Anaerobic Digester Survey of California Dairy Producers

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ABSTRACT

We conducted a survey to identify for the US Environmental Protection Agency examples of and reasons for the failure of many previously installed methane recovery systems. Six dairy producers participated in this survey. Installation costs of systems ranged from $100,000 to $950,000. Three producers have continued their dairy operations but no longer use methane recovery technology. Two producers were favorable to the technology but no longer operate a dairy. Of those surveyed, only one producer continues to use methane recovery technology. Identified problems associated with unsuccessful operations included poor design, collection of manure in a wet form, and incomplete cooperation from electric companies. Producers found that the technology required intense management and was economically risky. Increased cooperation between electric companies and small producers of electricity and greater prices paid for electricity might provide positive economic incentives that would encourage methane recovery and electricity generation. One producer indicated that the benefits from anaerobic digester technology to be emphasized to potential users were income from sales of final solids and the nutrient value of both solid and liquid effluent streams as fertilizer sources.

(Key words: anaerobic digestion, manure technology, California, waste management)

INTRODUCTION

The Clean Air Act was passed initially in 1955 (7). Amendments made in 1970 created “a federal-state partnership for the control of air pollution” (8). Section 109 of the Act, as amended (8), directed the Environmental Protection Agency (EPA) to establish national ambient air quality standards (NAAQS) for any air pollutants that might endanger public health or welfare. The EPA subsequently issued NAAQS for ozone, carbon monoxide, particulate matter, sulfur dioxide, nitrogen oxides, and hydrocarbons. The 1970 amendments required states to develop and submit state implementation plans (SIP) by 1972 that would provide attainment of NAAQS by 1975. The EPA was required to review the SIP and to disapprove any that failed to meet requirements, including attainment of NAAQS by the statutory deadline. When the EPA disapproved an SIP, the agency was required to develop a federal implementation plan (FIP) that would meet the requirements and take the place of the disapproved SIP.

A very long series of plan submissions, rejections, and litigation occurred for the California south coast (Los Angeles County) area. In 1988, Sierra Club and the Coalition for Clean Air filed a citizens' suit to require the EPA to enforce its obligation to promulgate ozone and carbon monoxide FIP for the south coast. A settlement agreement was reached in March 1989 that obligated the EPA to prepare, propose, and promulgate final FIP for the south coast (6). In a separate action, the Environmental Council of Sacramento, Inc., and Sierra Club filed suit against the EPA regarding NAAQS for ozone in the Sacramento metropolitan airshed (4). The proposed FIP to attain NAAQS for ozone in the Sacramento and Ventura nonattainment areas and for ozone and carbon monoxide in the south coast nonattainment area were signed February 14, 1994 (11). The FIP was to be promulgated February 14, 1995 following a 1-yr period for public review and discussion.

The FIP proposed stringent emission control measures for both stationary and area sources of the pollutants targeted for regulatory action. The FIP proposed enhanced motor vehicle inspection, stringent emission standards for previously exempt heavy duty vehicles, and innovative control programs to reduce...
emissions associated with airports, locomotives, architectural coatings, consumer products, aerosol spray paints, and pesticides. Included in both the stationary and area source categories was livestock, specifically dairy.

The livestock component of the FIP was directed to dairy cattle operations of \( \geq 400 \) head. Although other livestock waste operations (e.g., chicken, hog, and sheep facilities) were not being proposed for regulation at the time of the FIP, the EPA indicated it would continue to investigate potential options for reducing emissions from waste from other livestock operations as appropriate.

The US EPA Region IX office indicated that the volatile organic compounds (VOC) that were suspected to be emitted from decomposing dairy manure were acetone, ethyl alcohol, isopropyl alcohol, propyl acetate, trimethyl amine, ethylamine, and ethane (J. Ungvarsly, 1994, personal communication). The interest in these compounds can be traced to the report by Dickson et al. (2). Carter and Atkinson (1) reported mechanistic reactivities of several VOC. Reactivities are a measure of the ability of the compound to produce hydrocarbon radicals that oxidize NO to NO\(_2\). In the presence of sunlight, NO\(_2\) is converted to NO and O\(^+\). The O\(^+\) radical reacts with O\(_2\) to form O\(_3\) (ozone). Interestingly, ethane is considered the benchmark standard. Those VOC less reactive than ethane are not subject to regulation. Acetone, ethyl alcohol, and isopropyl alcohol are less reactive than ethane. The remaining VOC (propyl acetate, ethylamine, trimethyl amine) have not been evaluated.

