Recent Advancements in Wastewater Sludge Composting

Izrail S. Turovskiy and Jeffrey D. Westbrook

Many utility providers face growing problems with disposing of the wastewater sludges (residuals) that are created as a part of the wastewater treatment process. Other providers are looking at additional methods for converting the residuals into fertilizer or soil conditioner with higher economic and social value. New technology provides a composting method that can be used to produce a Class A biosolid that offers the utility operator the maximum flexibility for its disposal or use as a fertilizer or soil conditioner.

Composting wastewater residuals is a biothermal aerobic process that decomposes the organic portion of the residuals, reducing the organic material by approximately 25 percent. During composting, the heat generated by the decomposition of the organic material reduces the moisture content of the residual, stabilizes it and renders it harmless, transforming the residual into a usable biosolid.

Organic Content

In general, the higher a residual's organic content, the greater the quantity of heat released during composting. This greater quantity of heat results in the thermophilic phase (55 to 65 degrees Celsius) being reached earlier in the composting process. The greater heat release results in more moisture being evaporated.

Raw residuals from primary and secondary clarifiers typically contain 60 to 80 percent organic material, while digested residuals contain only 30 to 50 percent organic material, so it is reasonable to prepare compost from dewatered raw residuals. Thus, the digesters, pipe, pumps, electrical power, and personnel normally utilized in the digesting process can be reduced or eliminated.

The heat generated by composting 1.0 kilogram (kg) of organic material averages 21 Million Joule (Mjoule). Approximately 4.0 Mjoule of heat will evaporate 1.0 kg of moisture, taking into account heat losses and heating of the compost material; therefore, the composting of 1.0 kg of organic material facilitates the removal of approximately 5.0 kg of moisture from the residual (21 Mjoule/(4 Mjoule/kg of water)).

Before composting, it is necessary to dewater the residual to not only reduce the volume of the residual but also decrease the amount of moisture to be evaporated by the composting process.

Odor

A problem with composting raw residuals instead of digested residuals is the higher-intensity odor that can be released because of the higher percentage of organic material in raw residuals. Various methods can be used to control the odor, but the method favored by the authors of this article is adding quicklime (CaO) to change the pH of the residual.

Experiments show that organic material loses its odor when the pH is raised from the typical 5.5-6.5 to a pH of 10.0-10.5. In addition to changing the pH of the residual, the hydration of the quicklime (absorbing moisture from the residual) causes the quicklime to release heat to the residual. During the process of hydrating 1 kg of chemically pure (100-percent CaO) quicklime, 1,152 Kilojoules of heat is produced, requiring 320 grams of moisture/hydration from the residual.

This release of heat shortens the time span of the mesophilic phase (25 to 40 degrees Celsius) and drives the process to the thermophilic phase (55 to 65 degrees Celsius) quicker, reducing the overall composting time. If odor continues to be a problem even after the addition of quicklime, the simple procedure of drawing air through the compost piles and discharging the air to a biofilter can further reduce the associated odor.

Temperature and Moisture

The temperature increase caused by a predetermined dose of quicklime may be calculated by the following formula:

(1) $\Delta T = (1152 * A * M_l) / ((Ms_l * Cs_l) + (M_l * C_l))$

ΔT – temperature increase of the residual, °C,

A – quicklime activity in decimals, typically 0.9

M_l – mass of quicklime in kilogram (kg),

Ms_l – mass of residual in kg

C_l – specific heat of quicklime = 0.92 Kilojoules / kg°C

Cs_l – specific heat of residual in Kilojoules / kg°C that may be calculated as:

(2) $Cs_l = 1.8 (1 + 0.85 * Ws_l^3)$

Ws_l – moisture content (in decimals) of the dewatered residual

Izrail S. Turovskiy, D. Sc., is a wastewater and sludge treatment consultant in Jacksonville with over 45 years experience in the field. He was formerly with the All-Union Research Institute of Water Supply, Sewage Systems and Hydrotechnical Structures in Moscow, Russia. Jeffrey D. Westbrook, P.E., is a senior environmental project manager with Jacobs Civil Inc. in Jacksonville with over 20 years experience in potable water, wastewater and reclaimed water utilities/treatment facilities.

Raising the residual temperature by 10 degrees Celsius doubles the speed of the microbiological activity that accomplishes the composting process. The addition of quicklime absorbs moisture from the residual, thereby reducing the moisture content of the compost mixture. The residual moisture content after the addition of quicklime can be calculated using the following formula:

(3) $Wk = ((Mst * Ws_l) - (0.32 * A * M_l)) / (Ms_l + M_l)$

Wk – moisture content (in decimals) of the residual after the addition of quicklime

Lowering the moisture content of the residual decreases its volume, also decreasing the amount of quicklime required to raise the pH to 10.5. It is therefore reasonable to dewater the residual before adding quicklime.

