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# Technological Improvements for the Aerobic Digestion of Sludge

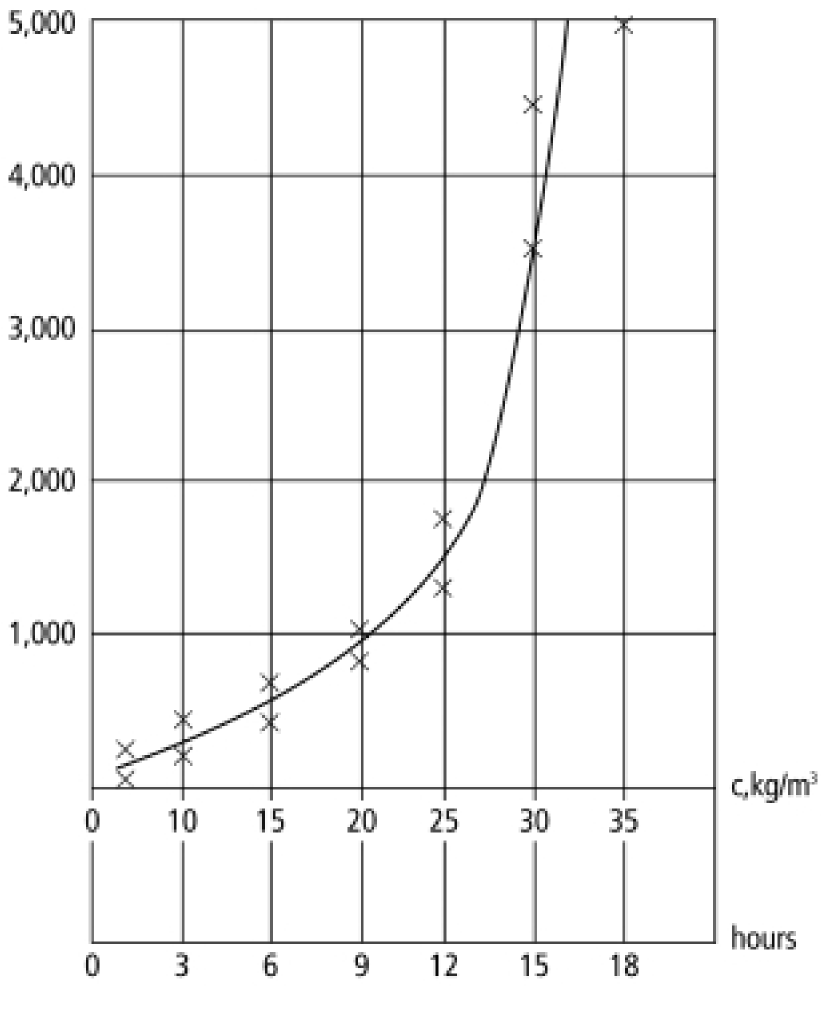
Aerobic digestion has been widely used in wastewater treatment plants (WWTP) for many years. The purpose of aerobic sludge digestion is to stabilize raw sludge and produce biosolids for further treatment and disposal.

The detention time required to reduce volatile solids and achieve stabilization for a digestion mixture of waste activated sludge and raw primary sludge is 10–15 days at an operating temperature of 20° C (68° F).[1, 2] Traditionally, digesters have been designed based on a detention time of 20–30 days.[3] In order to achieve 503 Class "B" sludge during aerobic digestion, Federal regulations (40 CFR 257)[4] require detention times of 40–60 days at temperatures of 20° C and 15° C and the reduction of volatile solids by a minimum of 38 percent. Long aerobic digestion time can result in significant deterioration of sludge dewaterability[1, 5] and the doubling of tank volumes or an increase of the solids concentration to 4–6 percent by belt thickening.[3]

Activated sludge thickening is a common method for reducing the volume in aerobic digesters.[6] However, the thickened activated sludge has a very high oxygen uptake rate in the first 10 days of digestion (up to 2 lbs. $O_2$/lb. VSS).[3] The oxygen requirement for the primary plus waste activated sludge is approximately nine times that of waste activated sludge alone.[1]

The author, together with the Medical and Hygiene Institutes in Russia and several wastewater treatment plants, conducted research of aerobic sludge digestion. The object of this research was to obtain sanitary harmless biosolids with an effective aerobic sludge digestion technology that also was cost effective.

