UBC Social, Ecological, Economic Development Studies (SEEDS) Student Reports

CHBE 363: SEEDS Project

UBC COMPOSTING

In-Vessel Compost Facility

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Abstract

The objectives of this project were to determine the composition of exit gases, estimate the yearly emission of CO_2, and investigate the presence of particulates in the emissions.

To analyze the composition of the exit gases, one ambient air sample and two samples from the bio-filter were taken. In the ambient air sample, the composition was made up of 98.77% $N_2 + O_2$, and undetectable amount of CO_2. In the first bio-filter sample, the composition was 95.77% $N_2 + O_2$, and 0.19% CO_2. In the second bio-filter sample, the composition was 96.81% $N_2 + O_2$, and 0.19% CO_2. No traceable amount of methane was detected in both samples of the bio-filter.

Several assumptions were made in order to predict the yearly emission of CO_2. The volumetric flow rate of exhaust gas was estimated to be 1860ft^3/min. The density of exhaust gas was assumed to be 1.2 kg/m^3 and the molar mass to be equal to that of ambient air. Estimating the operational hours of the exhaust fan to be 6 hours every day, the yearly emission of CO_2 was projected to be 23.97tonnes/year.

To determine the presence of particulates in the output stream of the composter, the samples taken in the ambient and bio-filer were grown on agar plates. The transfer and streak method were used to isolate the cultures of interest. There were two types of bacteria that were isolated in the bio-filter samples and none in the ambient air sample. The isolated and identified bacteria were Staphyloccocus and Bascillus. These bacteria are common and pose no concern with respect to the operation of the composter.

Upon all the findings, the UBC composter is demonstrated to be operating efficiently and meets the UBC's aim of sustainability.

Introduction

Composting is a process where organic wastes such as decomposed plant, animal, and other organic materials are decomposed into a soil-like material. Compost is therefore rich in nutrients and minerals and can be used as a soil conditioner, a fertilizer, and a natural pesticide for soil. Different types of composting methods include anaerobic digestion, in-vessel aerobic composting, tunnel composting, and vermi-composting.

UBC uses a large-scale in-vessel composting facility located at south campus. This composting system comes from Wright Environmental Management Inc. and it was set up in 2004. This facility is capable of processing 5 tonnes of organic waste daily and produces compost within two weeks. Environmentally speaking, this facility reduces the amount of material sent to landfills and the harmful gasses that are emitted by landfill materials. The Wright composting unit uses a moving floor system, a series of breaker bars, and an exit auger to transport the organic wastes from one end of the vessel to another. Unlike a batch system, the Wright unit allows loading to occur at anytime. It's a fully-enclosed system that allows for controlled composting.

During the process, exhaust gas is released from the compost. This gas is driven out of the vessel with the help of supply and exhaust fans. This gas flows through a PVC pipe attached to the unit, and is forced through a bio-filter. The bio-filter is a packed bed of bacteria and other microorganisms which helps to remove harmful particulates from the exhaust gas before it's released into the environment. Because composting is an aerobic process, presence of carbon dioxide in the exhaust gas cannot be ruled out. Therefore, it's important to make sure that the bio-filter is effective against harmful gases and particulates.

Problem Definition

The University of British Columbia's SEEDS (social, ecological, economic, and development studies) program has, to date, saved the university approximately $200,000, and received the ideas and hard work of over 3000 contributors in nearly 500 student projects. The in-vessel composter falls under a number of UBC's pillars of sustainability, air, food, human, and land. As a composter of human food waste, the in-vessel composter prevents a large amount of waste food from entering land-fills. Food waste that decomposes under non-ideal conditions produce a higher amount of green house gases (GHG) than the same amount of food waste composted under ideal conditions.

The main focus of the compost group was to determine the composition of the exhaust gasses exiting the composter, and with this information, estimate the yearly production of methane and carbon dioxide at the composting facility. A secondary objective was to investigate the possibility of harmful particulate matter leaving the composter in the exhaust stream, even after it had passed through the bio-filter. With the estimate of the yearly production of carbon dioxide and methane, recommended steps to increase the sustainability of the project would be made, such as the capture of methane gas, should the concentration be high enough to be economically viable.

