Efficiency of wastewater sludge disinfection by autoheated thermophilic aerobic digestion (ATAD)

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Abstract: This paper presents the process of autoheated thermophilic aerobic digestion (ATAD), a sludge treatment method for achieving both effective sludge disinfection and a high degree of stabilization for returning sludge into the natural cycle. The paper explains the principles of the ATAD process and presents performance data from existing ATAD facilities. Recent investigations presented in the paper focus especially on the disinfection superiority of the ATAD process. The superior disinfection of sludge treated by ATAD results in an odour-less biosolids product and prevents re-growth of pathogenic microorganisms after application in agriculture. The paper presents microbiological analysis data from different ATAD plants in Europe proving the superior disinfection quality of the process. Furthermore, microscopic photographs are presented demonstrating the change in microbiological life when passing through the process.

Keywords: ATAD: digestion: biosolids: sewage sludge: stabilization: disinfection: PFRP: Class A

INTRODUCTION

The requirements for disinfection of sludge are regulated well. In many countries all over the world different quality standards are defined for treated sludge (biosolids) with regard to the final application of the sludge. The ATAD process is capable of converting sewage sludge into a natural fertilizer otherwise referred to as Class A biosolids (according to EPA regulation 503). Class A represents a kind of international standard, the highest quality standard for disinfected biosolids. The ATAD process may be utilized to treat any kind of organic sludge. However, most of the existing ATAD’s are applied for treatment of municipal wastewater sludge (primary or waste activated sludge). Besides, a number of ATAD plants are also applied for treatment of sludge originating from the food processing industry.

The sludge treated in an ATAD plant is bacteriologically inoffensive, meets international disinfection criteria and may be used as a valuable fertilizer in agriculture. The process is characterized by a very stable course of biochemical reactions and short detention time (7-9 days). Based on that, an ATAD installation requires little space, which results in low investment costs. On the other hand, the limited detention time also results in low operational costs.

The paper also presents dewatering data of sludge treated by ATAD plants. As most of the treated biosolids are applied in agriculture in solid form the dewaterability of sludge contributes essentially to the quality of the final product. The paper presents promising dewatering data from ATAD plants in Europe and the USA which explain that sludge treated by ATAD's turns into a high quality and well accepted final biosolids product.

REGULATION REQUIREMENTS

In the United States the use and disposal of treated sewage sludge (biosolids), including domestic septage, are regulated under 40 CFR Part 503. The pathogen reduction requirements for sewage sludge are divided into two categories: Class A and Class B. The implicit goal of the Class A requirements is to reduce the pathogens in sewage sludge (including enteric viruses, pathogenic bacteria and viable helminth ova) to below detectable levels (…). The implicit goal of the Class B requirements is to reduce pathogens in sewage sludge to levels that are unlikely to pose a threat to public health and the environment under the specific use...
conditions. For Class B biosolids that are applied to land, site use restrictions are imposed to minimize the potential for human or animal exposure to Class B biosolids for a period of time following land application and until environmental factors (e.g. sunlight, desiccation) have further reduced pathogens. (...) Because Class A biosolids may be used without side restrictions, all Class A material must be tested to show that the microbiological requirements are met at the time when it is ready to be used or disposed. In addition to meeting process requirements, Class A biosolids must meet one of the following requirements:

- Either the density of faecal coliforms in the sewage sludge be less than 1,000 MPN per gram total solids,
- or the density of Salmonella ap. bacteria in the sewage be less than 3 MPN per 4 grams of total solids.

Furthermore it is important to note that it is mandatory for all sewage sludge particles to meet the time temperature regime. (...) Sewage sludge with less than 7% solids treated in processes with at least 30 minutes contact time has to meet the following time temperature function:

\[ D = \frac{50.070.000}{10^{0.14t}}, \quad \text{with } t \geq 50^\circ\text{C} \text{ and } D \geq 30 \text{ minutes} \quad (EPA, 2003). \]

**PROCESS REQUIREMENTS**

**ATAD process characteristics**

The process of autoheated thermophilic aerobic digestion (ATAD) of organic sludge provides simultaneous stabilization and disinfection. The ATAD process converts sludge into a natural fertilizer which is otherwise referred to as Class A biosolids.

Biological stabilization of wastewater sludge is based on the degradation of organic substances contained in the sludge. In an ATAD plant this degradation takes place aerobically based on the activity of aerobic microorganisms. Aerobic degradation takes place exothermically. The energy which is set free by the biochemical oxidation process is released mainly in the form of heat. The final degradation products are low energy substances, e.g. H2O and CO2. Efficient retention of the heat which is released by the degradation process results in high operation temperatures (>50ºC). This results in a high degree of stabilization of the sludge and in turn effective disinfection (Schwinning et al., 1997). In order to heat the sludge to the higher thermophilic temperature range provision of sufficient organic matter to feed the ongoing degradation process is required. To achieve this, the raw sludge fed to the ATAD process is typically thickened to about 4-6% dry solids.

