NAU Compost Monitoring Program
Final Report

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Final Report

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Acknowledgements

SAS Engineering would like to acknowledge the assistance of Howard Coldwell at NAU Facility Services with this project. The team would like to also acknowledge the technical help from CECMEE Lab Manager Adam Bringhurst. Special thanks to the continuous support and help from the teams grading instructor, Dr. Bero. SAS Engineering would also like to acknowledge Dr. Baxter for his laboratory help.

1.0 Introduction

1.1.Project Objectives

The purpose of this project is to create a comprehensive management plan for Northern Arizona University's (NAU) composting system so that the compost can be sold at the Flagstaff Community Market, including a demonstration that routine analyses can be performed by NAU's Engineering students.

1.2. Project Background

The NAU Compost Project site is located within the City of Flagstaff next to Interstate 40, as shown in Figure 1.1 Project Location Map within the City of Flagstaff.

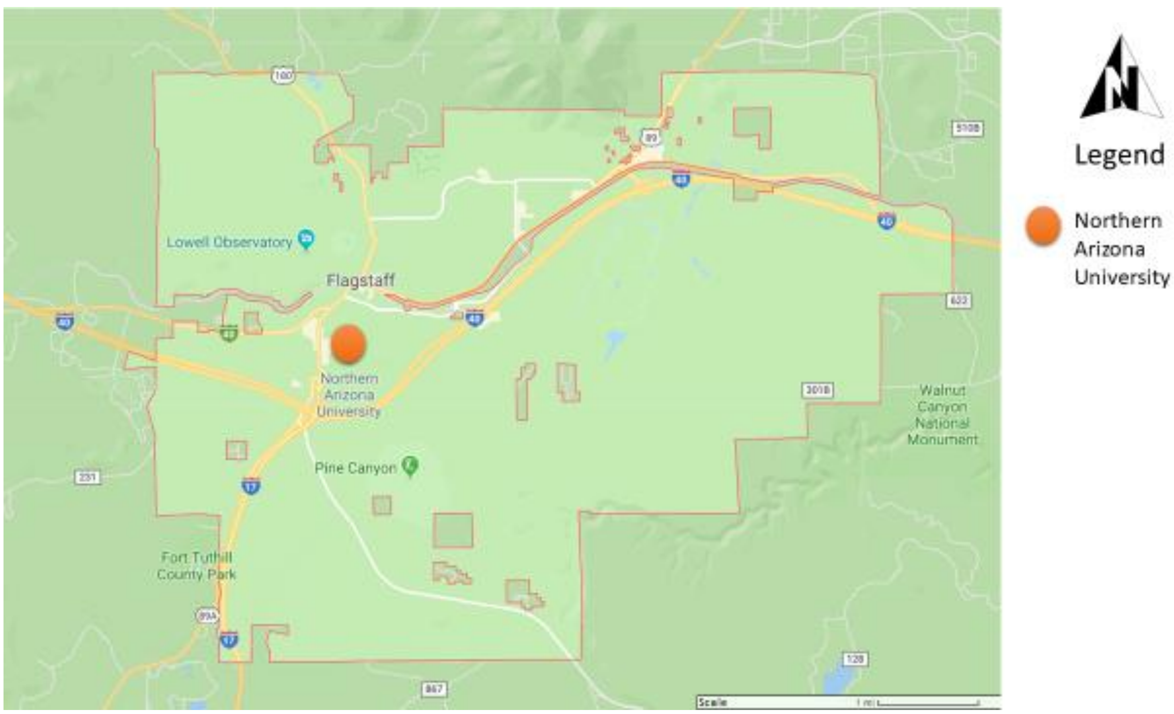

Figure 1.1 Project Location Map within the City of Flagstaff [1]

The compost piles are located on NAU's south campus adjacent to Interstate 40 and S Lone Tree Rd. as displayed in Figure 1.2 and Figure 1.3.

