PRETREATMENT OF MUNICIPAL SEWAGE SLUDGE FOR GASIFICATION

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ABSTRACT

The flow behavior of coal water slurry is significantly degraded when untreated sludge is mixed with coal at a sufficient concentration. Various methods of treating sludge were evaluated in an effort to make coal slurries (containing more than 25 per cent sludge) or treated sludge relatively more fluid so that they could be pumped through pipes and nozzles into a pressurized gasifier. Drying sludge in commercial dryers at temperatures ranging from 180 to 400°F significantly improved its slurrying characteristics with coal. The fluid characteristics could also be improved by removing water under vacuum, dewatering with high intensity filter presses and subjecting the sludge to shear stresses. Slurry viscosity measurements were made at 70 to 212°F in viscometers.

INTRODUCTION

Over 26 billion gallons of waste water are treated by about 15,000 publicly owned treatment works in the United States serving >70% of the population (1). This treatment results in the production of 7 million metric tons per year of sewage sludge. Most of this is applied to the land while about 20% is incinerated and another 6% is dumped into the ocean. The recent ban on ocean dumping along with a decreasing number of landfills and other environmental concerns have created a need for environmentally sound sewage disposal alternatives.

The Texaco Coal Gasification Process, which has operated satisfactorily in large scale facilities for several years, appears to offer attractive features as such an alternative. Coal slurries containing about 60% coal are a usual feed for the process and concentrated sludge slurries in the form of sludge filter or centrifuge cakes containing 70 to 80% water are a usual product of water treatment plants. Sludge in this form is a low quality fuel, however, with an insufficient btu content to be gasified alone in the process. It must therefore be mixed with an auxiliary higher quality fuel such as coal, oil or gas to form a satisfactory feed for the process.

In addition to having a satisfactory heat content, slurry mixtures that are suitable feeds for the process must be pumpable at high concentration and must contain sufficient sludge to justify the incremental cost of handling it.

This paper describes the results of our efforts to characterize the fluidity properties of sludge/coal slurries and to identify a treatment process that would enable sludge concentrations in pumpable slurries with coal to be increased to practical levels.

The hydraulic transport of particulate solids has recently been reviewed (2). Campbell and Crescuolo examined the rheological characteristics of dilute sludge slurries (3). Beshore and Giampa reported on the rheological properties of concentrated coal slurries containing small amounts (up to 10%) of sludge (4). No detailed studies of the rheological characteristics of coal slurries containing high concentrations of raw or thermally treated sludge have been reported. A fuel comprised of raw (undewatered) sludge and coal has also been claimed to be pumpable and useful as a boiler fuel (5).

EXPERIMENTAL

The viscometer used for this work was developed in our laboratory and calibrated with oils of known viscosity. Usually, apparent viscosity vs. solids concentration curves were obtained from which we determined the total solids that could be included in a slurry at a given viscosity. Replicate measurements indicated that the standard deviation of measurements using this technique was 0.79. About 80 grams of slurry was required for each measurement. Slurries were prepared by mixing the desired amounts of sludge, coal and water to a measurable consistency in the measuring cup and noting the torque at a stirrer speed of 600 rpm. Measurements were then repeated as incremental amounts of water were subsequently added. Torques were related to viscosities by measurements on the oils of known viscosity. In addition, a Haake viscometer RV-100 was also used for rheological measurements.

To establish the patterns of sludge behavior, dewatering of sludge was achieved by an advanced dewatering technique, high intensity press (HIP). The HIP was simulated by distributing dewatered cake on a 4"x4" piece of filter fabric which was supported by a specially designed perforated square metal tray. This was surrounded by a square metal box. A similar piece of fabric was placed over the sample followed by an upper square tray. Pneumatic piston pressure was then applied to the upper tray forcing out entrapped water. The applied pressure was changed in various retention times (zones 1 through 4) to simulate the actual HIP zone pressures. Upon completion of the pressure cycles, the pneumatic lever was pushed up and the pressure box removed quickly. HIP applied a mechanical pressure of 125 psi (compared to only 25 psi for commonly used belt press filters) to effect dewatering. It is important to minimize contact of the dewatered sludge with the wet belt to avoid resorption of moisture by the sludge. The solid content was determined by actual measurement and the throughput was calculated by empirical equations developed by Andritz, the manufacturer of the device.

RESULTS AND DISCUSSION

1. Sludge Characteristics

The digested sludge used for most of the measurements made in this study was obtained from water treatment plants in Los Angeles County, Los Angeles City and San Bernadino County in California. The as-received filter cakes were amorphous, fibrous materials containing 20 to 30% total solids. These materials were not pumpable but could be made so by diluting to about 15% total solids. Polymeric flocculating agents were employed in their preparation. Their composition is compared with coal and peat in Table 1. Digested sludge solids generally contain: 30-60% volatile solids, 5-20% grease and fats, 5-20% protein, 10-20% silica and 8-15% cellulose (6).

