

TEST MONITORING OF LIQUID MANURE TREATMENT SYSTEM

Final Report

Prepared for

BP ENVIRONMENTAL
(O/A 629223 Alberta Ltd.)

Prepared by

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Executive Summary

The objective of this project was to evaluate the effectiveness of the BP Environmental (BP) liquid manure treatment system in the treatment of swine manure. Effectiveness is measured using different physical, chemical and biological parameters including odor, microbial populations (total heterotrophic aerobic bacteria, total anaerobic bacteria, total coliforms, fecal coliforms, and *Escherichia coli*) in the liquids and solids during a 48-hour run. Environmental impacts of the treatment system on air quality was also investigated by monitoring bioaerosols in the exhaust air including biological indicators of air pollution such as total heterotrophic bacteria and fecal coliforms, and gases such as hydrogen sulfide, ammonia, sulfur dioxide, methane and oxygen.

Liquid, solid and air samples were collected from the equipment at scheduled intervals and analyzed for the test parameters using standard methodologies and equipment.

The results of the analysis show that:

- The treatment reduced the populations of odor producing anaerobic bacteria and increased the populations of heterotrophic bacteria.
- The critical time for the changes appear to be between 12 and 18 hours.
- Reduced the populations of total and fecal coliforms over 48 hours, but the populations of *E.coli* remained fairly the same, accounting for most of the FC and TC at 48 hours.
- Levels of odorous hydrogen sulfide and sulfur dioxide were dramatically reduced within 3 hours of operation.
- Ammonia concentrations reduced by 90% in the flue gasses within 3 hours, but increased gradually to 50% of the initial levels over the remainder of the investigation.
- Methane level in the flue gases was reduced from 11000 to 0 ppm within 3 hours. Methane has a GWP (Global Warming Potential) value that is 21 times that of carbon dioxide. Elimination of methane in the flue gases is a major environmental benefit from the use of the BP system, because it dramatically cuts down on the emission of green house gases.
- Odor intensity was also reduced by about 50% at 24 hours, and rose marginally after 24 hour of operation, which was characteristic of ammonia in the flue gases.
- The levels of bacteria (total coliforms and heterotrophic bacteria) were generally consistent throughout the duration of the project. A dip in the populations was observed at 9 and 12 hours, which could be attributed to a possible reduction in air flow and agitation in the tanks. The levels were within limits for recommended for manure treatment facilities.
- The levels of fecal coliforms and *E. coli* in the solids were reduced by 82% and 78% respectively, while the viable heterotrophic aerobic population increased by 344%.
- Airflow data would be needed in any future investigation for better interpretation of results.

Methodology

Collection of Samples

Duplicate liquid samples were collected for microbiological analysis from the BP system at 0, 3, 6, 9, 12, 18, 24, 36 and 48 hours. The samples were collected by using a pre-sterilized 20 L bucket to collect effluent samples from the effluent valves of the system. The first 2-4 liters of effluent was discarded, and another 2-4 litres of the liquid was collected. Duplicate samples were collected into sterile screw-capped tubes, and transported immediately to the laboratory for microbiological analysis.

Analysis of Samples

Samples collected were analyzed for selected microbial indicators of pollution, i.e. total heterotrophic aerobic bacteria, total anaerobic bacteria, total coliforms, fecal coliforms, and *E. coli*. The solids from the liquid manure were also analyzed for microbial indicators at the beginning and the end of the process.

Triplicate samples of 1, 10 and 20 liter volumes of the flue gasses were also collected during each sampling event using microbiological air sampler for the quantification of fecal coliforms and total bacteria populations.

Odor intensity measurements were taken using a panel of 5 participants during each sampling event and recorded. Corresponding measurements of hydrogen sulfide, ammonia, sulfur dioxide, combustible gases, and oxygen were also taken using gas meters. Data collected was analyzed and interpreted.

Results and Discussions

Figures 1 and 2 depict the populations of microorganisms enumerated from the liquid samples collected at the specified time in the treatment. Discussions on specific microbial groups are explained below.

Heterotrophic Aerobic and Anaerobic Bacteria Populations

The populations of aerobic heterotrophic bacteria and anaerobic bacteria were each at about 3.0×10^8 cfu/ml at the beginning of the experiment. Within 3 hours of the operation of the equipment, both populations were halved to about 1.5×10^8 cfu/ml and maintained about a 50/50 proportion for the first 12 hours. A shift in the populations occurred in favor of aerobic after 12 hours, which increased about 10 fold to 1.2×10^9 cfu/ml while the anaerobic bacteria population reduced by about 80%. The proportion of aerobic bacteria to anaerobic bacteria changed from 50:50 to 95:5, and this proportion was maintained for the remainder of the investigation (Figure 3). This change is critical in the conversion of nutrients in the manure to stable biomass by aerobic bacteria. The curves of the proportions are mirror images.