Composting Mixture

The new technology presented in this article requires quicklime to be mixed with the dewatered residual before a bulking agent (sawdust, peat, woodchips, bark, hydrolyzed liquin, etc.) and recycled compost are added. **Figure 1** shows the technological schematic of raw wastewater residual composting.

Once the quicklime and residual are thoroughly mixed, the bulking agent and a portion of recycled compost are added and mixed. The mixture is then formed into piles and allowed to compost until a temperature of 55 to 65 degrees Celsius has been maintained for three to 11 days. The piles are often covered with a layer of bulking agent or recycled compost to protect them from heat loss and to avoid attracting flies, mosquitoes, and other insects.

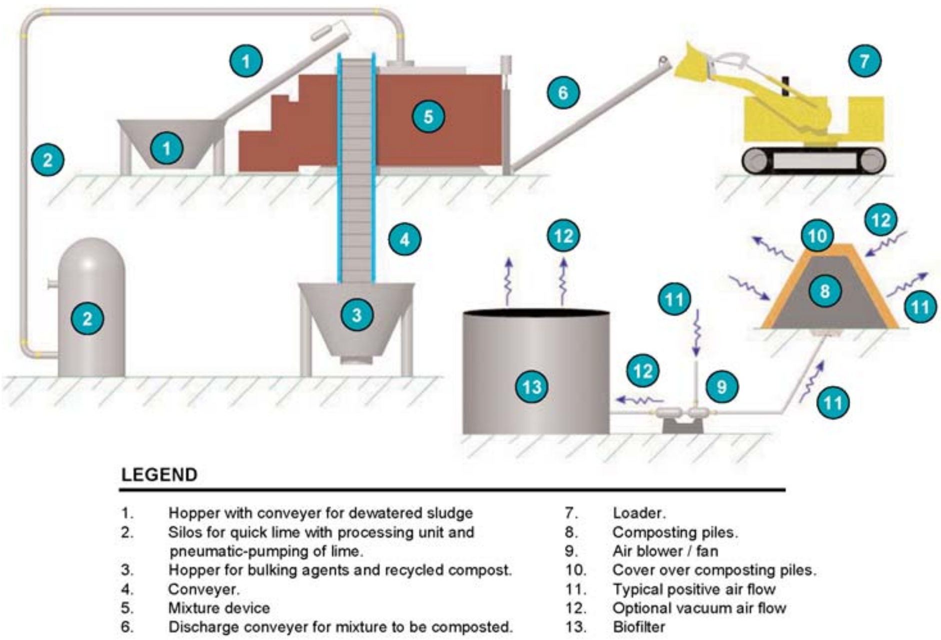

Figure 1: Technological Schematic of Raw Wastewater Residual Composting

Experiments indicate the following recommendations:

- Moisture content of the dewatered raw residual: 80% or lower
- Organic material in the composting mixture: 55% or higher
- Quantity of quicklime added to dewatered raw residual: 2.0% to 2.2% of residual mass
- Quantity of bulking agent added to dewatered raw residual: 100% to 120% of residual mass
- Quantity of recycled compost added to dewatered raw residual: 20% of residual mass

Compost Process Control

Experiments show that the type and population of microorganisms varies during the composting process. It is therefore critical to control the composting environment so the microorganisms can flourish. The composting environment parameters include the compost pile temperature; the moisture content of the compost; the oxygen and carbon dioxide levels in the compost pile; and the availability of nutrients for the microorganisms, including carbon, nitrogen, phosphorus, and potassium. These parameters must be monitored because they affect the vitality of the microorganisms.

The temperature in the compost pile most directly affects the type of microorganisms and their functions. The types of microorganisms change as the compost pile temperature increases from its initial temperature to the mesophilic (25 to 40 degrees Celsius) phase, to the thermophilic (55 to 65 degrees Celsius) phase, to the slow decrease in temperature following to completion of the composting process.

Experiments show that the thermophilic phase must be maintained for three to 11 days to produce a Class A biosolid. It is during the thermophilic phase that most pathogens are destroyed.

As the types of microorganisms change in relation to the compost pile temperature, so do their requirements for moisture and oxygen. The moisture content of the compost, the oxygen and carbon dioxide levels in the compost pile, and the compost pile temperature are closely related to one another. A change in one directly affects the others.

Oxygen is supplied to the compost pile by introducing air. The rate of air supplied depends on the moisture content of the compost pile; the higher the moisture content, the higher the rate of air required. A minimum oxygen level must be maintained, while carbon dioxide levels must not be allowed to exceed a maximum level.

As air is supplied the porosity of the pile increases, leading to increased evaporation and a resultant decrease in the moisture content of the pile. Supplying air can also lead to heat losses that result in a temperature reduction within the compost pile and a lower rate of microorganism functions; therefore, the oxygen and carbon dioxide levels and the amount of air supplied must be monitored and controlled.