2. As Received Sludge/Coal Slurries

For the purposes of this work we needed to know the maximum amount of sludge that could be incorporated into a pumpable slurry with coal. Economics dictated that commercially viable sludge containing feeds should include at least 25% sludge and have a total solids content of above 50%. Experience with coal slurries indicates that slurries having apparent viscosities of about 1000 cP are pumpable. Results of viscosity measurements on a number of sludge/coal slurries containing varying amounts of Los Angeles sludge in Utah-Sufco coal showed that the amount of total solids which can be incorporated into a pumpable slurry decreases with increasing sludge content. It was also apparent that in the 1000 to 2000 cP range, small increases in total solids content of slurries effect large increases in viscosity. None of these mixtures was considered a satisfactory fuel because either their sludge or total solids content was too low at the 1000 cP pumpable viscosity.

3. Rheology of Evaporatively Dried Sludge

Thermal treatment of sludge improves its slurrying characteristics. Heat treated sludge is readily dewatered on filters to solids concentrations of 30 to 50%, while unheated sludge is usually dewatered to about 20 to 30% only with the aid of polymeric or inorganic conditioning agents (6,7,8).

Dilute sludge slurries containing less than 5% solids are thermally treated on a commercial scale throughout the country in different types of dryers and thermal treatment units. Thermal treatment over the wide temperature range encompassed by these processes did, in general, improve slurrying properties. The products of various treatment processes are physically and compositionally different from raw sludge (**Table 2**). Some of the products are dry homogeneous powders somewhat coal-like in appearance while others are quite fibrous containing about 60% moisture. The moist products could not be ground into a powder satisfactorily for slurry testing without drying them first.

Results of viscosity tests on slurries prepared from these materials are summarized in **Table 3**. We usually measured the slurrying characteristics of the neat sludges and of mixtures containing 30% sludge and 70% coal (dry basis). Clearly, all of these materials demonstrated slurrying characteristics far superior to those of untreated sludge. Some treated sludges were coal-like in slurry behavior hardly affecting the fluidity of the coal at low concentrations, while the other materials degraded the fluidity of the slurries to varying extent. This behavior is not unexpected since these materials have not only been heated at different temperatures but under different conditions. For example, sludge is heated while suspended in oil in one process in a manner that oil soluble compounds can be extracted from it, while in others, organic components in sludge are simply volatilized. Overall, the rheological characteristics of sludge and the sludge we treated in various ways were found to be very consistent. The rheology of a thermally treated sludge, as a function of shear rate is shown in **Figure 1**.

Thermally dried sludge could also be slurried in oil but the viscosity of the slurry oil determined to some extent the amount of slurry solids that could be included in a pumpable mixture.

Another factor that influences the rheology of sludge slurry is the applied shear rate. At relatively low shearing rates, the untreated sludge filter cakes could be reduced from an intractable solid with no meaningful viscosity to pourable liquids. This behavior is consistent with the thixotropic nature of sludge. As would be expected, more of this sheared product could be incorporated into a pumpable slurry than the "as received" sludge. This phenomenon is attributable to at least two factors: the first of these is the simple shearing of the cellulosic and polyamide flocculating polymers in the sludge. The second is a consequence of the shearing stresses on the flocculated colloidal particles. The drag forces and unfolding of the flocculated particles probably release trapped water and make it available as a carrier fluid with a consequent decrease in viscosity (**Figure 2**).

In an effort to explore various means for treating sewage sludge for improving its slurrying characteristics with coal, we have found that virtually any means of removing water trapped in the raw sludge filter cake (including thermal treatment, advanced dewatering, shearing, vacuum drying and simple air drying) appear to improve the slurrying characteristics.

REFERENCES

1. R. K. Bastion, " An Overview of Sewer Sludge Programs in the U.S.", Proceeding of the National Conference on Sewage Treatment Plant Sludge Management, May, 1987.
2. P. A. Shamlou, "Handling of Bulk Solids, Theory and Practice",