Methodology

Gas Sampling

In order to determine the composition of the gas exiting the bio-filter, the gas needed to be transported to the gas chromatographer in the CHBE building's laboratory. The main problem faced with taking this gas sample was the fact that the bio filter itself covered a large surface area, making it impossible to simply take a sample at one point. In addition, the bio-filter did not filter the gas evenly, as about half of the filter appeared to not allow any gas at all to escape. To overcome this obstacle, a thin lightweight plastic sheet, essentially a tarp, was placed over-top of the operational section of the bio-filter in order to trap the gas. The edges of this tarp were then covered with heavy objects to allow the exit gas to build up within the tarp, prevent ambient air from entering the tarp, and to prevent the tarp from simply flying away. After waiting for a few moments to allow the tarp to fill with the in-vessel composter's exit gas, a hole was made in the top of the sheet, from which the gas samples would be taken. To take the samples, the gas sampling bags were placed into roughly the center of the plastic sheet 'dome' and sealed. Multiple samples were taken of the exhaust gas. As a method of comparison, two samples of ambient air were taken. These ambient air samples were taken at a distance away from the composting vessel, to ensure that the exhaust gas stream would have no effect of the results. With these ambient and exhaust gas samples collected, they were then transported back to the CHBE building, run through a gas chromatographer, and their compositions determined.

Gas Chromatographer

The gas chromatographer system was operated by a teaching assistant (TA) in the CHBE laboratory. The steps taken to operate this system are quite simple. First, the gas samples taken from the in-vessel composter were transferred into a syringe by simply piercing the bag with the needle, and pulling the plunger of the syringe back in order to transfer the sampled gas into the barrel of the syringe. Using the filled syringe, the sample gas was injected into the gas chromatographer, which then analyzed the sample, and returned the results to a computer. This procedure was followed for all of the gas samples collected.

Microbiology Analysis

There has been worry that particulate matter released from mold in the in-vessel composter is being released through the outlet stream. To accomplish the objective of determining whether or not there is harmful particulate matter present in the outlet gas flow from the in-vessel composting facility it was decided that a microbiological analysis would need to be done on site at the compost facility. This analysis was made possible through the use of equipment from the biology department at UBC, namely from Carol Pollock, Director of First Year Biology, from the department of Zoology. The procedure used to obtain samples was as follows:

1. Obtain four agar plates (sterile Petri dishes with agar bacterial food) from Carol Pollock
2. While the in-vessel composter exhaust fan is off, lay down 2' by 2' plastic sheeting on top of the bio-filter then cut several small holes in the plastic to allow air to flow through.
3. Place agar plate on top of plastic so that the holes in the plastic surround the plate.
4. Cover the plate with a plastic bag such that air can flow through the bio-filter, through the bottom plastic, and get caught in the bag and circulate onto the agar plate.
5. Repeat with a second agar plate on the bio-filter.
6. Place two additional agar plates, with their lids off, a minimum of 10 meters away from the bio-filter to act as ambient samples.
7. Let stand for four to five hours, or until the exhaust fan has sufficiently supplied enough gas flow to expose the agar plates.
8. Close the lids on all the agar samples and seal them using tape.
9. Let the samples grow for 24 hours if using an oven, or 48-72 hours if using ambient conditions.
10. Compare the cellular cultures of the ambient samples to the bio-filter samples. Look for common cultures between test plates and isolate cultures of interest.
11. Transfer the culture of interest to a new agar plate and use the streak method and sterile technique to ensure that there is no contamination of cultures.
12. Allow transferred cultures to grow on the new plates and prepare for isolation.
13. After sufficient growth and isolation of cultures, transfer a small amount of the culture of interest onto a slide for analysis.
14. Heat the slide over an open flame to kill bacteria and affix the culture in position.
15. Use the following chart and tests to identify the bacteria according to the flowchart.

16. Repeat chart for various cultures under analysis.

gram reaction (young culture)	+	+	+	+	+	+	+	+	+	+	–	–	–	–	–	–
shape	coccus (clusters)	coccus (clusters)	coccus (chains)	coccus (tetrads)	rod	rod	irreg. rod	rod	rod	rod	rod	rod	rod	rod	rod	coccus (pairs)
aerobic growth	+	+	+	+	+	+	+	–	+	+	+	+	+	+	+	+
anaerobic growth	–	+	+	+	+	–	–	+	+	–	–	–	+	+	+	–
endospores	–	–	–	–	–	–	–	+	+	+	–	–	–	–	–	–
motility (Motility Medium)	–	–	–	–	–	+	–	+ or –	+ or –	+ or –	+ or –	+ or –	–	+	+	–
catalase reaction	+	+	–	–	–	+	+	–	+	+	+	+	+	+	+	+
benzidine reaction	+	+	–	–	–	+	+	–	+	+	+	+	+	+	+	+
oxidase reaction	+	–	–	–	–	–	–	–	+ or –	+ or –	+	+	–	–	+	+
glucose fermentation to acid **or** to acid+gas	–	+	+	+	+	–	–	+ (or –)	+	–	–	–	+	+	+	–
Glucose O/F Medium											–	O	F	F	F	O
Micrococcus	X															
Staphylococcus		X														
Streptococcus			X													
Lactococcus			X													
Enterococcus			X													
Leuconostoc			X													
Pediococcus			X	X												
Aerococcus				X												
Lactobacillus					X											
Kurthia						X										
Arthrobacter							X									
Clostridium								X								
Bacillus									X	X						
Alcaligenes											X					
Pseudomonas												X				

