Assessment of Powdered Activated Carbon Addition to Anaerobic Digesters at Salt Lake City, Utah

to
U.S. Department of Energy
Urban Waste Technology Branch
Division of Building and Community Systems
Washington, D.C. 20545

by
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April 1978

Pacific Northwest Laboratory
Richland, Washington 99352
Operated for the
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ADDITION TO ANAEROBIC DIGESTERS AT SALT
LAKE CITY, UTAH

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SUMMARY

The Salt Lake City Water Reclamation Plant has added powdered activated carbon to its influent wastewater since January 1977. Battelle Pacific Northwest Laboratory has gathered and analyzed operational data from the treatment plant in an effort to identify beneficial effects of the carbon. Benefits occurring during anaerobic digestion were of principal interest. Three potential areas of enhanced treatment were investigated:

1. Reduced solids in the primary clarifier effluent;
2. Increased anaerobic digester gas production; and
3. Increased sludge stabilization rate.

Review of the data from the Salt Lake City plant indicates that carbon did not significantly effect these aspects of the plant operation. However, the carbon dose rate was generally lower than that used in other carbon addition studies. Therefore, data from Salt Lake City can be interpreted to mean only that carbon does not produce the above benefits at low doses. Potential benefits identified by other investigators using higher carbon dose rates have not been invalidated.

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ACKNOWLEDGMENTS

The authors wish to extend their gratitude to Jack Peterson, Willard DeVault, and Elgin Dyer of the Salt Lake City Water Reclamation Plant for their assistance in the collection of data necessary for the preparation of this report.

The secretarial and typing efforts of Nancy Painter are also gratefully acknowledged.

ASSESSMENT OF POWDERED ACTIVATED CARBON ADDITION TO ANAEROBIC DIGESTERS AT SALT LAKE CITY, UTAH

INTRODUCTION

Since 1976 Battelle Pacific Northwest Laboratory (PNL) has investigated for the U.S. Department of Energy (DOE), the effect of powdered activated carbon on the anaerobic digestion of municipal sewage sludge. Part of this research program has involved a national survey of wastewater treatment plants in order to predict the impact of carbon addition on existing anaerobic digesters. On January 3, 1978, PNL contacted the Salt Lake City Water Reclamation Plant and discovered that powdered activated carbon was being added to the wastewater treatment scheme in an effort to improve the digester operation as well as to enhance methane production. Most of the work at the Salt Lake City Plant was being sponsored by ARIES Consulting Corporation. At approximately the same time, a representative from ARIES contacted DOE and informed them of the carbon addition work at Salt Lake. Subsequently, DOE suggested to PNL that it would probably be worthwhile to learn more about this operation. This report presents Battelle's findings.

The major conclusions of the report are presented first. A description of the Salt Lake City plant and carbon addition system follows. The data gathering and reduction process is presented in the third section. The concluding section presents and discusses evidence relative to the claims that powdered activated carbon improves flocculation in the primary clarifier, enhances digester gas production, and yields a more stabilized sludge over the same digestion period.

CONCLUSIONS

- Studies at the Salt Lake City Water Reclamation Plant were conducted using an approximate carbon dose of 1 mg/l in the plant influent wastewater. This corresponds to a carbon concentration of about 350 mg/l of wet sludge in the anaerobic digesters. This dose is generally lower than that used by other investigators examining the addition of carbon to anaerobic digesters. Therefore, the results of the Salt Lake City research are applicable only to the low dose situation.
- Carbon addition failed to provide any definite measurable benefit as a flocculation agent in the primary clarifiers, as a means to enhance digester gas production, or as a catalyst in the sludge digestion and stabilization process.
- Any enhancement in the digestion system operation observed during the latter stages of the study period is probably attributable to the cleaning of digester No. 2.

DESCRIPTION OF TREATMENT PLANT AND CARBON ADDITION SYSTEM

The Salt Lake City Water Reclamation Plant provides primary and secondary treatment to an average flow of 42 mgd. The plant treats mainly municipal sewage. The only large industries contributing to the plant flow are Coke and 7-Up bottling companies, Union Pacific Railroad (pretreats waste), Union Oil Refinery (pretreats waste), and a very small chrome plating industry. The wastewater contains very few heavy metals, and only at low concentrations. As much as 22% of the plant flow is due to infiltration, mainly from sewer lines installed in the early 1900's.