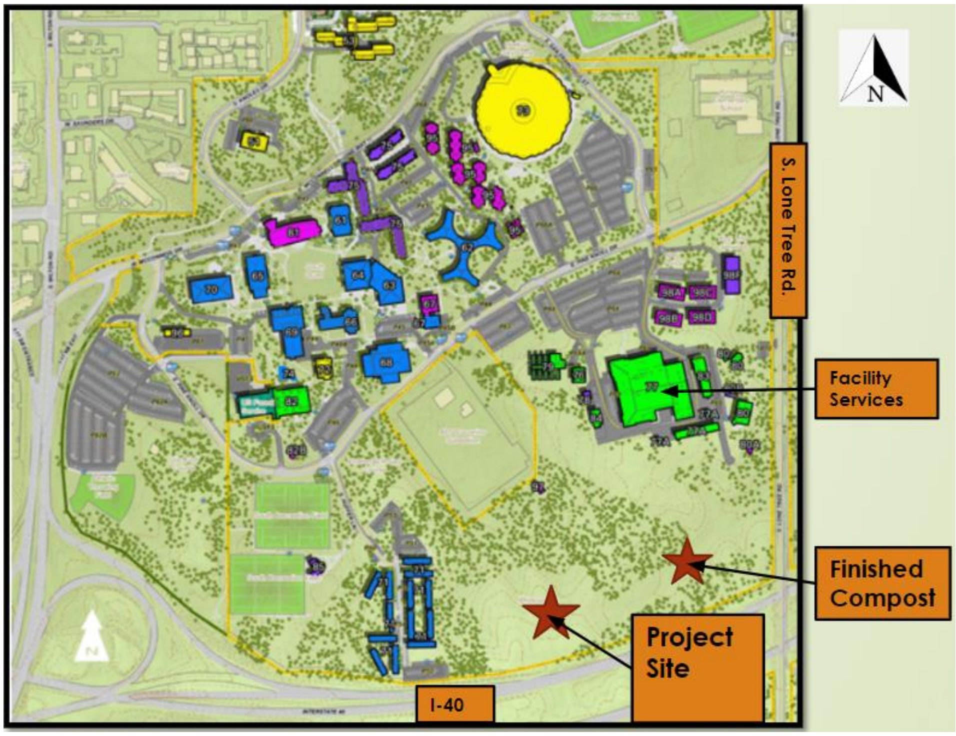

Figure 1.2 Northern Arizona University Site map [1]

Figure 1.3 Site Located, North of Interstate 40 and West of S Lone Tree Rd. [1]

A preliminary site visit was conducted on February 6th of 2019 shown in Figure 1.4. At that time of the site visit, 12 piles were observed at various stages of composting.

Figure 1.4 NAU Compost Piles February 6, 2019 [2]

NAU's composting program was created on April 30, 2012 [1]. Shortly after the composting program's creation, a composting study that spanned a year and a half, 2011-2012, was conducted by former forestry student in coordination with NAU, to develop the most effective means of composting on a large scale in Flagstaff [1]. According to an email exchange mentioned in the report from the City of Flagstaff Community Sustainability Specialist, McKenzie Jones, the amount of organic material deposited into Flagstaffs Cinder Lake Landfill made up ~28% of the City's waste stream [1]. The organic material being disposed into the landfill that could be turned into compost was estimated to be ~60,000 tons per year [1]. To combat the constant increase of waste produced per year, NAU created a compost recycling program that is intended to reduce the amount of total waste put into Flagstaff's Cinder Lake landfill. As a result of this program, NAU processed 10,000 lbs. of composted material per week during the 18-month study period. At the production rate of 10,000 lbs. per week NAU is projected to produce a maximum of 520,000 lbs. per year or 260 tons of composted soil from the initial composting pilot study [1].

The feedstock used in NAU's composting program consists of food scraps from the following locations along with horse manure and carbon-based material such as tree trimmings and grass clippings. From NAU, the compost pile accepts food scraps from NAU dining, operated by SODEXO, pine needles, grass clippings, and woody material from tree trimmings. From Flagstaff, the compost pile accepts food scraps from the Flagstaff Medical Center (FMC) Hospital, Mother Road Brewery, and horse manure from nearby stables [1]. Currently the NAU compost piles are being operated by a NAU Facilities Employee, Howard Cowell, who manages and turns the compost piles daily.