Figure 1: Bacteria Identification

Results and Discussion

Result of Gas Sample Analysis

Three samples were taken: ambient air sample, bio-filter sample 1 and bio-filter sample 2. All three samples were passed into a gas chromatograph column to analyze the composition of the gas samples. In the ambient air sample, the $N_2 + O_2$ content were found to be 98.77% and undetectable amount of CO_2. In the bio-filter sample 1, there were 95.77% $N_2 + O_2$ with 0.19% CO_2. In the bio-filter sample 2, similar results were obtained, with 96.81% $N_2 + O_2$ and 0.19% CO_2. Shown in all three graphs (Figure 4, Figure 5 and Figure 6), there was a huge spike in the graph, representing the mole percentage of $N_2 + O_2$. However, in both of the bio-filter sample graphs, there was a small peak, representing the mole percentage of CO_2 in the samples. It should also be noted that no methane was detected in both of the bio-filter samples, meaning that the composter and bio-filter were functioning normally.

Table 1: Summary of GC Results

Sample	$N_2 + O_2$ (%)	CO_2 (%)
Ambient Air Sample	98.77	0
Bio-filter Sample 1	95.77	0.19
Bio-filter Sample 2	96.81	0.19

Result of Flow Rate Analysis

To determine the flow rate without actually installing a manometer or flow meter, we made various assumptions to calculate flow rate. Two radial exhaust fans rotating at 3600rpms remove all gases from the composter to the bio-filter. Using the fan speed and size, it was assumed that 930ft^3/min of exhaust was removed by each fan. Therefore the total volumetric flow rate of exhaust gas was 1860ft^3/min. Also, we assumed the fan operated 6 hours per day because the current composter setup does not monitor the time that the fan is on per day. Not knowing the exact composition of exhaust gas, we assumed the density of exhaust gas to be 1.2 kg/m^3, which is the density of air at 20^oC and 1atm. Also, we assumed the molar mass of exhaust gas to be that of pure air. Finally, we assumed the composter ran 365 days per year. With these assumptions, and the fact that 0.19 mole% CO_2 existed in the exhaust gas, we predict that 23.97 tonnes/year of CO_2 is released to the atmosphere. There are many possible sources of error; in particular any of the above assumptions may be incorrect. Nonetheless, assuming upper limits for our assumptions such as the composter running every day, and volumetric flow is that of fan design spec; the calculated CO_2 flow rate can be assumed to be a good estimate. (Please refer to appendix A for calculations)

Result of Microbiology Analysis

The samples taken from the ambient air and bio-filter samples were grown on the agar plates as mentioned. The transfer method and streak method were used to isolate the cultures of interest. The cultures that were chosen to be isolated were in abundance on the bio-filter sample, but not present on the ambient air samples. The method chosen to analyze the samples was the flow chart presented in the earlier section of the report, Figure 1. The first isolated culture of interest tested positive on the gram reaction. It was able to grow in both aerobic and anaerobic environments. It also tested positive on the catalase reaction and appeared under the microscope as coccus clusters. This allowed for the identification of the bacteria as a Staphyloccocus. Most are harmless in this genus and can be found worldwide. They tend to reside on the skin and are a component of the soil microbial flora. They can be seen below under magnification.

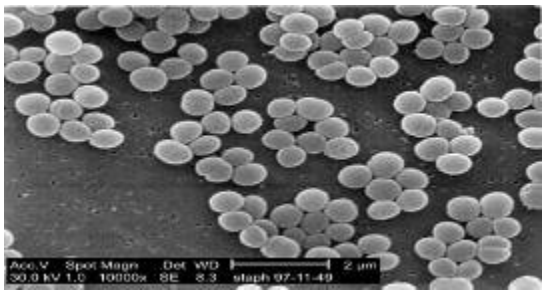

Figure 2: Magnification of Staphyloccocus

The next isolated sample from the bio-filter was analyzed and found to be positive for the gram reaction. Under microscopic identification, the cultures were found to be rods and only available for aerobic growth. The species was also found to able to produce endospores and tested positive as well for the catalase reaction. This left the bacterial culture in the Bascillus, which is ubiquitous in nature and very common to find. It is normally harmless; however, some strains can be dangerous.