Figure 1: Microbial populations in liquid manure during treatment

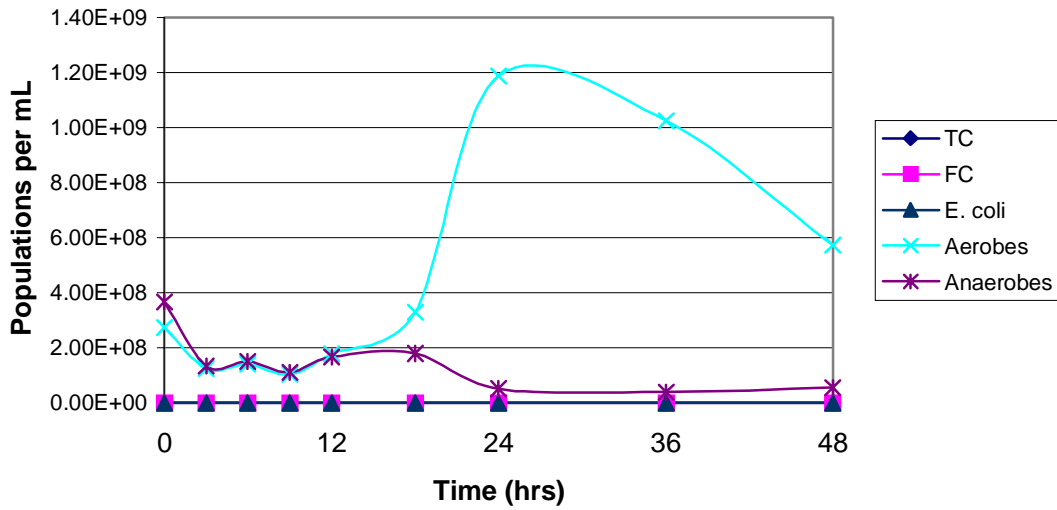
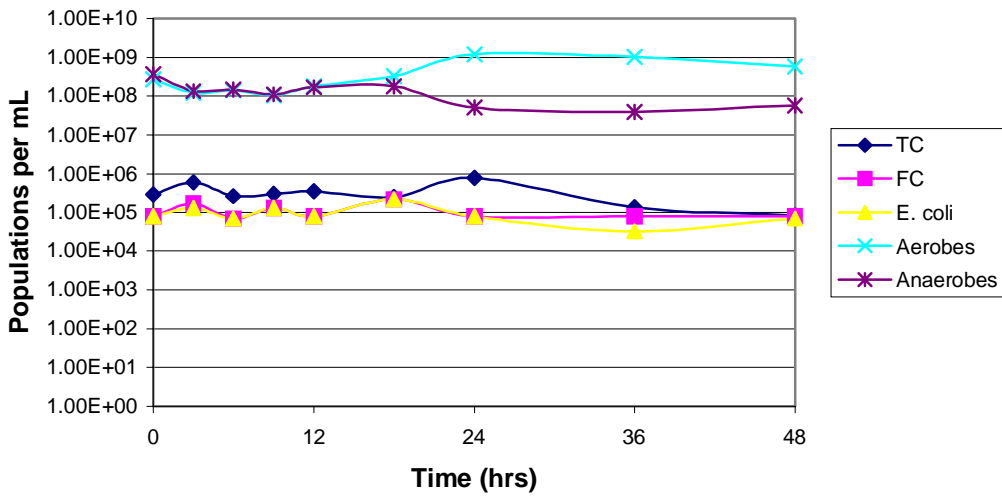
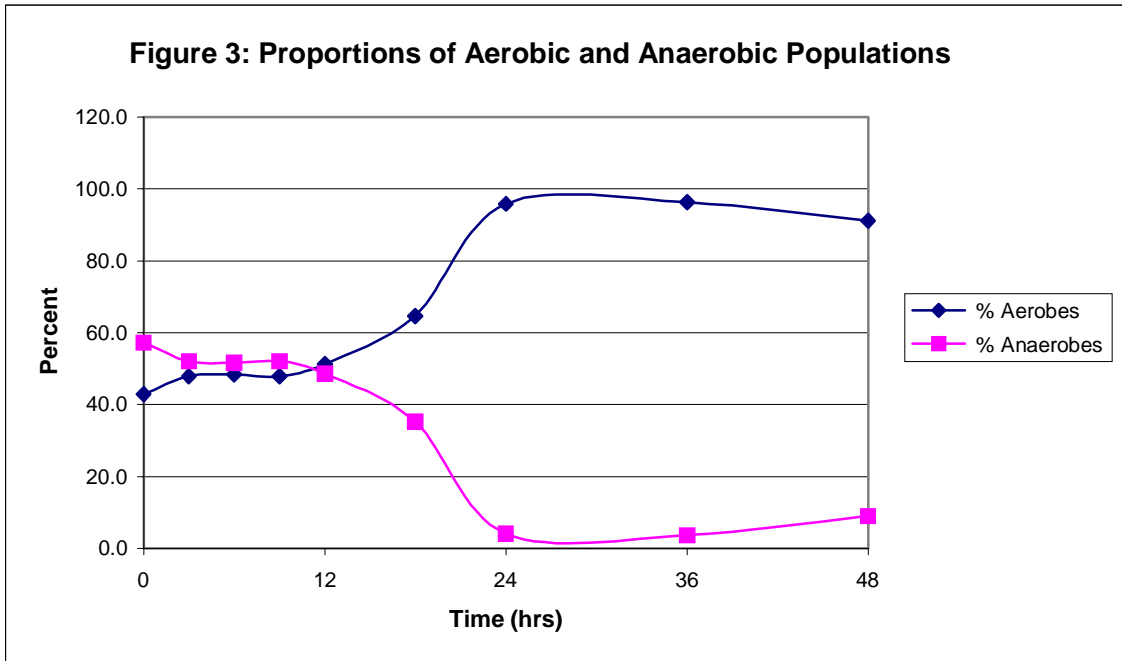