Two major reports were identified by the EPA to quantify contribution of livestock manure to VOC emissions. E. H. Pechan and Associates, Inc. (3) estimated VOC emissions for several categories of livestock waste. They assumed that VOC emissions were generated during aerobic and anaerobic decomposition and were 10% of total organic gases (TOG), which includes all organic compounds resulting from the decomposition processes (10).

E. H. Pechan and Associates, Inc. (3) used the TOG emission factors given by Dickson et al. (2), who identified an EPA document (9) describing organic gas emissions from livestock excrement. Additionally, no temporal variation in emissions was considered. The TOG species profile used in the development of the FIP for animal waste decomposition originated from these two contracted reports. Based on scant data, dairies of \( \geq 400 \) head were estimated to contribute 1.8 ton/d of VOC in Sacramento and 10.8 ton/d of VOC in the south coast area (11).

The primary strategies thought to be available to reduce VOC emissions included utilization of methane recovery systems, promotion of enhanced aerobic conditions in manure storage areas, or both. The methane recovery strategy was included because that strategy was assumed to generate additional income for the operator. Methods recommended for promoting aerobic decomposition of livestock waste included aerating manure storage piles every 3 to 7 d, scraping feedlots at least three times annually, and spreading oxidizing agents on feedlots. For waste management practices using a dry method, the proposed FIP measure required the periodic aeration and removal of manure storage piles. This measure was estimated to reduce VOC emissions from manure by 25% (11). No consideration was given to increased VOC emissions from equipment needed to carry out the management practice.

Identified technologies for methane recovery included covered lagoons, plus flow digesters, and complete mix digesters. Although these recovery systems represented a viable, demonstrated technology under research environments, few systems are functional on farms, and some systems have not been as successful as expected because of improper design or other factors. For these reasons, the EPA requested comment and information on any examples, circumstances, and reasons why a previously installed recovery system might not have achieved its full expectations (11). Although the livestock component of the FIP was not finalized in 1995, the South Coast Air Quality Management District continues to address similar housekeeping measures to reduce ammonia emissions.

The purpose of this survey was to quantify experiences of dairy producers with anaerobic digester technology. The inclusion of methane collection and energy recovery in the EPA FIP and the likelihood of similar technology appearing in future FIP warrant further information specific to conditions in California.

**MATERIALS AND METHODS**

This survey provided the logical first step of gathering information from producers who have had practical, firsthand experience with anaerobic digester technology.

The names of dairy producers who operated (\( n = 5 \)) or were currently operating (\( n = 1 \)) anaerobic digesters in California were obtained through discussions with dairy producers and dairy field personnel. This sample set represented all producers identified by the University of California Cooperative Extension.
Dairy Advisors, fieldmen from Western United Dairymen, and survey respondents. None of the identified dairy producers had covered anaerobic ponds. However, one swine operator successfully recovered methane from capped ponds. That producer indicated that installation costs for just the pond cap ranged from $2.00 to 4.00/ft² (929 cm²). Additional costs for equipment would be needed for engine, generator, gas piping, gas handling unit (gas pump, gas meter, and filters), electrical hookup to the generator, and hookup to the utility (R. Sharp, 1994, personal communication) (5). A manure management study indicated the mean total pond surface area on dairies in the south San Joaquin Valley to be 145,000 ft² (13,471 m²) (5).

Dairy producers were contacted by phone to determine their willingness to participate in a survey. A 30-min appointment was scheduled for detailed discussion. During the in-depth interview, producers were asked to describe their digester system, to approximate costs associated with installation and maintenance, and to provide price paid for generated electricity. The final question was designed to identify the type of economic incentive necessary for the producer to reconsider this technology. Finally, producers were provided an opportunity to comment further on anaerobic technology. Questions were non-biased and open-ended. Questions were designed to allow the producer to provide a precise picture of the potential efficacy of anaerobic digesters on dairies. Producers were very cooperative and interested in sharing their experiences.