The following diagram shows the temperature development in the three reactors of an ATAD in southwest Poland, within the first 10 days after initial start-up (start-up was June 20, 2006).

![Graph showing reactor temperatures after start-up](source: own research)
In most existing ATAD plants the process temperatures are limited to 60 ÷ 65°C, by application of heat exchangers for sludge cooling. Because operation takes place in the higher thermophilic temperature range, the microbiological processes develop fast and the microbiological activity is much higher than in conventional sludge treatment processes. This in turn leads to short detention times (5 – 6 days) by ensuring degradation rates of 38 – 50% of volatile solids and effective pathogen reduction at the same time (Schwinning et al., 1997). Bartlett reports from an ATAD plant in Ireland that the volatile solids destruction rate ranges from 42.3 to 57.2% with an average of 49.8% (Bartlett, 2005). The respective ATAD plant is based on the Fuchs ATAD technology described in the following.

**ATAD Equipment requirements**

ATAD plants usually consist of a two-stage process built-up of two or more reactors. In order to prevent short circuiting of pathogens the system is operated in a semi-batch mode, fed only once per day. Covered and insulated reactors are used in order to minimize heat loss.

Efficient mixing and aeration of the sludge is the key to successful ATAD operation. Mixing and aeration of pre-thickened sewage sludge represents a challenge for the installed equipment. Aspirating aerators which provide effective mixing and aeration at the same time have become widely accepted as the sludge aerators of choice. These aerators do not have any bearings at the immersed end and require little maintenance.

The development of a dense foam layer is associated with the aerobic thermophilic degradation process. By application of appropriate means this foam layer may be utilized to increase the oxygen uptake rate and to insulate the sludge against heat loss. With specially developed foam controllers the foam layer may be maintained regarding thickness and density.

The following picture shows the build-up of an ATAD reactor (FUCHS ATAD system).

![Figure 2. Cross-section of FUCHS ATAD reactor (Schwinning et al., 1997)](image)

1 – reactor, 2 – insulation, 3 – cladding, 4 – piping, 5 – spiral aerator, 6 – circulation aerator, 7 – foam controller, 8 – off-gas outlet

In the first stage of a typical 2-stage ATAD the temperature is maintained in the lower thermophilic temperature range (40 ÷ 50°C). Maximum disinfection is reached in the second stage where the temperature reaches 50 ÷ 65°C (Schwinning et al., 1993). Daily discharge of disinfected sludge takes place from the second stage only. After discharge is completed, partly treated sludge is transferred from the first stage to the second followed by feeding raw sludge into the first stage reactor. After completion of the discharge and feed cycle, the reactors remain isolated while aeration and mixing continuous for 23 hrs/day (Schwinning et al., 1993). A heat exchanger is installed in the second stage of the ATAD in order to cool the process if required.
The off-gas drawn from the ATAD reactors is loaded with odour causing substances. While there is a number of ATAD’s installed in Europe and the USA which are operated without any odour treatment, most of the existing ATAD plants are equipped with an odour control system. In the past mainly biofilters and chemical scrubbers were used for ATAD off-gas treatment. Chemical scrubbers often fail to provide adequate odour reduction. A relatively new development is the photo-catalytical off-gas treatment based on the application of UV-light and a catalyst. This technology has proven to be an effective and reliable odour treatment technology also for the ATAD process. (compare Augustin, 2006)

**ANALYSIS DATA**

**Disinfection of wastewater sludge with full-scale ATAD facilities**

Research on pathogen reduction by application of ATAD has been carried out on numerous wastewater treatment plants in the United States, Canada, and Germany. Seven of the existing 22 Fuchs ATAD plants in the USA have been investigated regarding their disinfection efficiency (Schwinning et al., 1997). Samples of treated sludge have been checked for bacteria of the *coli* group. Average numbers ranged from 2 to 97 MPN per g of dry solids. The obtained results showed much lower numbers as required by legislation (compare EPA requirements). This is understood as an indication for the high disinfection quality of ATAD.