Figure 1 presents the general plant layout. The anaerobic digesters are arranged to operate as a two-stage system. However, the secondary digester is open and acts mainly as a holding tank.

The primary digesters are heated by external heat exchangers. Raw sludge and sludge from the digesters are combined in a make-up tank. This sludge mixture is passed through hot water/sludge heat exchangers and then discharged to the digesters.

Mechanical mixers are used in the primary digesters. The mixers are effective in localized areas but do a poor job of mixing the entire digester contents. According to plant personnel, the present mixing capacity is about 25% of that needed. The plant operations supervisor mentioned that digester No. 3 may be 2/3 full of sand and grit. It also has a scum cap about 3 ft deep. Digesters No. 1 and 2 have been cleaned recently. They probably have a scum cap that is 6-8 in. deep.

As indicated in Figure 1, carbon is added to the plant influent just upstream of the primary clarifiers. Every two hours an operator adds a specified amount of carbon. Doses of 8 lbs/mgd and 10 lbs/mgd have been used. Assuming that all of the carbon settles in the primary clarifiers, this is equal to a concentration of about 316-396 mg of carbon per liter of wet sludge fed to the digesters. Other investigators seeking to determine if carbon benefits the digestion process have typically used doses of 1000-5000 mg/l. A powdered activated carbon made from natural vegetable base materials (mainly redwood sawdust) was used at the Salt Lake City plant. This carbon may have been combined with lime and other chemicals prior to addition. The exact mixture added to the plant is not available.

FIGURE 1. Salt Lake City Water Reclamation Plant Layout

Properties of the carbon are given in Table 1. Table 2 shows activities at the treatment plant pertinent to the operation of the anaerobic digestion system.

TABLE 1. Properties of the Carbon Used at the Salt Lake City Water Reclamation Plant

Density:	30 ± 2 lbs/ft ³	
Maximum Moisture:	3 percent	
Particle Size:	<u>Mesh Size</u>	<u>% Weight Passing Mesh</u>
	100	97
	200	85
	325	65

TABLE 2. Events Pertinent to the Operation of Anaerobic Digesters at Salt Lake City, Utah

<u>Date</u>	<u>Event</u>
September, 1965	Treatment plant began operation.
May-July, 1975	Digester No. 1 taken off line and cleaned.
November, 1976	Added hydro-degritting unit at main pump station to replace the original aerated grit removal unit.
January, 1977	Began carbon addition; Dose = 8 lbs/mgd.
July-November, 1977	Digester No. 2 taken off line and cleaned. No carbon was added during this period.
November, 1977	Started carbon addition again; Dose = 10 lbs/mgd.
February 7, 1978	Carbon addition stopped.

DATA GATHERING AND REDUCTION

Table 3 indicates the volume of data gathered by PNL from the Salt Lake City Water Reclamation Plant. The majority of this data was photocopied from the plant's daily operational records. One piece of data very important to the analysis of the digestion system, the amount of volatile solids in the feed sludge, was not available for a sufficient period of time to permit the comparison of conditions before and after carbon addition. Therefore, it was necessary to estimate this value.

The percent volatile solids and total solids in the feed sludge during the year 1977 were known. To estimate an average volume of volatile solids applied to the digesters from August 1975 to December 1976, the average percent volatile solids and percent total solids for 1977 were combined with the average volume of sludge pumped between August 1975 and December 1976. The formula used was:

$$\begin{array}{l} \text{Average lbs volatile solids} \\ \text{applied to digester daily} \\ \text{between August 1975 and} \\ \text{December 1976} \end{array} = \left(\begin{array}{l} \text{Average ft}^3/\text{day sludge} \\ \text{feed to digesters} \\ \text{between August 1975} \\ \text{and December 1976} \end{array} \right) \times (62.5 \text{ lbs/ft}^3) \times$$

$$\left(\begin{array}{l} \text{Average 1977 percent} \\ \text{total solids} \end{array} \right) \times \left(\begin{array}{l} \text{Average 1977 percent} \\ \text{volatile solids} \end{array} \right)$$

where volatile solids are expressed as a percentage of the total solids.