The piles are organized into different stages of composting on the site. The process consists of Howard Cowell mixing 24 yd^3 of food scraps and 24 yd^3 of bulking agents, consisting of wood chips and horse manure, into a pile every week. This continues for two months then a new pile gets started. When a new pile gets started, the older piles get turned once a week for a year [1]. This phase is called curing, and the compost needs to be well aerated, temperature checked once every other week, and kept moist at 60% moisture content. After curing for a year, the pile gets moved across the facility to the finished compost site. The compost is then utilized throughout campus and sold. The compost is currently sold to Flagstaff citizens who come to the compost site and buy the compost by volume at $24-28 per yd^3.

The Composting Pilot Study Research Report [1] examined the sources of feed to be used for a composting pile at NAU. The study also researched and tested the ideal range for soil nutrients in cured composted soil along with the various effects different types of composting methods have on the soil. The study selected the best method for composting in Flagstaff, turned piles with minimal watering. The Composting Pilot Study did not test for harmful bacteria such as e-coli and salmonella and the data graphs for thermophilic and mesophilic testing are unreadable because of missing axis labels.

The condition of the three completed compost piles as of September 20, 2019 can be seen below in Figures 1.5-1.7

Figure 1.5: NAU Finished Compost Pile 1. September 20, 2019 [3]

Figure 1.6: NAU Finished Compost Pile 2. September 20, 2019 [3]

Figure 1.7: NAU Finished Compost Pile 3. September 20, 2019 [3]

All three finished compost piles appeared to be well matured compost. The piles are located in safe locations away from potential contamination sources.

On May 2019, a pack of one gallon of sample from one of the piles was sent to Soil Control Laboratory, located in Watsonville, California for testing, and the results are shown in Figure 1.8 below.

ANALYTICAL CHEMISTS and BACTERIOLOGISTS Approved by State of California

SOIL CONTROL LAB

42 HANGAR WAY WATSONVILLE CALIFORNIA 95076 USA

TEL: 831-724-5422
FAX: 831-724-3188
www.compostlab.com

Account #: 9040549-1/1-10585
Group: Apr19C #28
Reporting Date: May 2, 2019

Northern Arizona University Campus Services
P.O. Box 6026
Flagstaff, AZ 86011
Attn: Paul Capps

Date Received: 17 Apr. 19
Sample Identification: Pile #1
Sample ID #: 9040549 - 1/1

Nutrients	Dry wt.	As Rcvd.	units
Total Nitrogen:	1.9	0.97	%
Ammonia (NH_4-N):	19	9.7	mg/kg
Nitrate (NO_3-N):	310	150	mg/kg
Org. Nitrogen (Org.-N):	1.9	0.95	%
Phosphorus (as P_2O_5):	0.84	0.42	%
Phosphorus (P):	3700	1800	mg/kg
Potassium (as K_2O):	0.97	0.48	%
Potassium (K):	8000	4000	mg/kg
Calcium (Ca):	2.0	1.0	%
Magnesium (Mg):	0.78	0.39	%
Sulfate (SO_4-S):	7.6	3.8	mg/kg
Boron (Total B):	26	13	mg/kg
Moisture:	0	50.1	%
Sodium (Na):	0.17	0.085	%
Chloride (Cl):	0.14	0.072	%
pH Value:	NA	7.77	unit
Bulk Density :	19	38	lb/cu ft
Carbonates ($CaCO_3$):	37	18	lb/ton
Conductivity (EC5):	2.4	NA	mmhos/cm
Organic Matter:	52.1	26.0	%
Organic Carbon:	22.0	11.0	%
Ash:	47.9	23.9	%
C/N Ratio	11	11	ratio
AgIndex	> 10	> 10	ratio

