# COLSEN'S TECHNOLOGY COMPLYING WITH US EPA BIOSOLIDS CLASS A

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## 1. Introduction

Recovery of valuable resources is becoming an integral part of treatment processes of organic waste streams. An interesting waste stream is biological sludge produced at wastewater treatment plants (WWTP). The process of anaerobic digestion results in conversion of sludge into biogas, a renewable energy source. What remains is liquid digestate, which is rich in organic matter as well as macronutrients such as phosphorus and nitrogen. As such, digestate has strong potential as a cheap fertilizer provided it is safe for use: pathogens require reduction below safe levels. The United States Environmental Protection Agency (EPA) set out regulations to control pathogens and vector attraction in sewage sludge under 40 CFR Part 503 (Code of Federal Regulation) [1]. The highest quality level that may be achieved is Biosolids Class A.

**This paper shows how Colsen's thermophilic anaerobic digestion (TAD) fits in as a technology for sludge treatment resulting in Biosolids Class A.**

## 2. Biosolids Class A-US EPA

Subpart D describes requirements for Biosolids Class A or B. For Class A. In fact, 6 alternatives are provided to comply with Biosolids Class A. All have as basis that either density of faecal coliforms is lower than 1,000 most probable number (MPN) per gram of total dry solids (DS), or density of salmonella sp. bacteria is less than 3 MPN/4g of DS when used or disposed. The first alternative (503.32 (a) (3)) provides a method to calculate how long sewage sludge needs to be maintained at a certain temperature to comply with Biosolids Class A. Minimum temperature to be applied is 50°C.
Besides this, a minimum vector attraction reduction has to be met. Again several alternatives are provided (503.33 (b)) of which volatile solids (VS) reduction to be achieved is the most straightforward one for anaerobic treatment of sewage sludge: minimum reduction is set at 38%. This is easily achieved through thermophilic anaerobic digestion.

***As such, thermophilic digestion is a suitable treatment method to obtain Biosolids Class A.***

Willis & Schafer [2] indicated that the time/temperature formulas result in a retention time that every particle in the sludge submitted to thermophilic treatment has to comply with. In other words, this is the detention time that needs to be guaranteed for all particles. They further provide various successful full-scale examples in achieving Biosolids Class A using thermophilic digestion. It is further stated that Alternative 1 is the most conservative approach to reaching Class A biosolids.

Please note that the reduction of enteric viruses and/or viable helminth ova are part of other alternative requirements mentioned to the one in Table 1. Nevertheless, for compliance verification they both are required. Applicable limits are 1 Plaque-forming unit/4g DS and 1 viable helminth ova/4g DS.

**Thermophilic anaerobic treatment is considered a process to significantly reduce pathogens (PSRP), and as such it is a recognized technique for vector attraction reduction.**

| Parameter | Description | Formula | Value |
|---|---|---|---|
| **Pathogen demand** | Faecal coliforms < 1,000MPN/g DS **Or** Salmonella sp. bacteria < 3MPN/ 4g DS | - | - |
| **Treatment (Alternative 1)** **Feed sewage sludge DS >7%** **Treatment temperature >50°C** | Detention time D (days) at which sewage sludge remains at temperature T in the treatment process | $D = \frac{131,700,000}{10^{0.1400.T}}$ | D (52°C) = 6.9 |
| **Feed sewage sludge DS <7%** **Treatment temperature >50°C** | | $D = \frac{50,070,000}{10^{0.1400.T}}$ | D (52°C) = 2.9 |
| **Vector attraction reduction** | Minimum volatile solids reduction of 38% | - | - |

*Table 1. Biosolids Class A requirements according to 40 CFR Part*

## 3. Thermophilic digestion by Colsen

Colsen applies thermophilic anaerobic digestion (TAD) to treat sewage sludge. Typically, Colsen's TAD operates at 55°C and a hydraulic detention time of 16 days. VS destruction values typically lie between 45 and 60%. **Taking these values into account, it is concluded that Colsen TAD meets EPA requirements for Alternative 1.**

Colsen has several TAD installations running worldwide. 3 installations were specifically sampled for analysis on pathogens as in their normal operation they don't have the requirement to reach Class A Biosolids quality. The table below summarizes results.

**As can be seen from the table all TAD installations comply with the requirement of either faecal coliforms or Salmonella. Please note that samples were all taken on the last point before biosolids leave the premises.**

All three plants do not require compliance with EPA regulations. In case compliance is required, Colsen applies 2-stage thermophilic anaerobic digestion at 55°C. Increasing the temperature reduces considerably the required detention time to 1 day. By applying 2-stage TAD, short circuiting is virtually eliminated.

| Parameter | Unit | 's Hertogenbosch (the Netherlands) | | Tiel (the Netherlands) | | Ajman (UAE) |
|---|---|---|---|---|---|---|
| | | Before dewatering | After dewatering | Before dewatering | After dewatering | Before dewatering |
| **Process set-up** | - | Single stage TAD | Single stage TAD | Single stage TAD | Single stage TAD | Single stage TAD |
| **VS reduction** | % | 46 | 46 | 39 | 39 | 46 |
| **Detention time** | d | 17 | 17 | 29 | 29 | 21 |
| **Temperature** | °C | 50.5 | - | 52.2 | - | 52.4 |
| **Faecal coliforms sample** | - | Not detected | Not detected | Not detected | Not detected | <10 CFU/g DS |
| **Salmonella sp. sample** | - | Not detected | Not detected | Not detected | Not detected | - |

*Table 2. Pathogen analyses results*

## 4. Literature survey results

Literature was surveyed on efficiency of thermophilic anaerobic digestion in reducing faecal coliforms & salmonella sp., helminth ova and enteric viruses. They are dealt with in this sequence.