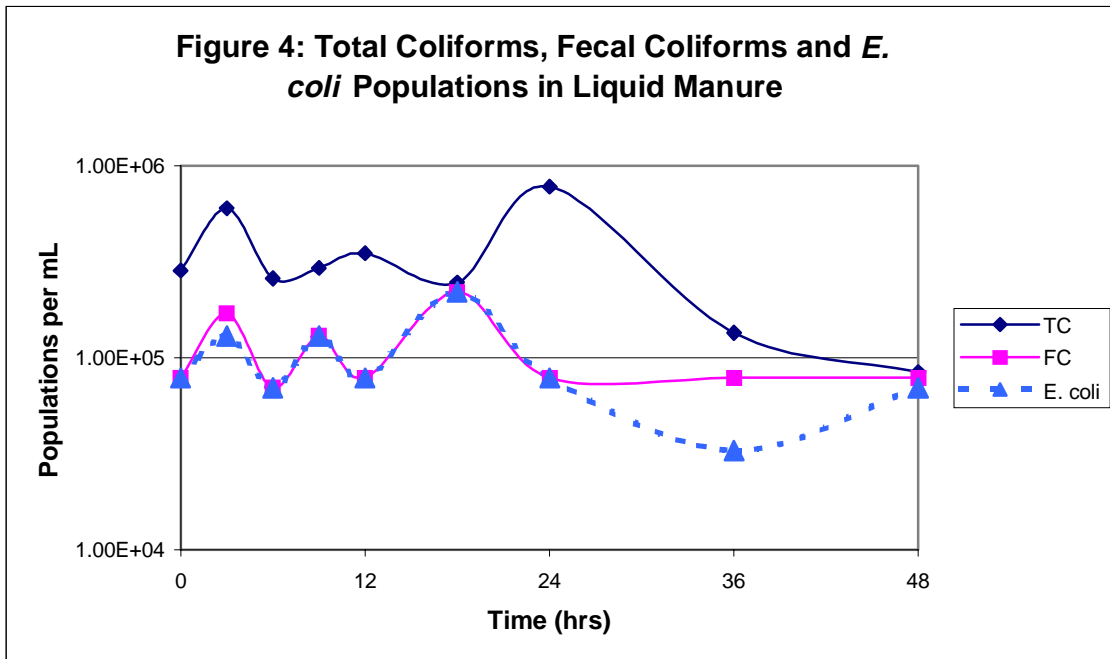
Figure 2: Log of Microbial Populations in Liquid Manure