**Figure 1: Specific Resistance of Activated Sludge vs. Thickening Time**




## Thickening

The experiments with activated sludge thickening were conducted with samples from WWTP thickeners using a simulator-plastic cylinder .25 m in diameter and 2.0 m in height. The cylinder was graduated in units of measure and equipped with a siphon for removal of supernatant and with valves for taking the samples and emptying the simulator.

The thickening of activated sludge significantly decreases its dewatering capacity. The longer the activated sludge is thickened, the higher its specific resistance (Figure 1). During the process of waste activated sludge thickening the concentration of dry solids increased from 0.2–2.0 percent and the specific resistance rose ten times. However, when concentrations increased from 2.0–3.0 percent, volumes were reduced only one and a half times, while the specific resistance rose from 1,000–3,500 m/kg (Figure 1). When thickening lasts over eight hours organic putrefaction takes place. In addition, the microorganisms of the activated sludge perish without the air, the amount of colloids increase and part of the free water transforms into the bound state of water with dry solids. Unthickened activated sludge usually has lower specific resistance and better dewatering capabilities than a thickened one. On the other hand, digesting non-thickened activated sludge does not make sense due to the large volume and low initial concentration of dry solids. The kinetics of the activated sludge thickening determines the rational concentration of dry solids.

## Detention Time

The duration of the volatile phase of solids oxidation depends on food/microorganisms ratio, temperature, intensity and quantity of the air aeration. The wastewater composition and technological demand also play a role. The process of aerobic digestion of sludge's organic elapses by one phase. (See Equation 1.)

At the beginning of the aerobic digestion process, the adsorption of contaminants in activated sludge takes place. This process is followed by its mineralization, and finally self-oxidation and the disintegration of activated sludge. In the process, volatile solids have reduced from 5 to 50 percent, fat has decreased 65–75 percent and protein 20–30 percent. Activated sludge needs 7–10 days to stabilize, while raw primary sludge takes 20–30 days to process at 20° C. At 8 to 10° C the stabilization increases in duration 2 to 2.5 times. Thickened activated sludge needs longer detention times for reducing volatile solids. Figure 2 shows how volatile solids reduce in activated sludge digestion. If the initial volatile solids is 100 percent, after 7–10 days of digestion in an activated sludge concentration of 10–18 $kg/m^3$ the solids content is 32–37 percent (1, Figure 2), with a concentration of 18–24 $kg/m^3$ the content is 25–33 percent (2, Figure 2), and at 24–30 $kg/m^3$ the content is 15–23 percent (3, Figure 2).