In Canada, research has been carried out on 3 wastewater treatment plants using ATAD processes for wastewater sludge treatment (Kelly et al., 1994). The sludge was analyzed for bacteria similar to *coli* bacilli, faecal streptococcus and bacteria of *Salmonella* group. It has been found that in 83% of samples analyzed for bacteria similar to *coli* bacilli less then 2 MPN/g have been found, and in the remaining samples less then 100 MPN/g. Faecal streptococcus were below 2 MPN/g in 30% of the samples, and in the remaining samples less then 100 MPN/g were found. Neither of the analyzed samples showed bacteria of the *Salmonella* group. The research has shown that destruction of pathogens is more efficient when at least two reactors are operated in series, which allows maintaining temperatures of at least 55°C in the final reactor.

Current performance data collected on the municipal wastewater treatment plant in Poland confirms the disinfection efficiency of ATAD. The ATAD plant has been started up in September 2003.

Before the ATAD plant was build, the sludge treatment line of the wastewater treatment plant consisted of partial stabilization, mechanical treatment and dewatering in drying beds.

Today the wastewater treatment plant has a capacity equivalent to approx. 67,000 p.e. (population equivalent). The ATAD was designed for treatment of approx. 96.5 m³/d of waste activated sludge with a dry solids concentration of 4 - 5%.

The wasted sludge is thickened mechanically. A former gravity thickener is utilized as the pre-ATAD holding tank for storing the daily batch volume. The ATAD consists of 4 reactors with a volume of 193 m³ each. The 4 reactors are operated as 2 trains of 2 stages. After digestion the sludge is stored in a post-ATAD holding tank followed by dewatering with a centrifuge (Bartkowska, Dzienis, 2003b).

Microbiological and parasitological investigations have been carried out in the Regional Veterinary Medicine Inspectorate in Białystok, Poland and in the Water Supply System Sewage Laboratory in Białystok, Poland. Neither *Salmonella* bacilli nor living eggs of helminths *Ascaris* sp., *Trichurus* sp. or *Toxocara* sp. were present in the treated sludge.

Microbiological investigations of the raw sludge have confirmed the presence of microflora and microfauna typical for activated sludge. In the investigated samples there were rotifers (*Monostyla pyiformis*, *Monostyla* sp., *Rotaria rotatoria*, *Cephalodella gracilis*), ciliates (*Epistylis lacustris*, *Prorodon teres*), rhizopods (*Arcella vulgaris*, *Euglypha tuberculata*), flagellata (mostly *Bodo* type), and different kinds of dispersed bacteria (bacilli, cubes, spiral). The investigation of the treated sludge has shown lack of organisms typical for activated sludge. There were observed hollow scuta of *Euglypha*, *Arcella*, and *Monostyla* organisms only. Dispersed bacteria of different kinds appeared to be a dominating form. Microscopic photographs of raw and treated sludge are presented in figures 3 and 4.
Figure 3: Microorganisms in raw sludge (Source: own research)  a) Monostyla sp.  b) Epistyliis lacustris  
c) Euglypha tuberculota  d) dispersed bacteria of different kinds (bacilli, cubes, spiral)

Figure 4: Microorganisms in treated sludge; a hollow Euglypha scutum and bacteria are visible (Source: own research)

Maintaining the disinfection temperature according to EPA 503 is an essential operation task. Temperatures are typically recorded continuously to prove that the requirements are met.

Figure 6 shows the recorded temperature of the ATAD-plant in Poland from January 2006. Temperature values varied from 20 to 25°C in the first stage. Temperature in stage 2 is constantly above 55°C except from 20.1. to 23.2.2006. At this time the ATAD was hydraulically overloaded. While the each of the two treatment tracks of the ATAD is usually loaded according to the design with approx. 96.5 m³/d, at this time the load was 116.5 m³/d. This corresponds with an overload of approx. 20%. After the loading had been reduced, the temperature recovered immediately.
CONCLUSION

Autoheated Thermophilic Aerobic Digestion (ATAD) is a process which provides effective disinfection of sewage sludge and, simultaneously, a high degree of stabilization. The treated sludge is bacteriological inoffensive, meets international disinfection criteria and may be used as a valuable fertilizer in agriculture. The process is characterized by a very stable course of biochemical reactions and a relatively short detention time. Based on that, the installation requires little space, which results in decreased capital costs.

Up to date observations and the authors’ experience enable to formulate the following conclusions:

• The ATAD process is an effective method to convert sewage sludge into a stabilized and disinfected natural fertilizer.

• The treated sludge (biosolids) is free of pathogenic microorganisms. Effective degradation at the high thermophilic temperature level together with semi batch feed operation ensures the high disinfection quality.

• The volatile solids contained in the raw sludge ensure that the process is operated autoheated. No external heating is required. Furthermore, the process requires cooling and provides the possibility for heat recovery.

• Based on a short detention time the required treatment volume and in turn investment costs and required footprint are low.

• Effective and well designed off-gas treatment provide for odour free operation.

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