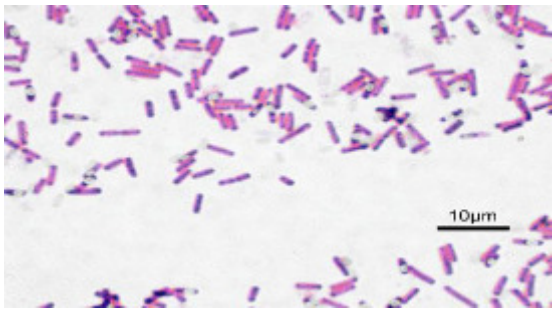

Figure 3: Magnification of Bascillus

We did not find it necessary to carry out analysis any further than this identification because there were no more cultures of interest that were isolated. The final result of this analysis is such that the bio-filter is performing its job and that no contaminants could be found in the isolated samples. A step further can be taken when analyzing the output of the composter in the future. It might be possible to look at the output before the bio-filter to determine if there is presence of particulates that need to be grown on a medium other than agar. This will diversify the analysis and possibly present some issues that the bio-filter is having.

Reflection (on UBC and sustainability)

As the University of British Columbia strives to become a more sustainable entity it is important to analyze every process under UBC's area of control. UBC has set forth extremely aggressive greenhouse gas (GHG) emission reduction targets for the coming years. They hope to accomplish a 33 percent reduction of GHGs from 2007 levels by 2015, a 67 percent reduction of GHGs below 2007 levels by 2020, and to make the University GHG neutral, i.e. reduce 100 percent of its emissions, by 2050. In order to achieve this goal UBC must audit and reduce emissions from every emitting source on campus. It might be easy to overlook many of UBC's process for GHG emissions, as they may not be easily identifiable as major sources of emissions. Intuitively, one might not think that a process such as an in-vessel compost facility would emit a significant amount of green house gasses, but if one considers the accelerated reaction conditions of this facility it quickly becomes obvious that emissions that might have been released over an extended period of time are now concentrated into a shorter period and could result in a net increase in emissions. Additionally, for the University to be as sustainable as possible, it is important to take into account other factors besides GHGs, such as worker conditions. If the compost facility were in fact releasing particulate matter into the air surrounding the compost facility it could be detrimental to the health of the employees. For UBC to effectively reduce its GHG emissions it is critical to understand itself fully before implementing change, which is where this project helps.

The UBC in-vessel compost facility is part of UBC's initiative to have a lesser impact on the environment. By removing a large portion of the UBC waste stream that goes to landfill the in-vessel composter helps to reduce transportation emissions, reduce emissions coming from landfills, and add bio-nutrients back into UBCs gardens. Now that we have an idea of the emissions that the in-vessel composter facility creates we are better able to determine the effectiveness of the compost program. Generally speaking, the conclusion of the project shows that the UBC in-vessel compost facility does not produce a significant amount of GHG emissions. As noted in our results section, there was no methane gas detected in our gas samples. This result is important because methane gas is a potent GHG (much more potent than carbon dioxide) and methane gas is likely to be produced if this same compost were sent to a landfill or stationary compost pile. This is one of the key benefits to using an aerobic compost facility rather than an anaerobic system. The result of having increased levels of carbon dioxide

present in the outlet gas of the in-vessel composter is significant, but not as detrimental as one might think. The result of having a net output of 23 tonnes of carbon dioxide per year is relatively insignificant. It is estimated that the average North American individual generates 15 tonnes of carbon dioxide per year on their own. When it is considered that the use of the in-vessel compost facility is reducing the amount of garbage that needs to be hauled to landfills, and thus reducing the number of truck trips, it is a likely conclusion that 23 tonnes of carbon dioxide emissions is insignificant when compared to the reduction in emissions made possible by the use of this facility. Furthermore, the result of having only ordinary particulate/bacteria present in our microbiological analysis suggests that the compost facility is not particularly detrimental to the health of the workers at this facility.

UBC is working strongly toward sustainability and it has high hopes for the way that the campus can be run. Using a somewhat closed loop system for compostable waste, UBC is working in the right direction toward being a fully sustainable entity. In order become fully sustainable in terms of organic matter UBC would have to grow all of its own food, process the waste through a compost facility, then use said compost as nutrients for more food to be grown. By starting with a compost facility that helps to keep some the organic matter on campus, while not emitting a significant amount of GHG emissions, UBC has taken the first step.

Recommendations for UBC Key Partners

Throughout the course of the SEEDS project, there was extensive communication between the students, the instructor Dr. Ellis, and the UBC Waste Management outreach coordinator, Christian Beaudrie. The discussions which took place are valuable resources for carrying on the project in years to come. Hence, it is highly recommended that there should be a constant effort made by the key partners involved in maintaining the established communication in order to ensure that a proper sampling module can be installed on the outlet pipe of the in-vessel composter. In addition, it is also recommended for the UBC Composting Facility to share its plant operating/maintenance schedule with future SEEDS project team in order to determine an ideal time for installing the proposed sampling port. This will minimize any disturbances in the compost facility's operation, and provide synergetic effects during plant turnaround with the required installations.