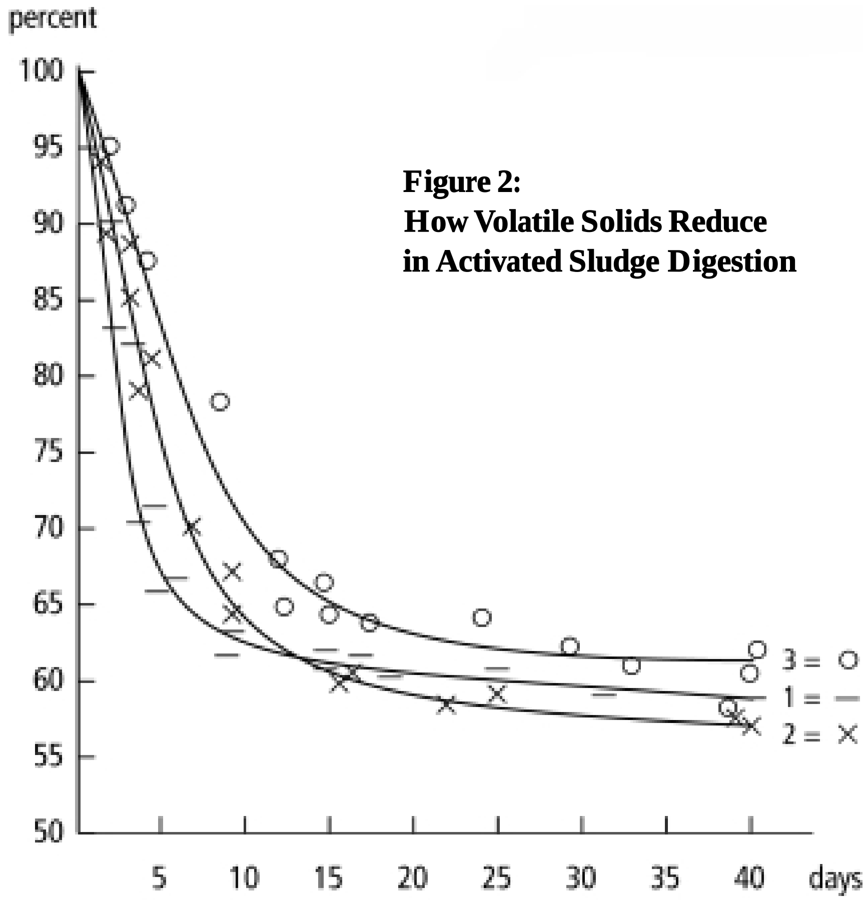



**Figure 2: How Volatile Solids Reduce in Activated Sludge Digestion**

Table 1 illustrates changes in specific resistance during the aerobic digestion of activated sludge. A long digestion time decreases the dewaterability of digested sludge. However, in several experiments, the specific resistance decreased. An effective process may be achieved by thickening the activated sludge 4–6 hours before aeration with a digestion detention time consisting of 3–5 days. Some reduction of specific resistance takes place when the organic part of sludge disintegrates and the sludge's particles become heavier. Restricting the length of the digestion process does not give full stabilization, but not decreasing the activated sludge particles worsens the sludge's dewatering abilities.

**Equation 1:**

$$C_5H_7O_2N + 5O_2 = 5CO_2 + 2H_2O + NH_3$$

or

$$C_5H_7NO_2 + 7O_2 = 5CO_2 + 3H_2O + 3H_2O + H + NO_3$$

($NH_3$ biological oxidized to $NO_3$).

Detention time also depends on air consumption. A higher food/microorganism ratio of concentrated activated sludge needs more oxygen, up to 2 $m^3$ of air for 1 $m^3$ of activated sludge in one hour at 20° C. When the volatile solids decreased, the air consumption changed (Figure 2). This fact needs to be considered when it is necessary to prevent sedimentation of activated sludge (approximately 1 $m^3$/1 mL of activated sludge for one hour). The oxygen requirement for a mixture of waste activated sludge and raw primary sludge is approximately 5–10 times more than it needs for only activated sludge. The aerobic digestion of sludge from primary clarifiers needs more oxygen, longer detention times and increases the specific resistance when compared to activated sludge. The volume of digested activated sludge decreases by 1.2–1.3 times.

For example, activated sludge before the digestion process had 73 percent volatile solids or 73g in 100g of dry solids. After seven days of aerobic digestion, 32 percent of volatile solids decomposed (Figure 2) or 73*32:100 = 23.4g. The

**Table 1: Changes in Specific Resistance During the Process of Aerobic Digestion of Activated Sludge**

| Percent of Dry Solids | Specific Resistance R, m/kg Days of Aerobic Digestion | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 3 | 5 | 10 | 15 | 40 |
| 1.0 | 300–400 | 160–270 | 70–180 | 230–390 | 400–690 | — | — |
| 1.5 | 500–700 | 360–530 | 220–370 | 410–640 | 540–870 | — | — |
| 2.0 | 800–1,000 | 810–1,100 | 1,150–1,480 | 1,290–1,850 | 4,140–5,510 | 4,030–4,690 | 1,900–2,600 |
| 2.5 | 1,200–1,800 | 1,360–2,100 | 1,480–2,600 | 1,670–4,500 | 5,780–6,250 | 4,970–5,800 | 2,810–3,960 |
| 3.0 | 3,500–4,500 | 3,800–4,100 | 4,090–4,920 | 5,300–6,170 | 6,190–7,020 | 5,910–6,690 | 4,300–5,720 |