Butterworth and Company, Ltd., 1988.
3. H. W. Campbell and P.J.Crescuolo, "The Use of Rheology for Sludge Characterization," Water Science and Tech., pp. 475, 1982.
4. D. G. Beshore and V.M. Giampi, U.S.Patent 4,762,527, "Slurry Fuel Comprised of Heat Treated, Partially Dewatered Sludge with a Particulate Solid Fuel and its Method of Manufacture", 1988.
5. L. A. Rodriguez, R.A. Ashworth, R. Armstead, P.A. Aristedes and N.B. Spake, U.S. Patent 4,405,332, "A Fuel Composition", 1983.
6. V. T. Chow, R. Eliassen and R.K. Linsley, Editors, "Wastewater Engineering: Treatment Disposal Reuse", McGraw-Hill, 1979.
7. T. P. Nichols, J.N.Lester and R. Perry, "The Influence of Heat Treatment on the Metallic and Polycyclic Hydrocarbon Content of Sewage Sludge," Science Total Environment, 14 (1), 19, 1980.
8. D. Reimann, "Thermally Conditioned Sewage Sludge", Umwelt, (6), 332, 1987.
9. W. D. Hatfield, "The Viscosity or Pseudo-plastic Properties Sludge," Sewage Work Journal, 10 (1), 3, 1938.
10. C. L. Doyle and D.M. Haight," Sludge Conditioning with Organic Polyelectrolytes," Proceedings of the National Conference on Municipal Treatment Plant Sludge Management, p. 103, 1986.

Figure 1

Apparent Viscosity vs. Shear Rate for 38.02 wt% Thermally Dried Sludge at 30, 60 and 90 C.

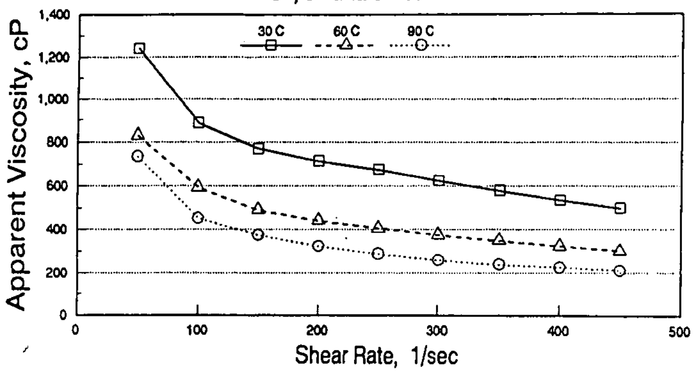

Figure 2

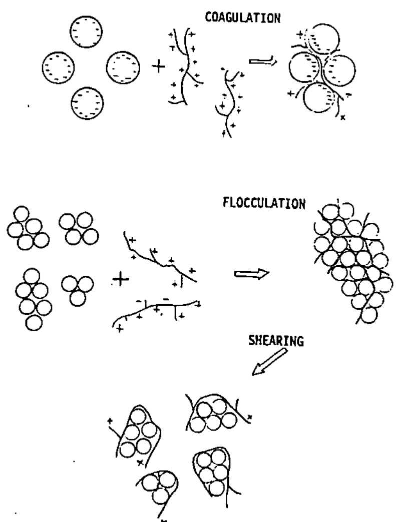

TABLE 1 TYPICAL ANALYSES OF SEWAGE SLUDGE AND OTHER SOLID FUELS								
FUEL	MOISTURE %	ASH	C	H	N	O BY DIFF	S	BTu/lb (DRY)
SEWAGE SLUDGE	80	36	31	4.8	3.9	22.1	1.7	6400
PEAT	83.7	3.4	47.1	5.4	1.4	42.6	0.1	
LIGNITE, TX	29.3	21.5	55.7	4.5	1.0	15.8	1.4	9788
SUBITUMINOUS C, WYOMING	28	7.8	68.1	4.9	1.1	17.2	0.6	11840
BITUMINOUS PITTSBURGH 8	0.8	8.6	76.5	5.1	1.4	5.8	2.5	13765

TABLE 2 ANALYSES OF DRIED SLUDGE FROM VARIOUS PROCESSES					
	LOS ANGELES AS RECEIVED	PROCESS A	PROCESS B	PROCESS C	PROCESS D
% MOISTURE	80.2	3.03	7.93	2.79	9.2
% ASH	36.3	50.91	32.29	31.38	44.0
% C	31.3	30.48	34.71	33.8	28.9
% H	4.84	4.49	4.99	5.32	3.81
% N	3.92	3.96	5.52	2.57	3.21
% S	1.66	1.6	.71	0.62	1.11
% O (BY DIFF)	22.00	8.6	21.8	26.3	19.0

TABLE 3 SLURRYING CHARACTERISTICS OF COMMERCIALLY AVAILABLE THERMALLY TREATED SLUDGES					
PROCESS	MAX TEMP, F	% ASH	SLURRY COMPOSITION SLUDGE %	COAL %	TOTAL SOLIDS AT 1000 CP
A	250	50.9	30 100	70 -	51.0 36
B	1200	32.29	30 100	70 -	58.5 48.2
C	365	33.8	30 100	70 -	45 30
D	358	44.0	30 100	70 -	62 53