### 4.1 Faecal coliforms & salmonella sp.

Franke's [3] review shows that E. coli O157 did not survive 60 minutes at 55°C. It is further indicated that TAD at 53°C resulted in 90% reduction of E. coli. after a retention time of 0.4h. Franke [3] further indicates that Salmonella is commonly used as indicator organism for pathogen reduction verification. Salmonellae are indicated to be efficiently destroyed at 56°C for 10-20 minutes. In TAD processes Salmonella was shown to be effectively inactivated after 24h of detention time.

Watanabe et al. [4] executed a field survey in Japan of 17 wastewater treatment plants and conducted laboratory experiments as well to investigate the inactivation of pathogenic bacteria. It is stated that thermophilic digestion is efficient in inactivating pathogenic bacteria. Field sampling was backed up with laboratory testing to show efficient reduction using thermophilic digestion. Here MPN analyses were used and showed compliance with EPA regulation.

Fröschle et al. [6] indicate that TAD has high potential for pathogen inactivation not only due to temperature, but also due to higher free ammonia concentrations. Decimal reduction time (so called D-value) are indicated for both E. Coli and Salmonella sp.. At temperatures between 50 and 55°C D-values for both did not go higher than 4 hours. This may be considered an indication that both indicator organisms are efficiently inactivated at thermophilic temperatures; specifically if relatively high concentrations of free NH3 are present.

Zhao & Liu [7] reviewed deactivation of sludge-associated pathogens by anaerobic digestion. They clearly state that TAD performs better than MAD. An inactivation rate 15 to 17 times higher is indicated for pathogens. Furthermore, TAD completely inactivated coliforms at detention times between 12 to 15 days. Again free ammonia at higher temperatures is indicated as beneficial for pathogen inactivation.

Sahlströhm [8] reviewed pathogen resilience in biogas plants. As other authors mentioned, temperature is crucial, but not the only factor influencing inactivation of pathogens. D-values for thermophilic digestion are indicated to be in the hours. Salmonella, for example was completely inactivated after 24h in TAD. Hill [9] also indicates temperature to be crucial. At 55°C >4.log10 was achieved for faecal coliforms. Besides this, NH3 is again indicated as important in inactivation of bacterial pathogens.

Elving [10] reports on pathogen inactivation in general. It is a further confirmation of importance of temperature and specifically above 50°C to get efficient inactivation. D-values for several indicator organisms are provided for temperatures above 50°C and normally up to a few hours.

In a series of publications Iranpour et al. [11, 12, 13] reported on applied research at the Hyperion Treatment Plant in Los Angeles, California (USA) on meeting biosolids Class A requirements. They performed full-scale studies [11] with thermophilic digesters operated between 55 and 60°C. 2-phase thermophilic digestion systematically met Class A requirements for both faecal coliforms and salmonella.

Ziemba & Peccia [14] conducted research on inactivation of faecal coliforms under thermophilic anaerobic conditions (50 – 60°C). They show first order kinetics for inactivation with the higher temperatures showing the highest inactivation rates: achieving 3 logs of inactivation requires around 11 hours at 50°C, 40 minutes at 55°C and 8 minutes at 60°C.

### 4.2 Helminth ova & enteric viruses

Fröschle et al. [6] clearly states thermophilic digestion inactivates helminth ova, while mesophilic digestion cannot assure complete inactivation. A temperature of 55°C is mentioned. They further indicate that enteroviruses are efficiently inactivated under thermophilic conditions: after 4 hours no active enterovirus was detectable.

Reimers et al. [15] did research on helminth parasites in sewage sludge and technologies to efficiently inactivate them. Thermophilic digestion is indicated as an effective technology to remove viable helminth ova. A temperature higher than 55°C is indicated. Kato et al. [16] showed efficient inactivation at 55°C: >99% inactivation after 1 hour. Bowman [17] states that thermophilic anaerobic digestion is considered by many the most effective stabilisation method for the reduction of helminth ova. With ammonia present (concentration 0.1%) at 52°C, 100% inactivation was obtained after a 1 day retention time.

Pecson & Nelson [18] report on the influence of ammonia on inactivation of helminth ova. Temperatures lower than 40°C are indicated as ineffective, while thermophilic temperatures (>50°C) may inactivate eggs to below detection limits. Free ammonia may reduce this temperature with increasing concentration. Thus, a combination of increased pH, a relatively high ammonium concentration and temperature should result in more efficient inactivation of helminth ova. Pecson et al. [19] investigated the combined effect. Apparently at temperatures above 50°C the effect of free ammonia is overshadowed by the temperature effect on inactivation of Helminth ova.

### 4.3 Conclusions

Literature review shows that thermophilic digestion is considered an adequate technology to reach Class A biosolids. At full-scale faecal coliforms and salmonella sp. were efficiently eliminated. The influence of ammonia on pathogen reduction should not be discarded. In fact, it may be used to achieve better reduction rates. For helminth ova and enteroviruses thermophilic conditions seem adequate to achieve indicated maximum concentrations. Again ammonia may help in achieving better inactivation of specifically helminth ova.

## 5. References


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