Total Coliform, Fecal Coliform, and *Escherichia coli*

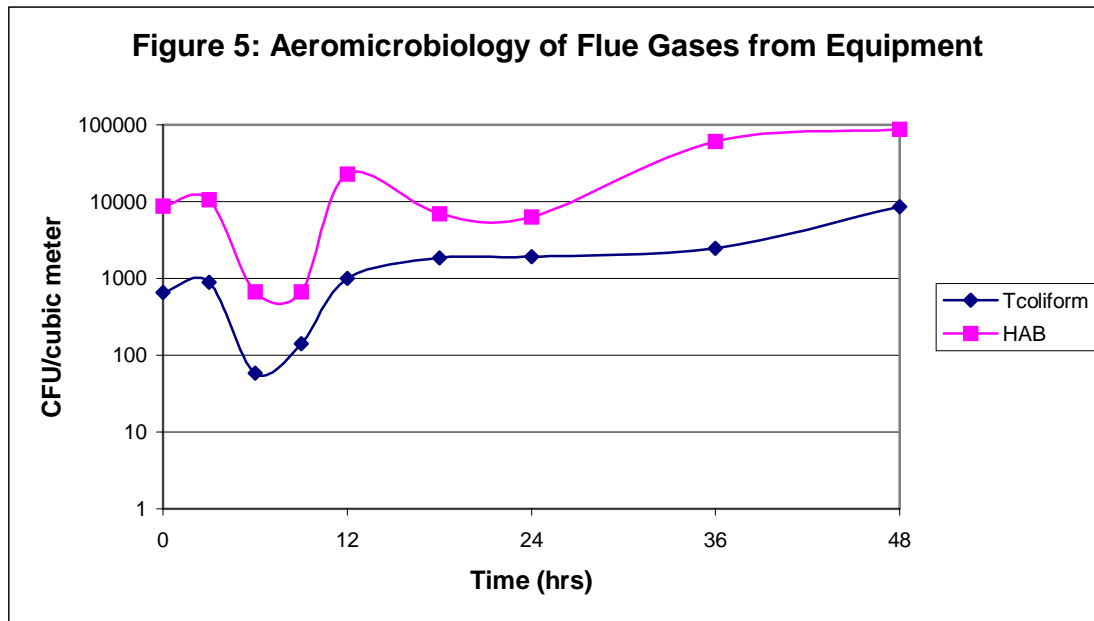
Total coliforms (TC), fecal coliforms (FC) and *E. coli* (EC) are indicators of fecal pollution, and are used to monitor the effectiveness of the system in the control of pathogenic organisms. Figure 4 shows the population patterns of the 3 groups of organisms. TC was highest at 24 hrs after which it dipped to the same level as FC and EC. The treatment process reduced the populations of total and fecal coliforms over 48 hours, but the populations of *E. coli* remained fairly the same, accounting for most of the FC and TC at 48 hours. The cyclic nature of the FC and EC curve during the first 18



hours may be due to changes and adjustments in airflow. Most FCs and EC are facultative anaerobes. Though they survive and grow in anoxic and anaerobic environments, they prefer aerobic environments for optimum growth and reproduction.

Total Aerobic Bacteria and Fecal Coliforms in Flue Gases

The population of fecal coliforms followed the same pattern as the heterotrophic aerobic bacteria in the flue gases (Figure 5). The levels of bacteria (total coliforms and heterotrophic bacteria) were generally consistent throughout the duration of the project. A dip in the populations was observed at 9 and 12 hours, which could be attributed to possible changes in air-flow and agitation in the tanks. The levels were within limits for recommended for manure treatment facilities. There is a high correlation ($r=0.9$) between the coliforms and the heterotrophic bacteria populations, though the levels of fecal coliforms in the flue gases were consistently about 10% of the heterotrophic aerobic bacteria. This means that there was no selective release of a particular population into the air, and that either of the two populations would provide reliable information of the other.



Odor Intensity and Flue Gas Composition

Odor intensity of the exhaust air was reduced from an average of 16 to 10 within 24 hours, beyond which the intensity of odor stabilized (Figure 6). Hydrogen sulfide dropped from 8.5 ppm to 2.5 ppm in 3 hours, and to less than 2.0 ppm for the remainder of the experiment (Figure 7). The levels of Sulfur dioxide were reduced from 8 to 0 ppm in 9 hours and remained at 0 ppm for the remainder of the investigation (Figure 8).