Recommendations for Future CHBE 363 Groups

Once additional data resulting from the proposed sampling port becomes readily available, it is recommended that a more in-depth analysis on the outlet flow of the compost facility should be conducted. The main parameters to investigate and compare are flow rate and composition, since it is these two variables that have the greatest amount of error due to the nature and shortcomings of the current data collection procedure. The effects of the bio-filter on the gas composition should also be analyzed to quantify the ability of the bio-filter to reduce harmful components in the exhaust gas from reaching the ambient environment.

Conclusion

The Gas Chromatography analysis of post bio-filter samples showed the slight larger values of CO_2 mole percentages in comparison with ambient air sample. The mole fraction of 0.19% was used to calculate the average CO_2 flow rate. The CO_2 emission rate was calculated to be 52.67m^3/min. After unit conversion to mass flow rate at an annual basis, the yearly mass flow rate of CO_2 coming out of the bio-filter of the compost was determined to be 23.97tonnes/yr. This number is quite low compare to the average metric tonnes of CO_2 emission per person in Canada, which is 17.4 tonnes in 2007 (US Department of Energy's Carbon Dioxide Information Analysis Center). We only used the exhaust air fan's parameter to calculate flow rate because that is what's ultimately coming out of the compost tank.

Furthermore, from the microbiology analysis, we concluded that the bio-filter is working efficiently because the bacteria culture samples from both ambient air and post bio-filter air showed no difference. It meant the bacteria existing in the post bio-filter region and ambient air were quite the same, because the bio-filter has removed the bio-organism produced during the compost process. Also the grass on top of the bio-filter is not dying, which further suggests that the post bio-filter air is not toxic. This is important for the safety of the workers at compost facility.

Sources of Error

The procedures that we undertook to collect post filter air samples were very prone to disturbance from ambient air. We simply used tarp to cover up the area where exhaust air distribution seemed more uniform compare to other areas, hoping that we could trap exhaust air inside and create an environment that's similar to what would be exiting the bio-filter outlet, which is where we want to sample from. The tarp was sealed around with objects like pots, shovels, and rocks to prevent ambient air from entering underneath. Ambient air could easily get underneath and into the tarp and alter the gas concentration inside. Referring back to the comparison with average CO_2 emission per person, the actual CO_2 emission could have been a lot higher. Even after proper sealing, our collection method of waving zip-locks inside the tarp was not ideal.

Also, the assumptions made for flow rate analysis might not have been right as well. Daily operating hours of exhaust fan might not be 6 hours, as it runs only when supply fans are on. The supply fans run when the temperature inside has risen above a pre-set level (72 Celsius). Due to different

material being loaded into the compost tank, the rate at which temperature increase varies. Also the time of loading material is not constant as well. Furthermore, the annual operating days might not be 365 days because there's always maintenance period when the plant seizes its operation for inspection. At last, the assumption for outlet flow density (1.2 kg/m^3) might not be accurate as well, because the exhaust temperature should be higher than 20 Celsius. We know this because when we were taking air samples, we saw steam forming above the bio-filter, and also the exhaust fan runs when the temperature inside exceeds 72 Celsius. The exhaust air, even after being treated by bio-filter should still be higher than 20 Celsius.

Acknowledgement

We would like to express the deepest appreciation to Dr. Ellis, our professor and Christian Beaudrie, the UBC Waste Management outreach coordinator for ongoing guidance and support in completion of the project. We would also like to thank George Roua, P.Eng, from Wright Tech Systems Inc. for providing us with necessary specifications of the composter for estimation of yearly CO_2 emission.

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6. Wright Environmental. In-Vessel Manual.