Experiments indicate that the rate of air supplied is approximately 15 to 20 cubic meters per hour for each ton of organic material being composted. Monitors and controllers should be employed to automatically supply air to the pile when the carbon dioxide level within the pile reaches 8 percent.

Data obtained from raw residual composting experiments indicate that the following recommendations should be followed:

- Moisture content of compost material: 60% to 65% by volume
- Oxygen level during composting: no less than 10% of gas mass
- Carbon dioxide level during composting: no more than 8% to 9% of gas mass
- 20 to 35 parts of carbon are used for every part of nitrogen
- 75 to 100 parts of nitrogen are required for every part of phosphorus
- Temperature: 55 to 65 degrees Celsius for three to 11 days
- Duration of composting process: 25 to 40 days, depending on climate conditions

Example

A wastewater treatment plant (WWTP) with a design capacity of 40 million gallons per day generates approximately 700 tons per day of thickened mixture of primary/thickened activated residual with moisture content of 97 percent, or 21 tons per day of dry solids (3 percent solids). The WWTP's dewatering system of centrifuges with polymer feed dewaters the residual to a moisture content of 80 percent (20 percent solids). This reduces the mass of residual to 105 tons per day ((700 tons/day)/(20%/3%) = 105 tons/day).

The composting process utilizes the addition of quicklime and the addition of sawdust as a bulking agent. *Note: The utilization of polymer by dewatered raw residual is almost two times less than by dewatered anaerobic digested residual.* The addition of 2.1 tons/day of quicklime (105 tons/day * 2%) increases the pH to 10.5, removes the odor from the residual, and increases the residual temperature by:

(1) $\Delta T = (1152 * A * M_l) / ((M_{sl} * C_{sl}) + (M_l * C_l))$

(2) $C_{sl} = 1.8 (1 + 0.85 * W_{sl}^3)$

$\Delta T = (1152 * 0.9 * 2100) / ((105{,}000 * (1.8 (1 + (0.85 * 0.83)))) + (2100 * 0.92))$

$\Delta T = 2{,}177{,}280 / 273{,}184.8$

$\Delta T = 8.0^{o}C$,

Duration of the composting period and the thermophilic phase depend on process performance, quantity, and composition of the compost mass (moisture content, organic and chemical content of the residual, type of bulking agent, viability of the recycled compost, etc.) and can last from several days to several weeks. For example, the use of biodegraded wood chips and/or recycled

Continued on page 44

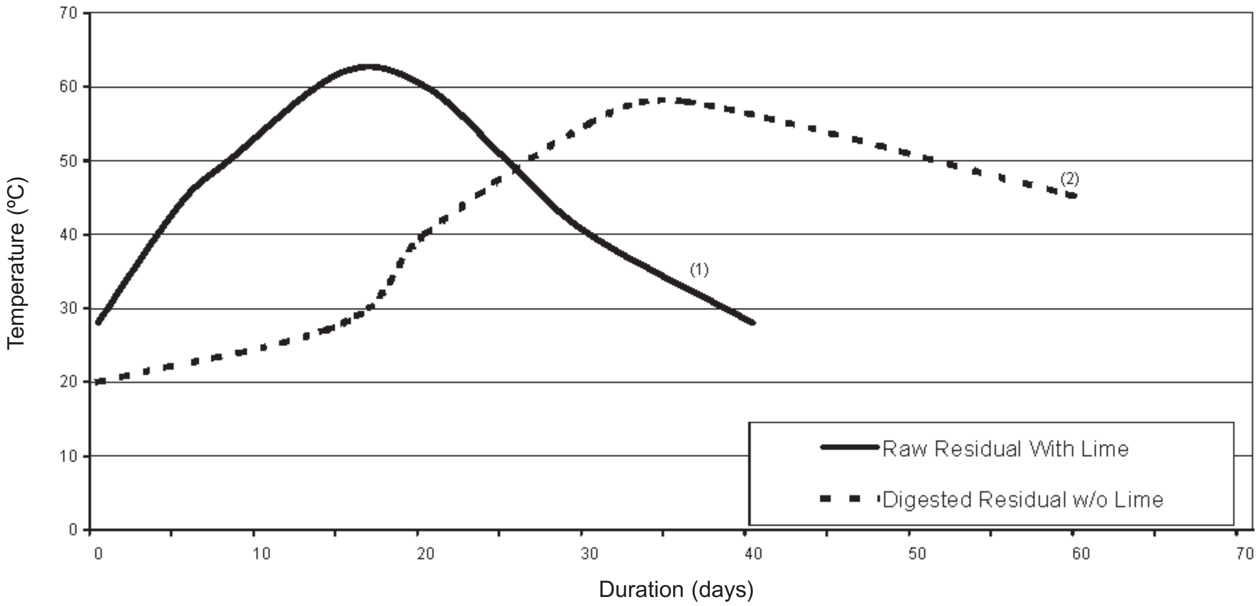

Figure 2: Diagram of Temperature Versus Duration during composting of raw wastewater residuals with lime(1) compared to digested wastewater residual without lime(2)

Continued from page 43

compost increases the temperature in the compost pile at a faster rate, since these materials are already in a state of biodegradation. Quicklime added to the residual shortens the composting process by increasing the starting temperature through a chemical reaction.