No attempt was made to estimate the volatile solids variation from month to month.

The remainder of the data evaluation process simply consisted of calculating monthly averages from daily values and combining monthly averages according to the following equations. When monthly averages were not available, the yearly average was used.

$$\begin{array}{l} \text{Cu Ft Gas per lb} \\ \text{Volatile Solids Applied} \end{array} = \frac{\text{Average Gas Production for Month (ft}^3/\text{day)}}{\text{Average Volatile Solids in Feed Sludge} \\ \text{During Month (lbs/day)}}$$

$$\begin{array}{l} \text{Percent Volatile Solids} \\ \text{Destruction} \end{array} = \frac{VS_F - VS_D}{VS_F - (VS_D)(VS_F)}$$

$$\text{where: } VS_F = \frac{\text{lbs Volatile Solids in Feed}}{\text{lbs Total Solids in Feed}}$$

$$VS_D = \frac{\text{lbs Volatile Solids in Digested Sludge}}{\text{lbs Total Solids in Digested Sludge}}$$

TABLE 3. Data Obtained from the Salt Lake City, Utah
Water Reclamation Plant

<u>Parameter</u>	<u>Period of Measurement</u>
Plant Flow	August 1975 to February 1978
Grit Removal	August 1975 to February 1978
Daily Chlorine Use	August 1975 to February 1978
Digester Temperature	August 1975 to February 1978
Gas Production by Digester	August 1975 to February 1978
Volume of Sludge Pumped to Digesters	August 1975 to February 1978
BOD	August 1975 to February 1978
TSS	August 1975 to February 1978
Settleable Solids	August 1975 to February 1978
Digested Sludge:	
Alkalinity	January 1976 to February 1978
pH	January 1976 to February 1978
Volatile Acids	January 1976 to February 1978
Total Solids Concentration	January 1976 to February 1978
Volatile Solids Concentration	January 1976 to February 1978
Feed Sludge:	
Total Solids Concentration	January 1977 to February 1978
Volatile Solids Concentration	January 1977 to February 1978

DATA PRESENTATION AND DISCUSSION

The data presented in this section are grouped into three categories, each of which investigates a potential benefit of carbon addition. Based on a preliminary analysis by ARIES Consulting Corporation and Salt Lake City Water Reclamation Plant personnel, each of these benefits was occurring at the Salt Lake City plant.

The first claim was that the carbon acted as a flocculent in the primary clarifier. It collected fines and made them more available to the biological community in the anaerobic digesters. If this was occurring one would expect to see a change in the concentration of total suspended solids (TSS) in the primary clarifier effluent as well as in the volume of sludge pumped to the digesters. Suspended solids include those particles that will settle to the bottom of a container under quiescent conditions as well as solids that are removable only by coagulation. Figure 2 presents the average monthly TSS values from August 1975 to February 1978. During the period of carbon addition (January-July 1977 and November 1977-February 1978) the TSS concentration of the primary effluent remained very near those values recorded when no carbon was added. The fluctuations that did occur were erratic and more probably due to changes in the influent concentration, weather conditions, or plant operation than to the addition of carbon. Figure 3 shows the volume of sludge pumped to the digesters. Again, the volume during periods of carbon addition does not deviate outside the historical range of values.

The second claim was that gas production during digestion had increased by 80-90%. The actual volume of gas produced during digestion is shown collectively in Figure 4 and by individual digester in Figure 5. When viewed over a period of 31 months, gas production during carbon addition fell within the range of values recorded when no carbon was added. As shown in Figure 5, the cleaning of digester No. 2 resulted in a notable improvement in gas production. For six months prior to cleaning but during carbon addition, digester No. 2 produced 50,000-70,000 cu ft of gas per day. After cleaning but during carbon addition the production rate increased to values between 160,000 and 180,000 ft³/day. The enhanced operation of digester No. 2 was responsible for the improved total gas production indicated in Figure 4 during the period November 1976 to February 1978.