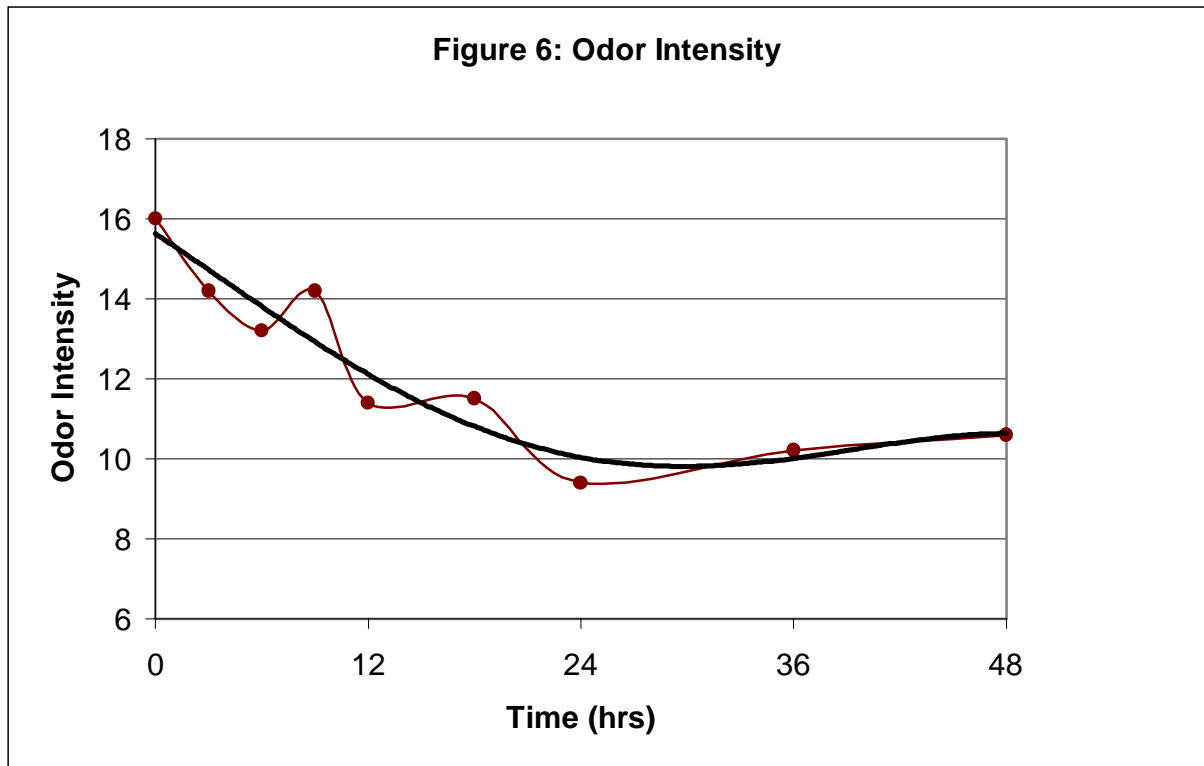


Figure 9 shows the pattern of oxygen in the flue gases from the equipment. Oxygen concentrations increased in the flue gases from 19.4% to between 20.5% and 20.6% throughout the first 24 hours of the operation. The level of oxygen dropped to 20.4% in the last 24 hours of the operation, which coincided with increased ammonia in the flue gases (Figure 10).

The levels of methane in the flue gas dropped from 11,000 ppm to 0 in the first 3 hours of operation (Figure 11). Methane is an inflammable gas and a greenhouse gas that has a global warming potential that is 21 times as high as carbon dioxide. The BP system eliminates both the risk of explosion in manure storage and the contribution of methane to global warming.