quantity of the new dry solids will be 100 - 23.4 = 76.6g. Therefore, the digested sludge has 73 - (73*32:100) = 49.6g of volatile solids in dry solids or 49.6*100:76.6 = 64.75 percent. The volume of activated sludge reduced in 100:9100–73*32:100 = 1.3 times.

## Disinfection

Aerobic digestion of activated sludge with a detention time of 40 days and a temperature of 20° C leads to relatively safe levels of coliforms and pathogenic viruses. Reduction in indicator organisms and viruses in 10 days at 20° C takes place from 70 to 99 percent. A more microbial population can be found in agricultural soils.[7] One of the possible causes of destroying pathogens and viruses is the high eh-potential of the digesting process (200–700 mill volt). However, aerobic digestion destroys only part of the helminthes eggs.

These eggs number several hundred in one kg of aerobic digested sludge and they can survive for a long time. Our experiments showed that helminthes eggs could be destroyed by heat digested sludge at 50° C within two hours, at 60° C within several minutes and at 70° C within several seconds.[8] After mechanically dewatering and heating to 65° C, aerobically digested sludge revealed no presence of the intestinal typhoid group of bacteria inoculation on the Wilson-Bleaur or Ploshiryov medium, on media with different inhibitors or on Miller, Kaufman and other media. Our studies showed that because of the extreme changeability of the *colon bacillus* (revealed in the process of reactivation), there should be no fear of livability or virulence of pathogenic microbes during the utilization of dewatered, heated biosolids. This process meets the pathogen requirements and can be classified as Class "A" biosolids.

## Technological Decisions

Technological schemes developed by the author are shown in Figure 3. For municipal WWTP treating up to 1,500 $m^3$/day with BOD up to 150mg/L the scheme shown without primary clarifiers (3) can be used. Waste activated sludge should be thickened in a special zone (8) inside the digester (7). Duration of thickening should be 3 to 5 hours with a concentration of thickened sludge 10–13 g/L. By using this scheme, the detention time of activated sludge aerobic digestion should be 5–8 days with the air rate 1 $m^3/m^3$ of activated sludge in one hour. Sedimentation time of digested sludge is 1.5–3 hours. Supernatant with BOD up to 100 mg/L goes (9) to the aerator tank (4). After sedimentation (8), the digested sludge concentration (1.5–2.5 percent of dry solids) goes (13) to the heater (18) where it is warmed to 65° C and sent (16) to drying beds (20). The loading rate of the drying beds with drainage in a region, a mean annual ambient temperature of 4–6° C and precipitation up to 500 mm is 3.0 $m^3$ per 1 $m^2$ of drying beds per year. The resulting biosolids have a moisture content of 75–80 percent and can be used as soil fertilizers.

For municipal WWTP treating up to 5,000 $m^3$/day a scheme that includes aerobic digestion of the mixture of raw, primary sludge (10) and thickened activated sludge (6,8) can be used. The duration of thickening of waste activated sludge is 5–6 hours with the concentration of the thickened activated sludge 13–15 g/L. The detention time for digestion should be 10–15 days at 20° C with air consumption 6 $m^3/m^3$ of mixture in one hour. This scheme has been used in different parts of Russia.

Experience also has shown that in northern regions in winter, when temperatures drop to –30° C and digester temperatures are 3° C, this technology can be used by sending digesters a mixture of wastewater and activated sludge from aerotanks, warming up the primary sludge to 60° C or by heating the pumped air. Two to four hours of thickening of the digested mixture yields a concentration of 3 to 7 percent of dry solids. Digested sludge from thickener (8) is pumped (17) to the drying beds (20). The loading rate on the drying beds with drainage is 2 $m^3/m^2$ per year. Sludge from drying beds (moisture content of 70–78 percent) is composted with bulking material such as sawdust, wood chips and compost. The composted biosolids are a good organic fertilizer.

