FUNDAMENTALS OF HYDROTHERMAL PRETREATMENT OF SEWAGE & INDUSTRIAL SLUDGES: FEEDSTOCKS FOR CLEAN ENERGY.

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Sludge rheology and slurry solids loadings are significant from pumping and slurry heating value standpoints. In this paper, we discuss the fundamental aspects of hydrothermal pretreatment of sludge which impacts the physical and chemical characteristics of the sludge. The fundamental work served as a basis of the development of a continuous 5 ton/day Process Demonstration Unit.

INTRODUCTION

Texaco Inc. has investigated techniques to prepare dewatered sewage, industrial and biological sludges as feedstocks for gasification/oxidation processes, as part of its waste gasification program.[1A] One of the most promising pretreatment methods has proven to be the hydrothermal treatment developed by Texaco R&D. A number of patents have been issued[1B-D]. The objective of this paper is to present the fundamental aspects of hydrothermal pretreatment of sludge. Based on extensive bench-scale and pilot-scale runs, a demonstration plant was built to process 6 dry tons per day of centrifuged sludge cake. The results of the inaugural run are presented.

The Texaco Gasification Process produces synthesis gas, principally carbon monoxide and hydrogen, from carbonaceous feedstocks by partial oxidation. One hundred commercial plants have been licensed to use this technology over the last thirty years and the synthesis gas generated has been used for end-products ranging from hydrogen, ammonia and alcohol to electric power. The feedstocks have included natural gas, distillate oils, petroleum coke, and coal.

The proposed technical standards for the use/disposal of sewage sludge (40 CFR Part 503) cover the following options: incineration, agricultural and non-agricultural land application, marketing and distribution, monofilling, and surface disposal. Most large treatment plants would prefer incineration, land application, or marketing/distribution. However, the first option could be limited to plants with existing incineration facilities and the next two, the so-called "beneficial use" options, could be limited by land availability and assurances of pathogen reduction. Solids handling is a significant operating cost for municipal wastewater treatment plants. As an example, Greater Chicago spent over half of its 1990 operating and maintenance budget on solids processing and disposal. These costs will increase at all plants because new regulations and public concerns are limiting old options. Ocean dumping is banned, landfills are closing, and the public is demanding that sewage sludge be put to beneficial reuse.[3,4]

Obviously, there is a market for new sludge management technologies. Recently, wastes have been considered for gasification because they are a good source of hydrocarbons and cost less than traditional feedstocks. Gasification research and development is conducted by Texaco at its Montebello Research Laboratory in Los Angeles, California. Montebello was established in 1945 and has three 15 to 25 ton per day pilot units. In 1988, under a Hazardous Waste Reduction Grant from the State of California Department of Health Services, a demonstration at Montebello proved that low-Btu hazardous waste could be gasified safely with coal and with little impact on thermal efficiency.[1] The successful testing of hazardous wastes showed that gasification would be an environmentally-acceptable method of disposal for other high-volume, low-hazard wastes such as sewage sludge.

In order to maintain the highest efficiency in gasification there is a need to limit the amount of water carried in the feed. The high viscosity of partially-dried sludge limits its suitability as a feedstock, yet too much water in a less viscous slurry decreases its heat content. It was observed that even after complete drying, sewage sludge had a tendency to reabsorb water and did not form a good slurry for gasification. This phenomenon is known to occur with low-rank coals, so developments in this area were investigated. Several steam and hot water processes were developed to thermally dewater low-rank coal. The first of these was the Fleissner process patented in 1927.[5] When coal is heated various oxygen functional groups are decomposed releasing carbon dioxide and water from the coal structure. The tendency to reabsorb moisture is reduced so that the slurring characteristics are similar to higher rank coals.[7]

EXPERIMENTAL

<u>Bench-Scale Results/Discussion</u>: Bench-scale and pilot tests were begun at the Texaco Research Center at Beacon, New York to investigate various techniques to improve the physical, chemical and transport properties of sludge.[4,6] An indicator viscosity for all feedstocks was established at 1000 centipoise to allow comparisons of different pretreatment methods.

The Texaco Research Center at Beacon conducted extensive autoclave and other testings including pilot plant runs to demonstrate that hydrothermal pretreatment of sludge can significantly improve the physical/chemical properties of sludge. Hydrothermal treatment of sludge is somewhat similar to that of low-grade coals; however, there are significant differences between the pretreatment of coal and sludge. The viscosity of the product can be greatly reduced depending on the conditions used during pretreatment.