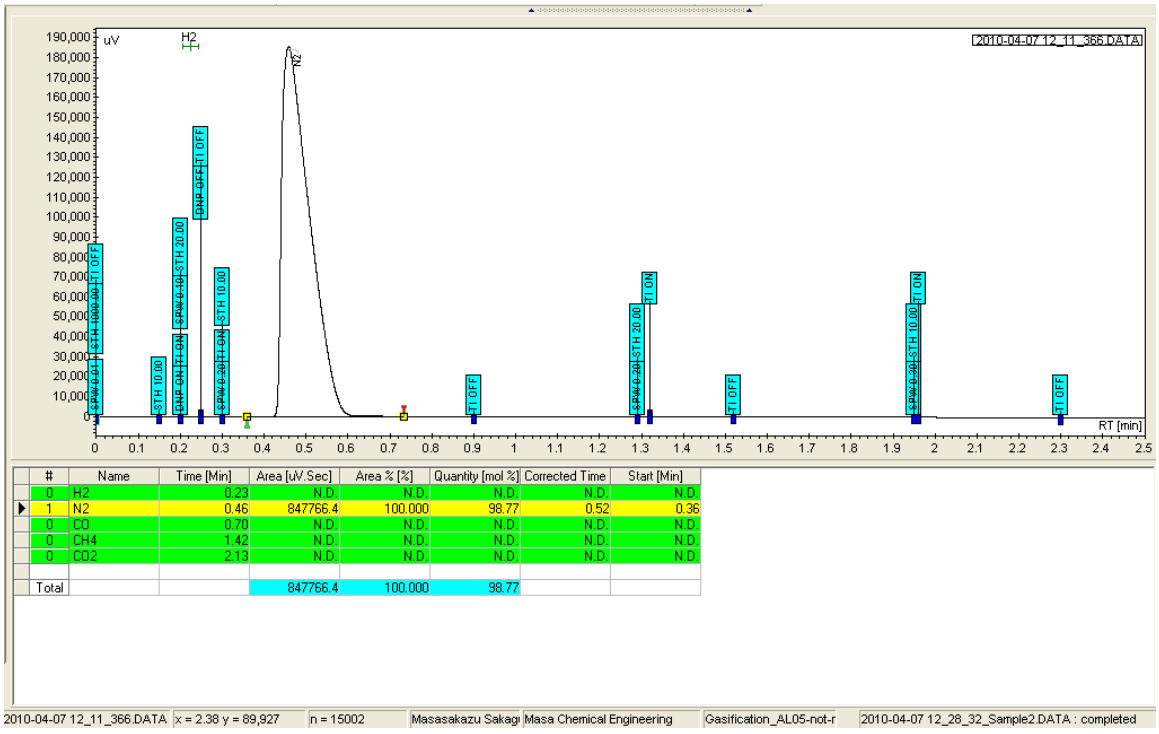
Appendix

Calculation to estimate the yearly emission of CO_2 in the composter

Given that 1 exhaust fan releases 930 ft^3/min, therefore, both exhaust fans release 1860ft^3/min. Using the molar mass of air as 28.97 kg/kmol and the density of air to be 1.2 kg/m^3. Also, using 0.19% as the mole fraction of CO_2 in exhaust air, below are the calculations to determine the mass flow rate of CO_2 per year.

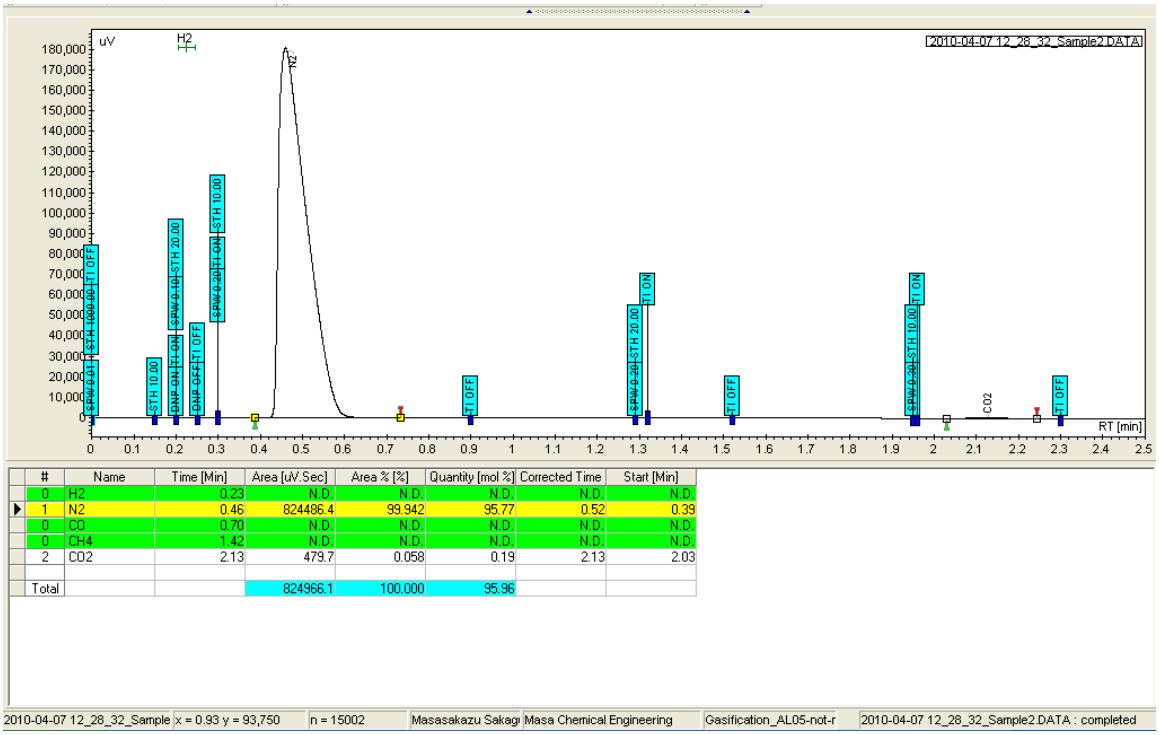
930 ft^3/min *2 = 1860 ft^3/min
1860 ft^3/min * 1m^3/35.32ft^3 = 52.66 m^3/min
52.66 m^3/min * 1.2 kg/m^3 = 63.19 kg/min
63.19 kg/min * 0.0345 kmol/kg = 2.19 kmol/min
2.19 kmol/min * 60min/hr = 131.4 kmol/hr
131.4 kmol/hr * 6hr/day = 788.4 kmol/day
788.4 kmol/day * 365days/1year = 287766 kmol/year
287766 kmol/year * 0.0019 = 546.755 kmol/year
546.755 kmol/year * 44.00 kg/kmol