FIGURE 2. TSS Values of Wastewater Treated at the Salt Lake City Water Reclamation Plant

FIGURE 3. Average Volume of Sludge Pumped to Anaerobic Digesters at the Salt Lake City Water Reclamation Plant

FIGURE 4. Average Total Digester Gas Production at the Salt Lake City Reclamation Plant

FIGURE 5. Average Anaerobic Digester Gas Production at the Salt Lake City Water Reclamation Plant

Since gas production can fluctuate over a wide range, depending on the volatile solids content of the feed sludge, a more accurate comparison between gas production values can be made by taking into account the volume of volatile solids available to the biological community in the digester. Figures 6 through 9 represent the average volume of gas produced for each pound of volatile solids added to the digesters. Figure 6 indicates the gas production for all digesters; Figures 7 through 9 are for the individual digesters. Averages of the monthly gas production values over carbon-addition and no-carbon-addition periods are plotted on each graph. Typical values for municipal plants should range from 8 to 12 ft³/lb volatile solids added. However, excessive gas production rates sometimes occur during startup. As seen in Figure 8, during startup of digester No. 2, which had been down for cleaning, an extremely high production rate was recorded. It is expected that this gas production rate will stabilize at a value nearer the 8-12 ft³/lb range. However, sufficient data to substantiate this expectation is not currently available.

Figures 6 through 9 lend very little substance to the claim concerning enhanced gas production. The increase in total gas production observed during the last four months in Figure 6 is due to improved operation of digester No. 2 during that startup period. It is unfortunate that more accurate data is not available for the control period (August 1975-December 1976). However, based on the estimated average value for the period, it appears that carbon addition has failed to significantly improve the gas production rate.

The third benefit claimed to have occurred at Salt Lake City's Water Reclamation Plant was that a more stabilized sludge could be obtained over the same period of time if carbon was added to the feed sludge. This claim is best investigated by studying the percent reduction in volatile solids during the digestion period. Figures 10 through 12 present the average, and when available the monthly percent volatile solids destruction for each digester. Results of a PNL survey of municipal anaerobic digesters indicated volatile solids destructions range from 32-70%. An efficient digester typically operates at a value greater than 45%. Except with the possible exclusion of digester No. 1,

FIGURE 6. Total Gas Produced Daily by Anaerobic Digesters at the Salt Lake City Water Reclamation Plant

FIGURE 7. Daily Gas Production in Digester No. 1 --
Salt Lake City Water Reclamation Plant

FIGURE 8. Daily Gas Production in Digester No. 2 --
Salt Lake City Water Reclamation Plant

FIGURE 9. Daily Gas Production in Digester No. 3 --
 Salt Lake City Water Reclamation Plant

FIGURE 10. Volatile Solids Destruction Accomplished in Digester No. 1
 at the Salt Lake City Water Reclamation Plant

FIGURE 11. Volatile Solids Destruction Accomplished in Digester No. 2 at the Salt Lake City Water Reclamation Plant

FIGURE 12. Volatile Solids Destruction Accomplished in Digester No. 3 at the Salt Lake City Water Reclamation Plant

Salt Lake City has not consistently maintained this degree of solids destruction over the past 31 months. Carbon addition does not appear to have improved the degree of stabilization.

After digester No. 2 was cleaned, one would expect the average volatile solids destruction to be in the 45% and above range. Figure 11 indicates that such was not the case. This may be the result of a lack of data for the months November-December 1977 and January 1978. No monthly average for November was calculated since only one measurement was taken. Ten measurements were averaged to determine the December value. The average destruction in January was based on three daily measurements.

Data collected at the Salt Lake City Water Reclamation Plant provide little substance to the three potential benefits of carbon identified above. However, it should be pointed out that the carbon dose was relatively low (about 300-400 mg/l) and the digesters were generally unstressed, with volatile acids typically ranging 100-300 mg/l. Alternatively, experiments at PNL have not evaluated carbon doses of less than 1500 mg/l in unstressed systems. At this higher dose, increases in gas production of 5-20% and corresponding improvements in volatile solids destruction have been observed. In stressed digesters, gas productions were enhanced by as much as 30% with a 500 mg/l carbon dose. In summary, none of the experimental studies conducted at PNL accurately simulate test conditions at the full-scale facility. The most that can be said is that PNL research does not refute the findings at Salt Lake City.

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