Metals	Dry wt.	EPA Limit	units
Aluminum (Al):	8500	-	mg/kg
Arsenic (As):	3.5	41	mg/kg
Cadmium (Cd):	< 1.0	39	mg/kg
Chromium (Cr):	20	-	mg/kg
Cobalt (Co)	5.1	-	mg/kg
Copper (Cu):	36	1500	mg/kg
Iron (Fe):	12000	-	mg/kg
Lead (Pb):	5.4	300	mg/kg
Manganese (Mn):	330	-	mg/kg
Mercury (Hg):	< 1.0	17	mg/kg
Molybdenum (Mo):	1.7	75	mg/kg
Nickel (Ni):	15	420	mg/kg
Selenium (Se):	< 1.0	100	mg/kg
Zinc (Zn):	100	2800	mg/kg

Stability Indicator:			
CO2 Evolution		Respirometery	
mg CO_2-C/g OM/day		3.4	
mg CO_2-C/g TS/day		1.7	
Stability Rating		*stable*	
Maturity Indicator: Cucumber Bioassay			
Compost:Vermiculite (v:v)		1:2	
Emergence (%)		100	
Seedling Vigor (%)		114	
Description of Plants		*healthy*	
Pathogens	Results	Units	Rating
Fecal Coliform	110	MPN/g	*pass*
Salmonella	< 3	MPN/4g	*pass*
Date Tested: 17 Apr. 19			
Physical Contaminants**		% by weight	
Total Plastic		< 0.1	
Film Plastic		< 0.1	
Glass		< 0.1	
Metal		< 0.1	
Sharps		ND	
Total		< 0.5	

Size Distribution	
MM	% by weight
> 50	0.0
25 to 50	0.0
16 to 25	0.0
9.5 to 16	4.4
6.3 to 9.5	7.3
4.0 to 6.3	11.4
2.0 to 4.0	15.2
< 2.0	61.6

**Greater than 4mm in size (Sharps greater than 2mm)

Analyst: Assaf Sadeh

*Sample was received and handled in accordance with TMECC procedures.

Figure 1.8 External Lab Analysis Report

The above report that was received from Soil Control Laboratories, shows the results for one finished compost pile. The report provides values for many different metals and nutrients, with the most important being the metals, organic carbon, ash content pH, Salmonella, E. Coli, nitrate/nitrite, and moisture content. The results provided above indicate that the compost that was sampled is up to codes and within regulation. Codes and regulations will be provided in the research regulation section below.

2.0 Research

The regulations research consisted of researching the requirements that need to be met for composting in Arizona.

2.1.Regulations

NAU compost facility is working under regulations and standards with respect to Environmental Protection Agency (EPA), and Arizona Administrative code. According to AZ Admin Code Title 18, composting should be managed in a way to not induce insect breeding or cause a nuisance [9]. Also, as Code of Federal Regulations stated that during composting, the temperature must exceed 55 degrees Celsius [10]. The below Table 2.1 shows the allowable parameter levels for compost [11]. The regulations are set for the quality of the compost to ensure that there will not be any risks, and, to protect soil. and groundwater from contamination. According to EPA, the maximum allowable level of *E. coli* is 3 MPN/g of compost, and for *Salmonella* is 4 MPN/g of compost [12]. MPN refers to Most Probable Number which is a method used to determine the number of microorganisms in a sample.

Table 2.1 Allowable Contaminant Levels by Compost Grade

Parameters	Determination	Importance
pH	6-7.5	Too Basic causes damage to plants.
Ash Content	~50% ash weight	Higher shows mineralization (shows in older compost).
Heavy Metals	Varies	Toxic substances that can harm human health.
E. Coli	3 MPN/g dry weight compost	Toxic microbes that can harm human health.
Nitrate/Nitrite	Below 100 PPM	Not enough nitrates indicates insufficient amount of oxygen; causing gaseous loss of nitrogen.
Ammonia	100-550 PPM	Indicates why pH is high or low.
Salmonella	4MPN/4g dry weight compost	Toxic microbes that can harm human health.
C:N Ratio	Below 14 Ratio	Shows the rate of decomposition. Accurately depicts when compost reaches ripeness.