Figure 7: Leves of Hydrogen Sulfide in Flue Gases during Treatment

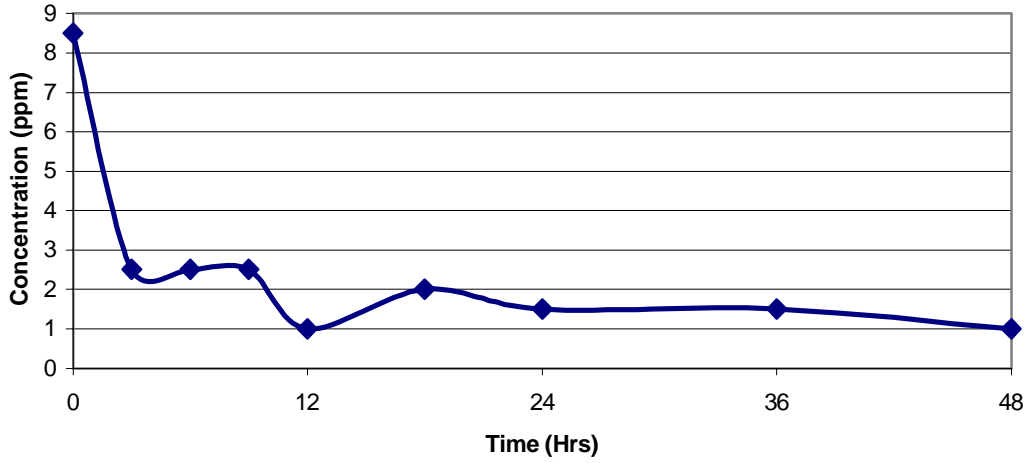
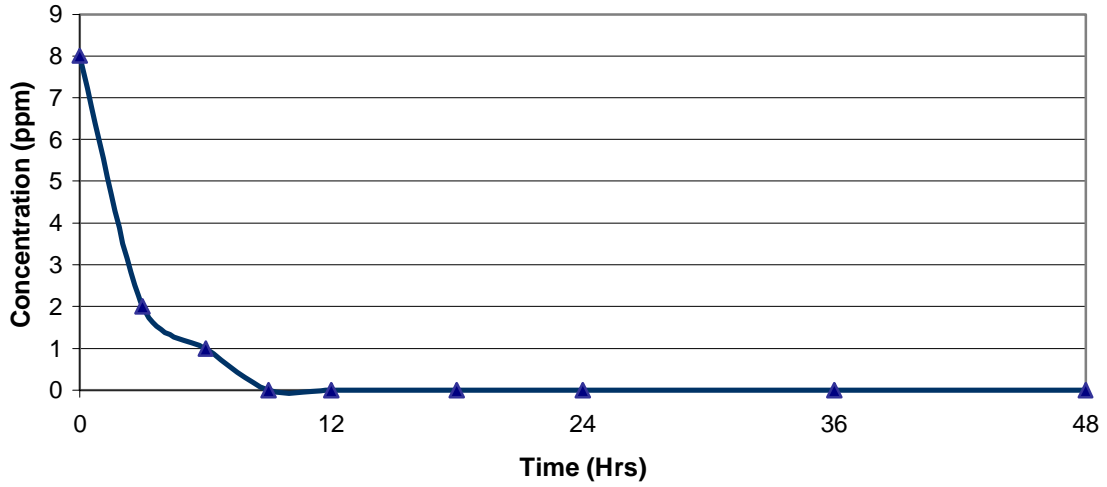
