DISCUSSION

Of: **Gasification of char from wastewater solids pyrolysis,** K.M. Lee, **70,** 133 (1998).

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This is a timely article about an important subject. Because there are limited opportunities to use sludge as fertilizer, landfill space is becoming more difficult to acquire, and as there have been many observations of health risks associated with incineration, finding another way to dispose of it is a highly beneficial area of research. Moreover, burning the char from pyrolysis has some of the same drawbacks as incineration, so substituting gasification for combustion further reduces the environmental impact of sludge disposal. These considerations apply equally to many other forms of organic solid waste, such as yard waste, waste wood from construction, unrecyclable paper products, old tires, and large quantities of plastics.

The author has performed a well-planned experiment and has presented a clear description of the work. He has done a good job of surveying plausible parameter combinations, and it is significant that temperature turns out to be the most important parameter for the efficiency of volatile solids (VS) reduction.

There are a few specific questions that are not answered by the text that would clarify the results further.

1. Does the process produce impurities in the condensed steam, such as cyanides or sulfides? Was any attempt made to analyze the contents of the condenser?
2. Where did the heavy metals go? Were they left in a residue in the reactor? Did significant quantities appear in the condenser? In either place, is anything known about their chemical state?
3. What, if any, residue was left in the reactor when "100% reduction" occurred?

We also have a few questions and comments that pertain to the future of the development of which this paper is an initial step.

1. Has anyone done an economic analysis of the combined pyrolysis–gasification process contemplated in this paper? Obviously, high precision would not be possible until the process parameters had been clarified by a study such as this one. However, even in the absence of this detailed knowledge, pyrolysis and gasification at these temperatures of the many tons per day of sludge produced by wastewater treatment in a large city can be expected to impose substantial fuel costs. On the other hand, landfilling and incineration of sludge impose their own costs, and the author indicates that recent research has been driven to a large extent by public opposition to landfilling and incineration. The author says that the existing wastewater solids-to-oil (STO) process using char combustion is "viable" (presumably including economics in this evaluation), but how does substituting gasification for combustion change the economics?
2. Has the author or the references he cites investigated possible sources of the heat needed for the pyrolysis–gasification process? We presume that a plant designed for operational use would include provisions for recovering heat from the outgoing products to heat the reactants going into the pyrolysis or gasification reactors, but as these are endothermic processes occurring well above environmental temperatures, there would be a continuous demand for additional heat. For example, are there any sources of waste heat (such as power plants or steel mills) that could reduce the amount of energy needed to raise the reactants to the needed temperatures? Is there any chance of using a contribution from solar heat, at least in some climates? We have also heard encouraging claims for the "Patterson power cell," which is said by its developer, Clean Energy Technologies, Inc., to generate surprising quantities of heat from an electrolytic cell by a process that is not fully understood, but seems to operate at a very low cost (Patterson, 1994, and Patterson and Cravens, 1997). Something like this could make a significant difference in the economics of the process if it is operated at a sufficiently high temperature, but we do not know the current status of this research.
3. One possibility that has occurred to us, which is somewhat related to the present study, is that the fraction of the sludge that becomes char instead of oil might decrease if pyrolysis were done at a lower temperature than 500 °C, and if so, then there would be less char that had to be gasified. On the other hand, the reactions slow rapidly with decreasing temperature, so that the temperature could not be reduced much if current types of reactors are used. This reasoning has led us to wonder whether anyone has ever investigated the possibility of using geothermal heat for pyrolysis by drilling to a depth where the temperature is perhaps 300 °C, or perhaps even less, and allowing passages in the rock to act as a natural pyrolysis chamber with a retention time of weeks or months instead of the 25 minutes used in the experiment. In addition to reduced char production, the benefit of developing such a process would be that lower pyrolysis temperatures and longer retention times also favor formation of more complex molecules, as described in Blumer (1976). Thus, this could be a source of some kinds of petrochemicals that could survive the exhaustion of the world's natural petroleum supply. It also may be worth noting that in a geothermal system, high pressure might be achieved hydrostatically with less difficulty and cost than in aboveground equipment, but drilling deep holes would impose large capital costs. Obviously, assessing the potential economic and technological significance and feasibility of this versus other approaches to pyrolysis would be a very large and challenging project, and as we have not seen any discus-

sions of the issues that would be involved, we would like to know whether any of them have ever been considered by researchers known to the author.

Let us close by repeating that this is a timely paper and that we hope to see more work along these lines by the author.

Acknowledgement

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Closure

Kun M. Lee

I would like to express my gratitude for the kind comments on the gasification of char from wastewater solids pyrolysis. Responses to the questions and comments are prepared following the questions in the discussion. Response to specific questions are

1. No attempt was made to analyze the condensates. It is, however, reasonable to assume that impurities may be present in the condensed steam.
2. The fate of heavy metals was not followed during the gasification process. However, Schuller and Brat (1993) reported the fate of lead (Pb), cadmium (Cd), chromium (Cr), mercury (Hg), and zinc (Zn) after pyrolysis of wastewater solids at 550 to 650 °C and gasification of char at 900 °C in a fluidized-bed reactor. Except Hg and Cd, all heavy metals exhibited similar trend; 85 to 92% of metals reside in char after pyrolysis and 67 to 91% in ash after gasification. For Cd, 64 and 28% reside in char and cyclone residue after pyrolysis, respectively, and 42 and 43% after gasification, respectively. For Hg, more than 94% goes into the gas stream after pyrolysis, and all 100% after gasification.
3. A reduction was defined in this study as the reduction in volatile solids (VS) quantity. Thus, even after 100% reduction during gasification, inert substances such as silica and other metals are left in the gasification residue (ash).

Responses to questions and comments pertaining to the future research in this area are

1. Samsung Engineering and Construction (SEC) company has performed an economic analysis between the combined pyrolysis–gasification process and traditional technology, such as incineration and landfill. The SEC report written in Korean was prepared based on a pilot-scale wastewater solids pyrolysis reaction system, and the combined pyrolysis–gasification process was claimed to be more economical than the traditional technologies. The full economic analysis, however, can only be possible when a full-scale plant is installed and operated.
2. A major source of heat requirement in the combined pyrolysis–gasification process of wastewater solids is the evaporation of water from the solids. Noncondensible gases from pyrolysis and gasification processes can be combusted to provide heat for the drying of wastewater solids. However, supplemental heat must be provided in the form of fossil fuel burning. Heat requirements for the pyrolysis and gasification processes are low compared to that for the drying process. Clearly, a waste-heat recovery system such as an economizer and preheater needs to be installed in the system to maximize heat recovery.
3. A vertical tube reactor consisting of annular tubes extending 1 500 m into the ground had been tested on a pilot scale to wet-oxidize wastewater solids in the 1980s (U.S. EPA, 1985). The feed-solids concentration was 2 to 3% total solids (TS) and oxygen was injected to sustain wet oxidation, which in turn provided heat to maintain a reaction temperature of 265 °C. In theory, vertical-tube-type reactors can be used for the pyrolysis of wastewater solids. However, the pyrolysis process should employ a special carrier such as carrier oil together with a high-capacity pump to transport solids through the reactor. The waste solid, itself at higher TS concentrations, cannot be transported along the reactor depth because of friction losses.

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