2.2. Operations Research

When examining the composting methods used at NAU, our team determined that that NAU uses an aerated turned windrow composting technique. Aerated turned windrow composting is commonly used to process large volumes of compost. The Aerated windrow composting method gathers organic waste into long rows or piles that are periodically aerated through turning. The Aerated windrow method is the most efficient way to process large volumes of compost while still obtaining the desired temperatures to kill pathogens.

The operations of the compost facility includes collection of waste food from the Düb Dining District and the Hot Spot on the NAU campus, emulsification to homogenize the waste food prior to entering the compost facility. The emulsified waste is shown below in Figure 2.1. Woodchips are donated from Arizona Public Service (APS) and local tree trimming companies, a pile of donated wood chips can be seen in Figure 2.2. Horse manure is donated from various local stables. The composting facility does not spend or receive money for the materials that they use for compost.

Figure 2.1 Emulsified Food

Figure 2.2 Woodchips

3.0 Work Plan

The Work Plan details sampling and analysis protocols as well as the health and safety protocols used throughout the project. This is needed as a checklist in the field and to produce consistent, high quality results. The Work Plan may be viewed in Appendix A.

4.0 Sampling

Sampling was performed according to the Work Plan. Three of the twelve finished compost piles were sampled. The piles were sampled at four feet height with an auger. Compost was taken from eight locations within the pile and composited to create one sample.

The samples were collected on September 20, 2019 at 10:30 AM with sunny and windy weather conditions. Images of the log notebook, chain of custody, and field work are found in Appendix B: Sampling Event Information.

5.0 Analysis

Testing and analysis were performed in the Environmental Lab at Northern Arizona University. The test methods, results, and result interpretation are described below.

5.1. pH

pH is important for compost because if it becomes too basic (pH of 8.5 or higher) the compost will damage the plants growing in it.

The pH testing followed TMECC 4.11A 1:5 SLURRY pH method. 40 grams of dry weight equivalent of normal compost was added to an Erlenmeyer flask. Deionized water was then added to achieve 200 mL to create a 1:5 solids to liquid ratio. The mixture was placed on a shaker table for 20 min at 180 rpm. Once the mixture became a slurry, the pH was recorded with a digital pH sensor with a glass differential electrode (PEEK).

The pH results are tabulated below in Table 5.1 pH Results. Additional data are found in Appendix C: Raw Testing Data.

Table 5.1 pH Results

Sample	pH	Avg pH	Determination: Needs to be between 6 -7.5 [2] [8]
1.1	6.89	6.79 ±0.09	Good
1.2	6.71		
1.3	6.77		
2.1	7.06	6.97 ±0.13	Good
2.2	7.02		
2.3	6.82		
3.1	7.27	7.23 ±0.04	Good
3.2	7.20		
3.3	7.22		

pH of the tested samples meets the standard. Compared to the external lab (Figure 1.8), pile 1 was 7.77, while in-house testing yielded 6.79. The percent error is 14%.

5.2.Percent Ash

The percent ash indicates whether if the compost has high organic matter. The lower the ash percentage, the higher amount of nutrients are in the compost [8].

The percent ash test followed TMECC 3.02A Unmilled Material Ignited at 550℃ Without Inerts Removal. 50cm^3 of compost was dried at 70℃ for 24 hours before placing into a muffle furnace at 550℃ for 2 hours. The compost weight was recorded before and after the furnace. Ash content is recorded as a percentage from initial dried weight. The percent ash results are tabulated below in Table 5.2 Percent Ash Results. Additional data are found in Appendix C: Raw Testing Data.