An example of temperature versus duration is the composting of raw wastewater residuals with quicklime compared to composting digested wastewater residuals without quicklime, as shown in **Figure 2**.

The residual moisture content after the addition quicklime is:

(3) $W_k = ((M_{st} * W_{sl}) - (0.32 * A * M_l)) / (M_{sl} + M_l)$

$W_k = ((105{,}000 * 0.8) - (0.32 * 0.9 * 2100)) / (105{,}000 + 2100) = 0.78$ or 78%.

The quantity of sawdust added is 105 tons/day (105 tons/day * 1.0) and recycled compost added is 21 tons/day (105 tons/day * 0.2).

The technological scheme of raw wastewater residual dewatering and composting is shown in **Figure 3**.

It takes several days to reach the thermophilic temperature (55 degrees Celsius) with the addition of quicklime. Maintaining that temperature for 10 to 11 days (Figure 2) provides the highest level of pathogen reduction/vector control and produces a compost meeting the 40CFR Part 503 Biosolids Rule. By comparison, an aerated static-pile system requires longer composting times, more operational processes, and a large area to store the composting materials. The proposed lime stabilization technology allows a decrease in the quantity of added lime by three to four times.

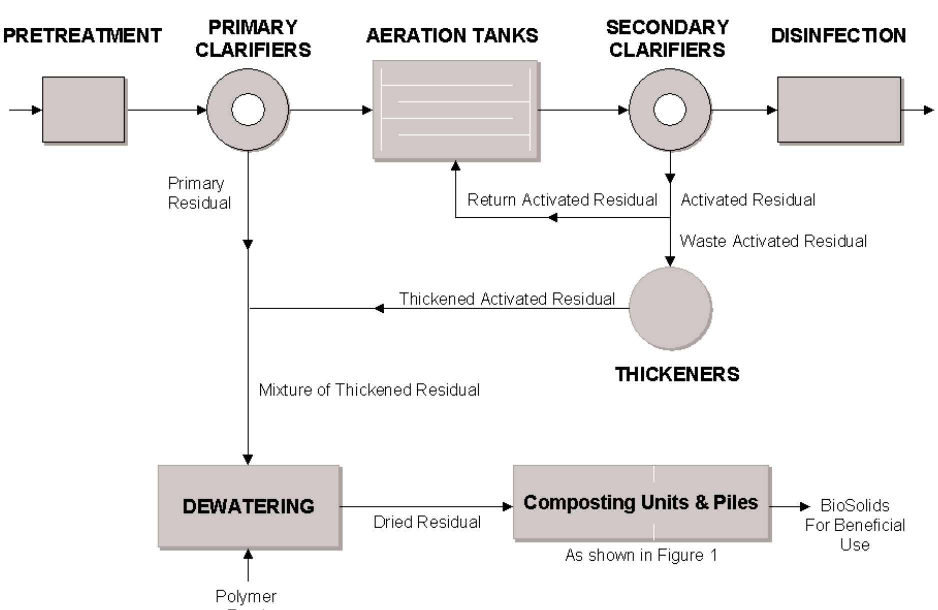

Figure 3: Technological Schematic of Raw Wastewater Residual Dewatering and Composting

Conclusion

This new technology offers a cost-effective method of raw residual composting, which reduces or eliminates the need for digesters and all associated expenses. It includes adding quicklime and bulking agents to the raw residual and recycling compost to aid in the composting process. The technology facilitates the elimination of odor, increases the temperature at the beginning of the composting process, and reduces the duration of the composting process.

References

1. *Clark, Viessman and Hammer, 1977, "Water Supply and Pollution Control", 3rd Edition, New York, Harper and Row, Publishers, Inc.*
2. *Frank R. Spellman, "Wastewater Biosolids to Compost", Technomic Company, Inc., 1996, Page 258*
3. *Gregg E. Harkness, Charles C. Reed, Charles J. Voss and Curtis I. Kunihiro, "Composting in the Magic Kingdom", Water Environment and Technology, Volume 6, Number 8, August 1994*
4. *U.S. EPA, Biosolids Generation, Use, and Disposal in the United States, EPA530-R-99-009, September 1999*