\geq 70^{\circ}\text{C}$  for a minimum of 30 minutes, and

8.3.3.2 Combined naturally with the vector attraction reduction, raise the pH to  $\geq 12$  for a minimum of two hours, and maintain the pH  $\geq 11.5$  for an additional 22 h.

### 8.4 Alkaline Process for Meeting Class B Pathogen Reduction Requirements:

8.4.1 Alternative 2—PSRP listed in Appendix B, 40 CFR Part 503: Alkaline stabilization—sufficient alkaline reagent is added to the biosolids to raise the pH of the biosolids to 12 after two hours of contact time.

8.4.2 Unlike the comparable Class A requirements, this alternative does not require microbiological monitoring for regrowth of fecal coliform or *Salmonella* sp. bacteria.

### 8.5 Alkaline Process for Meeting Vector Attraction Reduction:

8.5.1 Option 6 Alkali<sup>5</sup>, addition under specified conditions:

8.5.2 Biosolids are considered to be adequately reduced in vector attraction if sufficient alkaline material is added to achieve the following:

8.5.2.1 Raise the pH to at least 12, measured at 25°C, and without the addition of more alkaline material, maintain a pH of at least 12 for two hours, and

8.5.2.2 Maintain a pH of at least 11.5 without addition of more alkaline material for an additional 22 h.

8.5.3 The conditions required under this option are designed to ensure that the biosolids can be stored for at least several

days at the treatment works, transported, and then used or disposed without the pH falling to the point where putrefaction occurs and vectors are attracted.

8.6 *Septage Treatment:*

8.6.1 *Option 12—Alkaline Treatment for Domestic Septage:*

8.6.2 This option pertains only to vector attraction reduction for domestic septage. Under this option, the pH of domestic septage must be raised to at least 12 and remain at pH 12 or above for a minimum of 30 min during which no additional alkaline material may be added.

## 9. Keywords

9.1 alkaline stabilization; biosolids; high-lime byproducts; sewage sludge; stabilization; wastewater treatment plant

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<sup>5</sup> 40 CFR Part 503 uses the term “alkali” for any alkaline material. For beneficial use options, sodium (Na)-based alkaline materials are usually unsuitable due to the negative effects of sodium on soil physical properties.

## REFERENCES

- (1) Lime—Handling, Application and Storage, *National Lime Association Bulletin 213*, Arlington VA. 1995.
- (2) Technical Support Document for Reduction of Pathogens and Vector Attraction in Sewage Sludge, *USEPA, Office of Water*, NTIS: PB93-110609.
- (3) POTW Sludge Sampling and Analysis Guidance Document, *USEPA, Permits Division*, Washington, DC, First edition. August 1989, NTIS: PB93-227957.
- (4) Preparing Sewage Sludge for Land Application or Surface Disposal—A Guide for Preparers of Sewage Sludge on the Monitoring, Record Keeping and Reporting Requirements of the Federal Standards for Use or Disposal of Sewage Sludge, 40 CFR Part 503, *USEPA, Office of Wastewater Enforcement and Compliance*, EPA/813-B-93-002a. NTIS: PB94-102415.
- (5) Environmental Regulations and Technology: Control of Pathogens and Vector Attraction in Sewage Sludge, *USEPA, Office of Research and Development*, EPA/625/R-92/013.
- (6) A Plain English Guide to the EPA Part 503 Biosolids Rule, *USEPA, Office of Wastewater Management*, EPA/832/R-93/003.

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