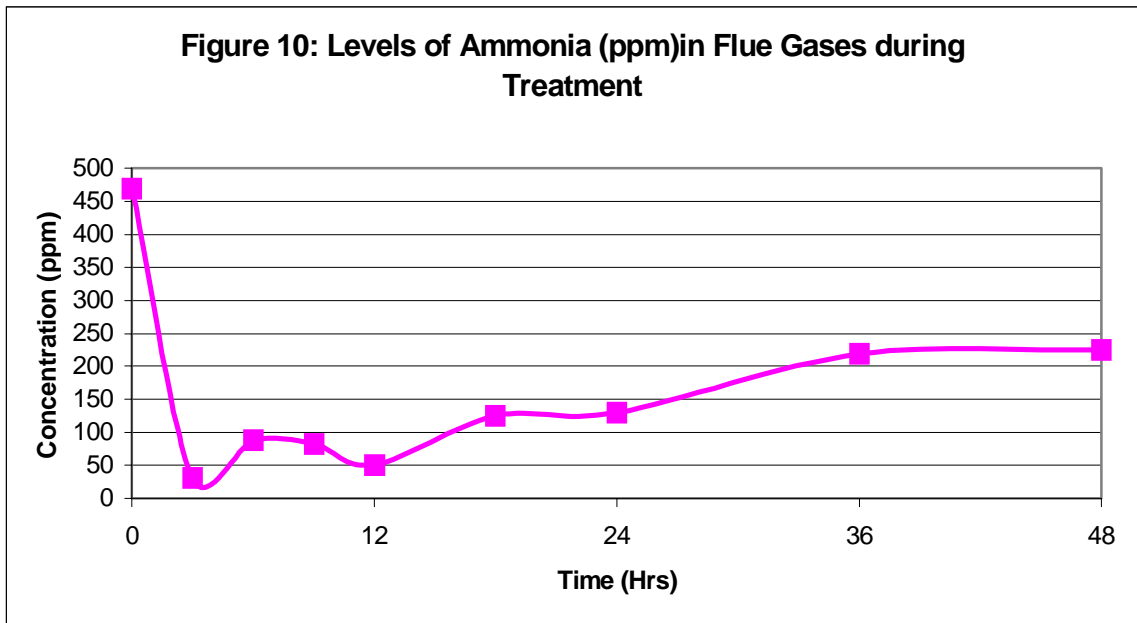
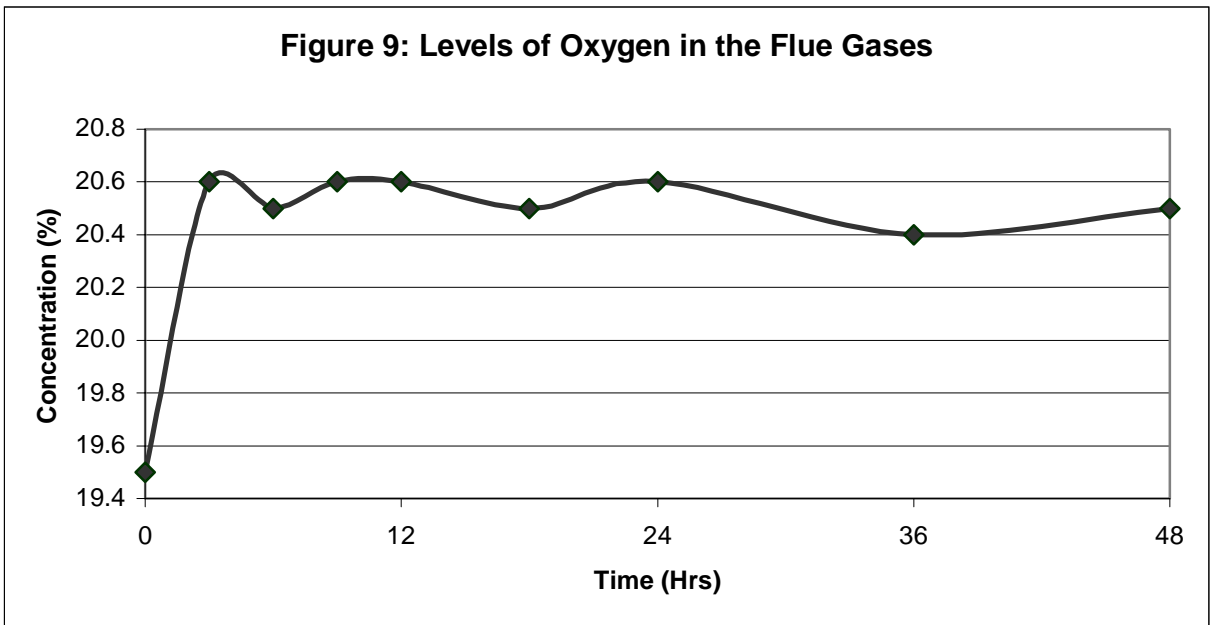
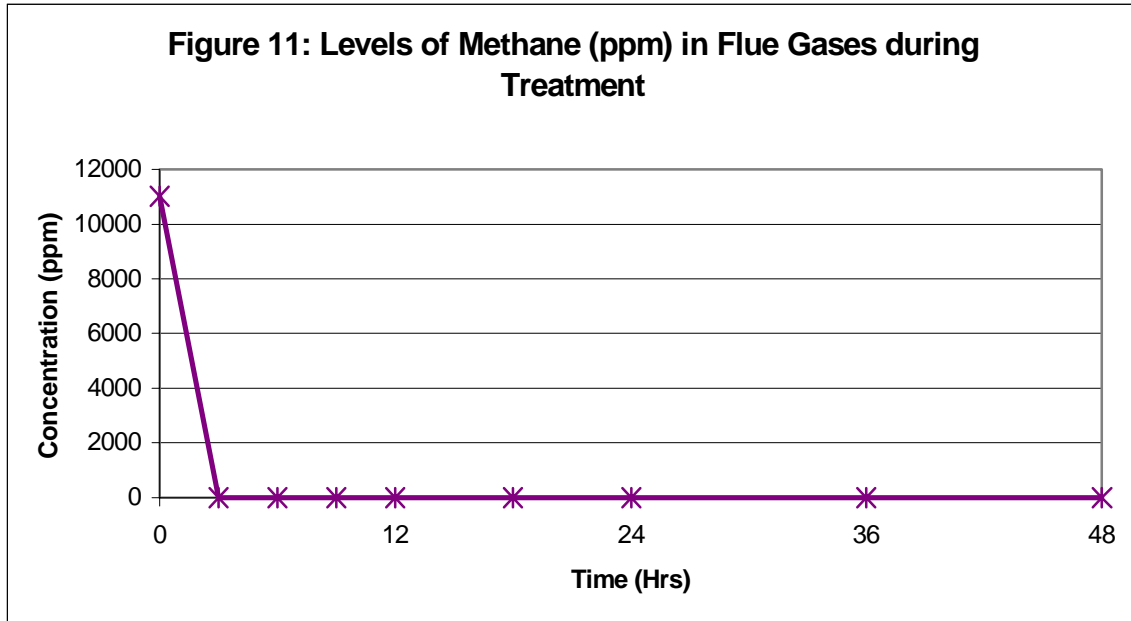