RESULTS AND DISCUSSION

Initial costs ranged from $100,000 to $950,000. Producer 2 received some grants and low interest loans. Producer 6 indicated that the actual costs paid by the dairy were $60,000, paid through a low interest rate loan from the California Energy Commission. Additionally, an unknown amount of money was contributed for research and development from a private foundation. This producer noted that the initial installation costs were distributed equally between capital costs associated with the digester proper and capital costs associated postdigestion (engine, electricity generation, or transfer component). Unknown maintenance resources were distributed in a 20:80 ratio of digester to postdigestion.

Three of the six dairy producers expressed satisfaction with the effectiveness of their systems (Table 1). Producer 2 was quite pleased with his functional digester, boasting a $2000 savings in the monthly electric bill. This producer indicated that management dictated the success or failure of the system. Producer 5 operated a functioning digester for 6 mo before his herd was sold during a dairy buyout. Producer 6 successfully operated a digester for 8 yr.

Despite repeated attempts to manage digesters, the remaining three, producers—dairy producers 1, 3, and 4—reported poor experiences with their systems. Difficulties associated with digester management included faulty design, inability to handle manure in its collected form, excessive collection of soil, temperature control, wind damage to cover, high maintenance costs, and daily labor requirements to monitor inflow.

Even those producers who were satisfied with their systems noted that sand, gravel, and rocks collected during manure collection were detrimental to the digester system. Such components settled out of the material flow stream. Producers concurred that digesters designed without a means of removing sand and gravel were destined to fail.

Further issues discussed included the differential (two to three times) between the price producers paid electric companies for electricity and the price electric companies paid producers for electricity. The higher price paid to producers for electricity might provide a financial incentive for producers to use such technology. Producer 1 mentioned the disincentive that was associated with one-way meters, indicating that all electricity used on the property was purchased from the electric company. His $2000 monthly savings was based on produced electricity. Also, producers 4 and 5 noted challenges encountered when working with their electric companies.

Extensive discussion with producer 6 revealed that the current approach to the economic viability of digesters was in error. Although economic returns could be achieved from sales of electricity, this producer indicated that 80% of the maintenance efforts and costs were associated with the postdigestion components of the system (engine repair, maintenance, and dealing with the electric company).

Greater focus should be devoted to the utilization and marketing of solids and liquids from the system. The solids, which are free of pathogens and weeds, make an excellent soil amendment or potting mix. The liquid fraction has a high value as fertilizer. Producer 6 indicated that a significant reduction in supplemental CP for heifers and dry cows could be met by utilizing the liquid effluent from the digester as a dietary supplement. The material was 40 to 50% CP (DM basis). The mean daily production of CP was
TABLE 1. Summary of data collected from current and former users of anaerobic digester technology.