Therefore, **23.97 Tonnes/year CO_2** is estimated**.**



#	Name	Time [Min]	Area [uV.Sec]	Area % [%]	Quantity [mol %]	Corrected Time	Start [Min]
0	H2	0.23	N.D.	N.D.	N.D.	N.D.	N.D.
1	N2	0.46	847766.4	100.000	98.77	0.52	0.36
0	CO	0.70	N.D.	N.D.	N.D.	N.D.	N.D.
0	CH4	1.42	N.D.	N.D.	N.D.	N.D.	N.D.
0	CO2	2.13	N.D.	N.D.	N.D.	N.D.	N.D.
Total			847766.4	100.000	98.77		

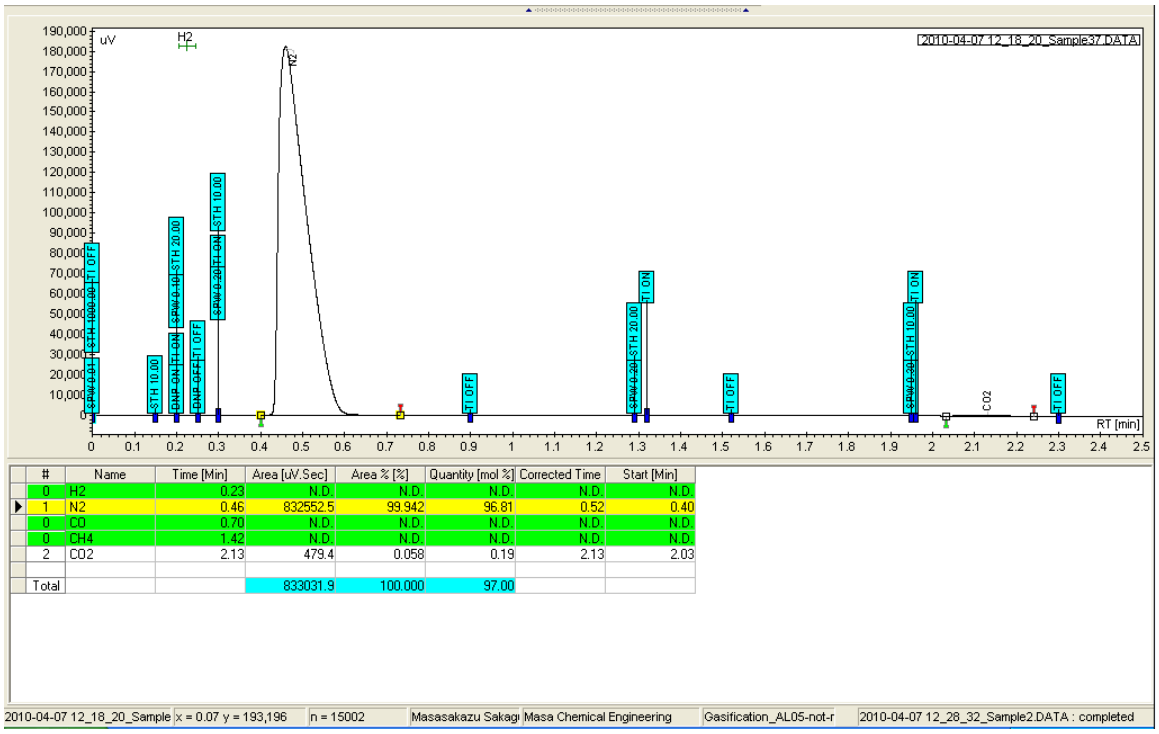
Figure 4: Gas Chromatography Analysis in Ambient Air Sample