Figure 8: Levels of Sulphur Dioxide (ppm) in Flue Gases during Treatment







Microbial Populations in the Solids

The populations of microorganisms in the solids at the beginning and the end of the 48 hour run are depicted in Figure 11. The figure is in log values for comparative purposes. The process increased the heterotrophic aerobic bacteria in the solids by 344%. The increase in viable microbial cells implies that unstable nutrients in the manure are converted into biomass. The increase reported here is only of viable cells. When non-viable biomass is added, the total cell increase (viable and non-viable) would greatly exceed reported value. Total coliform population increased by 55%, while fecal coliforms and *E. coli* populations were reduced by 82% and 78% respectively. Both fecal coliforms and *E. coli* are potential pathogens. The dramatic reduction in their populations is significant in terms of control of pathogens by the BP manure treatment system.

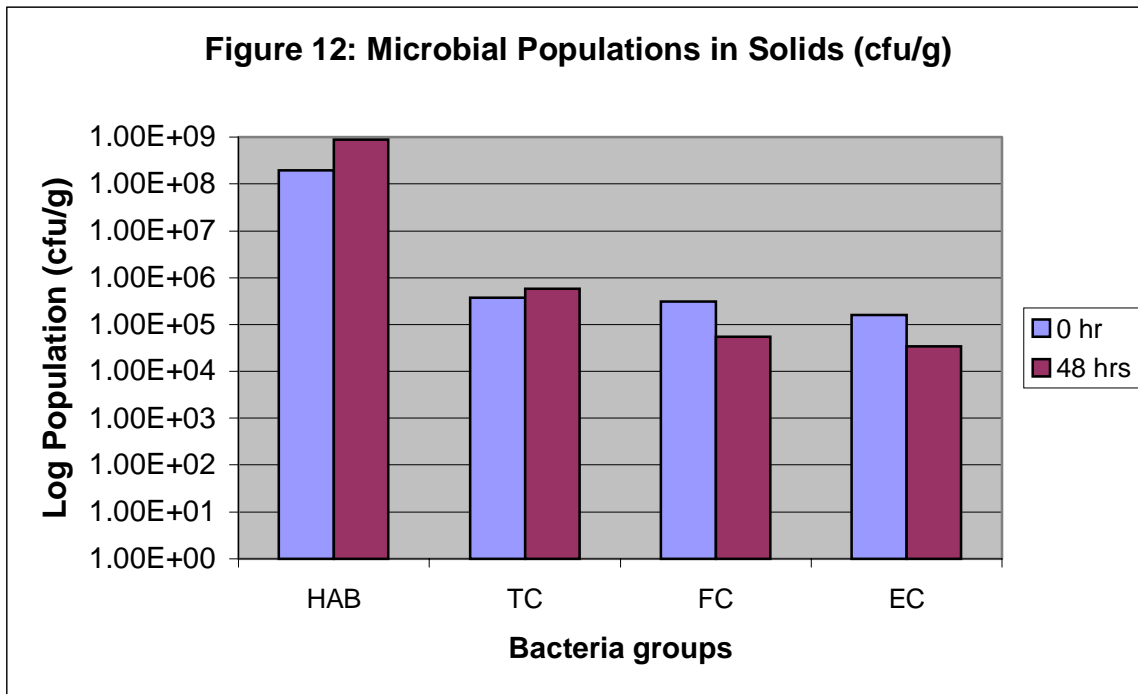


Table 1: Populations of microorganisms in solids before and after processing

	0 hr	48 hrs	% Change
Heterotrophic Aerobic Bacteria (HAB)	1.98E+08	8.80E+08	344.4
Total Coliforms (TC)	3.80E+05	5.90E+05	55.3
Fecal Coliforms (FC)	3.10E+05	5.42E+04	-82.5
<i>Escherichia coli</i> (EC)	1.60E+05	3.50E+04	-78.1

Acknowledgements

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