Figure 1 shows the influence of heat-treatment temperature on the oxygen content of the sludge. The greater the pretreatment temperature the lower the sludge oxygen content. However, the overall solids loading for a pumpable slurry is increased as a function of pretreatment temperature. Figure 2 shows the similar trends for a different sludge. The sludge was mixed with coal after the former was hydrothermally pretreated (for the data shown in Figures 1 and 2).

Figure 3 shows the influence of sludge pretreatment on the various functional groups of (dried or hydrothermally treated) sludges. The treated sludge contains significantly lower oxygenated functional groups compared to the feed sludge. Similar results were also noted for an industrial sludge (Figure 4).

Figure 5 shows the typical "Coalification" curve as applied to sludge as a function of sludge pretreatment temperature. The sludge O/Cx100 versus atomic H/C ratio of various sludges are plotted in this Figure along with various other fossil fuels feedstocks. It is interesting to note that the as the pretreatment temperature of sludge is increased, a pathway is followed by sludge which is similar to the pathway followed by geological maturation of various fossil fuels.

Process Demonstration Unit Results: Based on these results, it was decided that construction of a larger process demonstration unit was justified. Burns and Roe Industrial Services Company was retained to provide detail design and construction services for a trailer-mounted PDU with a capacity of 900 kg/h or 6 dry tons per day at 25% solids. The process is shown schematically in Figure 6. The effect of PDU Hydrothermal treatment on the viscosity of the slurry is shown in Figure 7. The dramatic effect is qualitatively similar to our pilot test results (not shown) and demonstrates that the pilot-scale and bench-scale results can be achieved in a commercial unit.

CONCLUSION

Hydrothermal Pretreatment Process, developed based on fundamental investigation, converts sewage and industrial sludges into attractive feedstocks for gasification/combustion and offers municipalities an environmentally-acceptable alternative to other disposal options.

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Figure 1. Relationship Between Heat-Treatment-Temperature and Slurry Solids Loading as a Function of Sludge Oxygen Content.

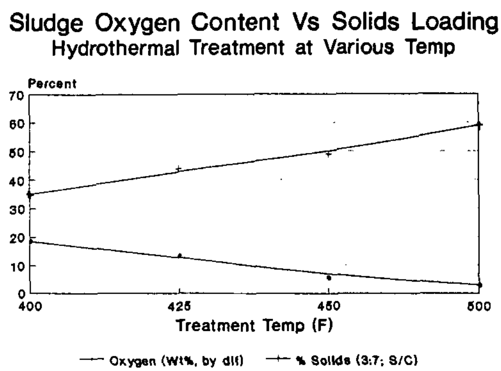

Figure 2. Relationship Between Slurry Solids Loading as a Function of Sludge Oxygen Content.