#	Name	Time [Min]	Area [uV.Sec]	Area % [%]	Quantity [mol %]	Corrected Time	Start [Min]
0	H2	0.23	N.D.	N.D.	N.D.	N.D.	N.D.
1	N2	0.46	824486.4	99.942	95.77	0.52	0.39
0	CO	0.70	N.D.	N.D.	N.D.	N.D.	N.D.
0	CH4	1.42	N.D.	N.D.	N.D.	N.D.	N.D.
2	CO2	2.13	479.7	0.058	0.19	2.13	2.03
Total			824966.1	100.000	95.96		

2010-04-07 12_28_32_Sample | x = 0.93 y = 93,750 | n = 15002 | Masasakazu Sakagi | Masa Chemical Engineering | Gasification_AL05-not-r | 2010-04-07 12_28_32_Sample2.DATA : completed

Figure 5: Gas Chromatography Analysis in Bio-Filter Sample 1



#	Name	Time [Min]	Area [uV.Sec]	Area % [%]	Quantity [mol %]	Corrected Time	Start [Min]
0	H2	0.23	N.D.	N.D.	N.D.	N.D.	N.D.
1	N2	0.46	832552.5	99.942	96.81	0.52	0.40
0	CO	0.70	N.D.	N.D.	N.D.	N.D.	N.D.
0	CH4	1.42	N.D.	N.D.	N.D.	N.D.	N.D.
2	CO2	2.13	479.4	0.058	0.19	2.13	2.03
Total			833031.9	100.000	97.00		

2010-04-07 12_18_20_Sample | x = 0.07 y = 193,196 | n = 15002 | Masasakazu Sakagi | Masa Chemical Engineering | Gasification_AL05-not-r | 2010-04-07 12_28_32_Sample2.DATA : completed

Figure 6: Gas Chromatography Analysis in Bio-Filter Sample 2

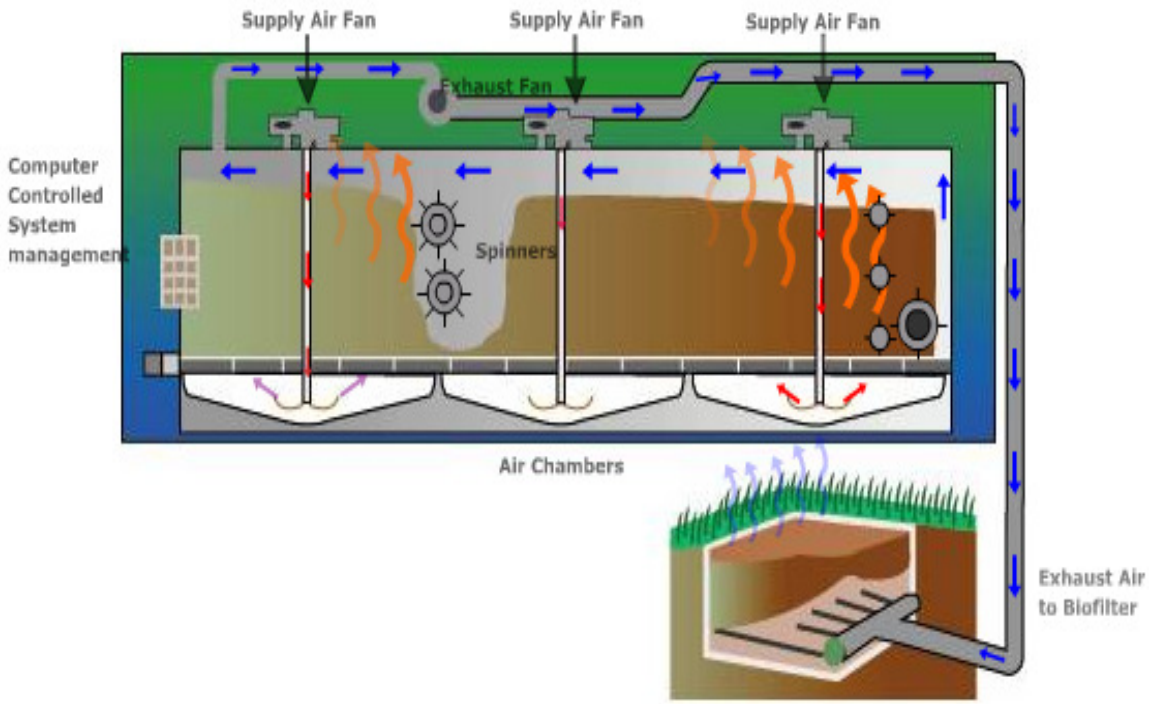


Figure 7: In-vessel Compost Diagram

Figure 8: In-vessel Composter

Figure 9: Outlet Pipe of the Composter

Figure 10: Bio-filter

Figure 11: Gas Sampling

Figure 12: Sampling for Particulate Analysis

Figure 13: Agar Plate Sample #1

Figure 14: Agar Plate Sample #2