<table>
<thead>
<tr>
<th></th>
<th>Producer</th>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Herd size</td>
<td>1500</td>
<td>400</td>
<td>1000</td>
<td>500</td>
<td>200</td>
</tr>
<tr>
<td>Initial cost, $</td>
<td>950,000</td>
<td>200,000</td>
<td>500,000</td>
<td>375,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Maintenance, $/yr</td>
<td>25,000</td>
<td>4000 to 5000</td>
<td>. . . . . . .</td>
<td>. . . . . . .</td>
<td>. . . . . . .</td>
</tr>
<tr>
<td>Price electric company, $/kWh</td>
<td>0.04</td>
<td>0.03</td>
<td>0.04</td>
<td>0.03</td>
<td>. . .</td>
</tr>
<tr>
<td>Price producer paid to electric company, $/kWh</td>
<td>0.08</td>
<td>0.095</td>
<td>. . .</td>
<td>. . .</td>
<td>. . .</td>
</tr>
<tr>
<td>Benefits</td>
<td>System broke even for the first few months.</td>
<td>Saved about $2000/mo. and benefited the environment.</td>
<td>Technology may work, but not with current dairy design.</td>
<td>Good idea, but technology still experimental.</td>
<td>We used all the power we produced and had to buy a little from electric company. Dairy produced energy to operate 15 hid.</td>
</tr>
<tr>
<td>Comments or challenges</td>
<td>Flush system brought in too much dirt (dirt corrals). Scrape system would not be much better. One-way meters would not offset one another (had to buy back power at twice the rate).</td>
<td>Management is the key. Correct temperature essential. Design must be proven to work for the specific situation. Electric company price paid should be comparable with price charged for electricity.</td>
<td>Dairy facility design did not lend itself to manure collection. Flush system gathered too much dirt. Scrape system also gathered too much dirt. Too much time spent collecting. Many materials used to cover pit would rip in wind. Costs exceed revenue.</td>
<td>Experienced a faulty design. With hard, inflexible top, could not get gas out. Later replaced with panels that did not seal (gas escaped). Warming grid of pipes leaked (biomass coils and gas production stops). Power company very uncooperative.</td>
<td>Required daily attention. Details and problems to work out initially. More maintenance on postdigestion and electricity generating and selling side. Gas from chimney may need to be scrubbed for hydrogen sulfide.</td>
</tr>
<tr>
<td>Incentive to reinstall</td>
<td>Would like to make it work, but economic environment not right. Eliminate producer risk.</td>
<td>System works just fine. Would do it again.</td>
<td>High price for electricity system design needs modification. Eliminate producer risk.</td>
<td>Would do again had buyout never taken place.</td>
<td>Would still operate if dairy was functioning. Would increase focus to market solids and utilize high protein liquids. Reduce or eliminate the sale of electricity.</td>
</tr>
</tbody>
</table>

1Unsure.
400 lb, which replaced supplemental CP for the diet priced at $0.20/lb, a value of $80.00/d.

A shortcoming related to digester function and daily maintenance was the lack of an available service industry to aid producers in managing both the digester and the engine technology. None of the producers interviewed indicated that they had received training. Initially, most producers did not realize the daily attention needed to maintain a properly functioning digester. The expertise needed to operate digester technology successfully could come from a service industry, which would remove the need for producers to focus resources on education for themselves and their employees.

Casual discussions with dairy producers who have not had anaerobic digesters often led to a common conclusion. Most producers associated digester technology with the generation of electricity. Few individuals identified the economic value of the solid and liquid end products. This lack of vision resulted in discouragement because of past failures, low prices for electricity, and minimal cooperation from electric companies. Certainly, successful digester technology should market all end products of the digestion process and not be limited to a single component.

A different approach to emissions collection may prove to be successful. Current efforts on swine operations may gain acceptance in the dairy industry also. Capture of biogas from anaerobic treatment ponds has been effective on one California swine operation. Biogas recovery of methane from covered holding or treatment ponds (liquid waste) is far less sensitive to dietary changes in animal feed than are anaerobic digesters (solid waste). Additionally, biogas recovery requires less maintenance and monitoring.

CONCLUSIONS

The EPA FIP included installation of anaerobic digester or covered lagoon technology without sufficient data to identify practicality or efficaciousness. Although regulatory requirements have altered management decisions on dairies, the large capital outlay and specialty required for this technology may prove to be a large disincentive to continue dairying in the future. The digester technology is not necessarily economically feasible even though it is required by federal regulations.

The economics of biogas capture are sensitive to the price paid for electricity, the amount of electricity used on the farm, and the labor and other additional costs that are necessary to maintain the digester. Low returns for electricity sold to power plants, combined with the high amount of maintenance of anaerobic digesters, have contributed to the lack of popularity of solid digesters. Evaluation of the economic merit of digester technology should include the value of solid and liquid waste streams from digesters. Once all previous concerns are addressed and a trained service industry is established, more producers may consider the use of anaerobic technology.

ACKNOWLEDGMENTS

The authors are grateful to field staff from Western United Dairymen and the University of California Cooperative Extension Dairy Advisors for identifying cooperators. The authors are appreciative of the time producers spent to provide requested data.

REFERENCES

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