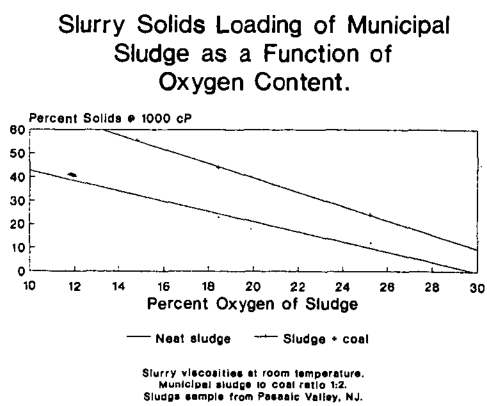

Figure 3. FT-IR Analysis of a Municipal Sludge

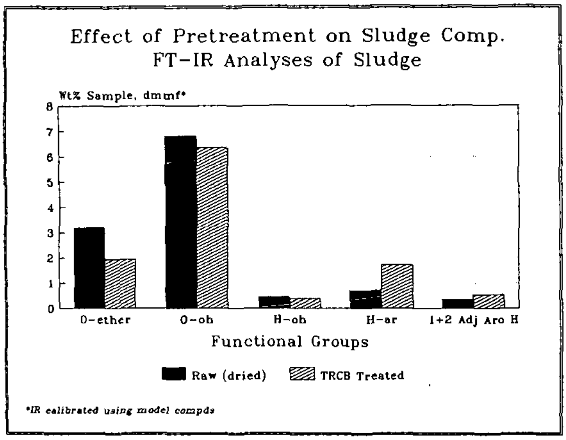

Figure 4. FT-IR Analysis of an Industrial Sludge

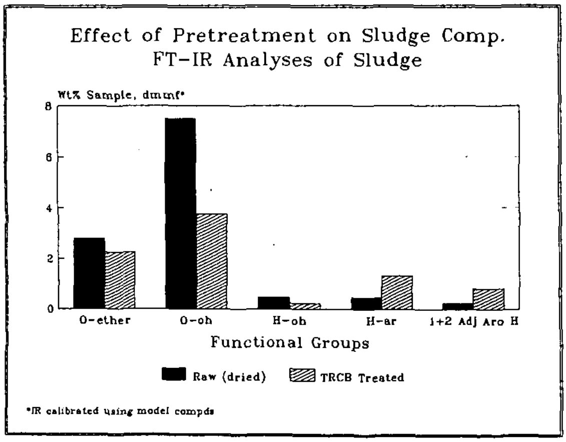

Figure 5. "Coalification" Curve: Atomic O/C Ratio Versus Atomic H/C Ratio

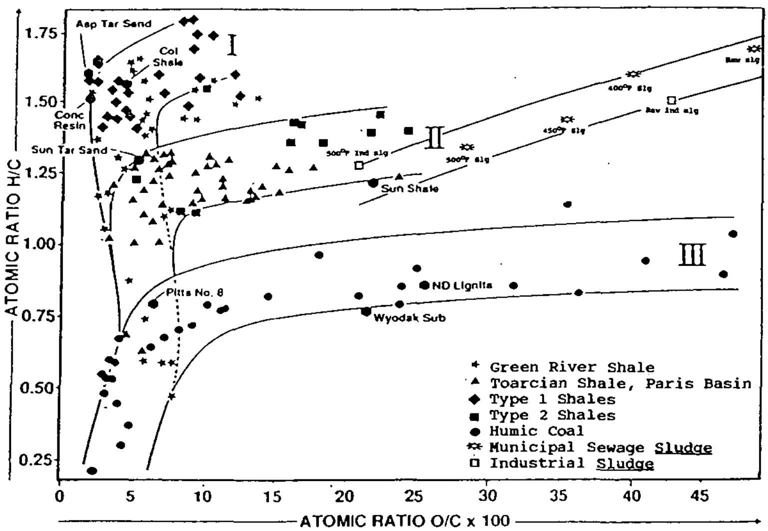

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Figure 6.

Texaco Hydrothermal Treatment

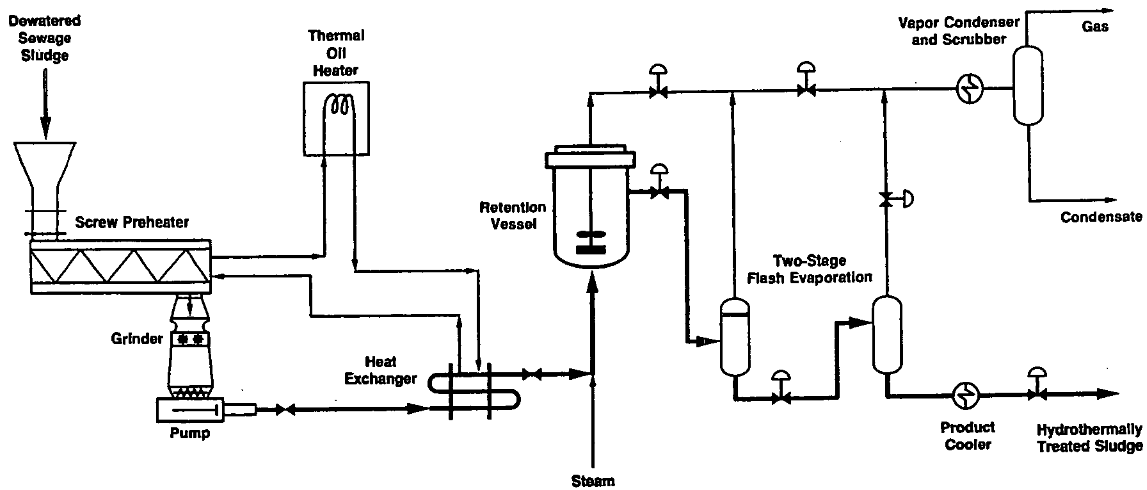

Figure 7.

TEXACO HYDROTHERMAL PDU RESULTS
Sludge:Coal 1:2; Slurry Rheology