For municipal WWTP with a capacity of more than 5,000 $m^3$/day an effective scheme includes separate treatment of waste activated sludge and raw primary sludge (e.g., aerobic digestion of waste activated sludge and anaerobic thermofilic digestion of primary sludge). In this scheme, waste activated sludge is thick-

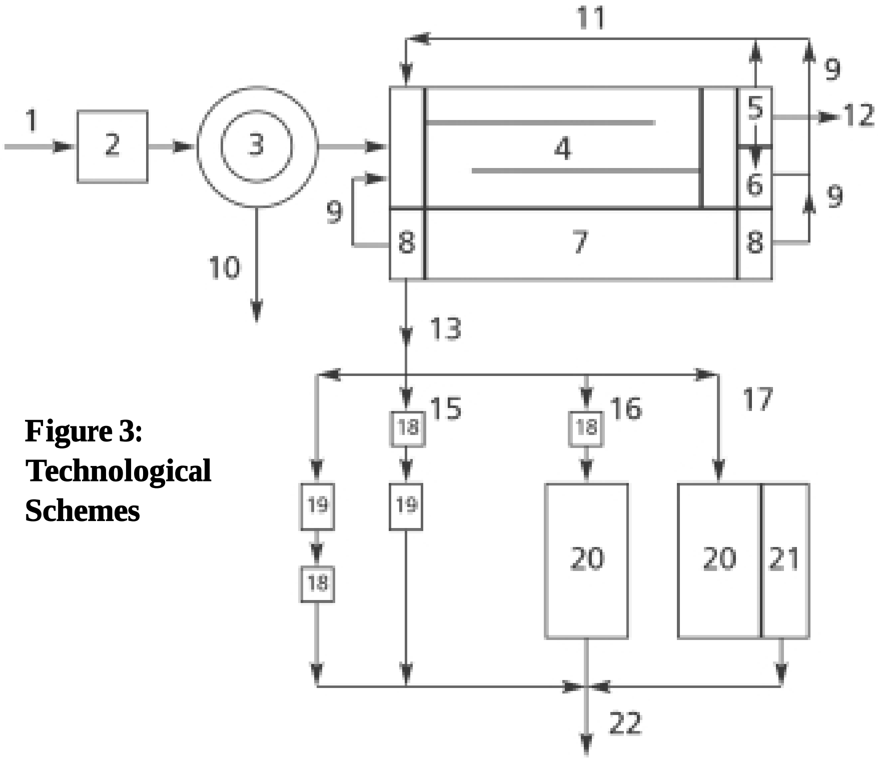



**Figure 3: Technological Schemes**

ened 3–8 hours (6,8). Concentrated to 10–18 g/L, the activated sludge goes to the digester (7). Detention time is 7–10 days with air consumption being 2 $m^3/m^3$ of sludge in one hour at a temperature of 20° C. Digested sludge is concentrated (8) 3–5 hours to 2.5–3 percent of dry solids, depending on the particular condition. The digested thickened sludge is pumped to mechanical dewatering (14 or 15) accomplished by belt filter presses or centrifuges. Due to a low specific resistance, less polymer is required for the digested sludge. Heating it to 65° C before or after dewatering disinfects the sludge. Sludge converted to Class "A" biosolids may be used as fertilizer on land, lawns and soil. This scheme, with separate treatment of waste activated sludge and primary sludge, is more practical due to the decrease in the detention time, consumption of oxygen and dewatering improvements.

## End Result

Aerobic digestion of low concentrated activated sludge with the heating of digested sludge allows one to decrease the volume of thickeners and digesters, reduce detention time for digestion, reduce the polymer demand for dewatering and produce biosolids that meet 503 Class "A" sludge regulations.

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