Table 5.2 Percent Ash Results

Sample	Ash %	Ash % Avg	Determination: needs to be ~50% [8]
1.1	59%	54% ±7%	Good
1.2	45%		
1.3	56%		
2.1	50%	51% ±3%	Good
2.2	49%		
2.3	55%		
3.1	82%	83% ±1%	High
3.2	84%		
3.3	84%		

For compost, 50% ash is typically found [8]. When a higher ash percentage occurs, the usual reasons are due to over mineralization (found in older compost) or soil contaminating the compost during turnings [8]. Pile 3 was found to have the largest amount of ash likely due to the pile being the oldest and having more soil added. The third pile is roughly four years old, while the other two piles are one and two years old. The conclusion of percent ash meets the standards except for pile 3. Compared to the external lab source (Figure 1.8), pile 1 was 47.9%. In-house testing was 54%. The percent difference is 11%.

5.3. Heavy Metals

Heavy metals are regulated at both state and federal levels. For each element, there is a maximum allowable concentration [2] [8]. The heavy metals are regulated through EPA 503.

The heavy metals were tested using a subcontractor within NAU. The subcontractor tested the samples with a Portable XRF Thermo Fisher Niton XRL3 utilizing the EPA Method 6200. The samples were dried and sieved through a #60 sieve and packed into small testing cups. Four sub-samples were tested per pile. The cups were placed into the portable XRF then tested for 90 seconds. The heavy metal results are tabulated below in Table 5.3 Heavy Metal Results. Additional data are found in Appendix C: Raw Testing Data.

Table 5.3 Heavy Metal Results

Metals	Pile Sample 1 Avg	Pile Sample 2 Avg	Pile Sample 3 Avg	Standard Deviation	External Lab Results	EPA Limit: [2] [8]	Within Limit:
As	6.4	12.1	12.1	2.7	3.5	41	Good
Cd	< 10	< 10	< 10	7.2	4.0	39	Good
Cu	28.5	35.2	37.3	9.3	36	1500	Good
Cr	<10	26.7	40.9	10.2	20	1200	Good
Pb	7.3	9.2	19.4	3.1	5.4	300	Good
Hg	<5	<5	<5	5.9	<1	17	Good
Ni	<15	<15	32.3	16.0	15	420	Good
Zn	120.1	116.4	120.7	8.0	100	2800	Good
Mo	2.9	<1	< 1	2.9	1.7	75	Good
Se	<3	<3	<3	2.4	<1	100	Good

All heavy metal contents meet the standards. Compared to the external lab source (Figure 1.8), pile 1 was within all bounds of the EPA Limit. In-house testing was also in all bounds of the EPA Limit.

5.4.Nitrate/Nitrite

Nitrate/nitrites are important in compost to supply nitrogen to plants. If there is not enough nitrate within the compost, the compost has an insufficient amount of oxygen causing gaseous loss of nitrogen by denitrification [2].

The nitrites/nitrates were tested utilizing TMECC 4.02-B to create the slurry. The slurry was filtered once using a glass membrane filter, and once using a gridded coliform filter. Then, HACH method 8039 was followed to test the nitrates/nitrites with calorimetry using cadmium as a reagent. The test had to be modified due to the lab not having an Ion Chromatograph Dionex DXI20. The nitrate results are tabulated below in Table 5.4 Nitrate Results. Additional data are found in Appendix C: Raw Testing Data.

Table 5.4 Nitrate Results

Sample	Nitrate (mg/L)	Nitrate Avg (mg/L)	Determination: Needs to be >100 [2] [8]
1.1	5.1	6.8 ±1.7	Fail
1.2	6.7		
1.3	8.5		
2.1	12.5	13.6 ±1.3	Fail
2.2	15		
2.3	13.4		
3.1	5.4	4.1 ±1.2	Fail
3.2	3.8		
3.3	3.1		

For mature compost, nitrates should be above a 100 mg/L [8]. The test shows that the filtered samples resulted in a very low concentration of nitrates. All piles were significantly below the required level of nitrates. These poor results are likely due to testing errors because of use of the HACH method. The EnE Lab at NAU, does not have an ion chromatography meter as required by TMECC, so the colormetry HACH method was the alternative. The liquid sample of compost was stained due to the coloration of the compost. The conclusion is the test method was unsuccessful, and the true nitrate concentration is unknown. Compared to the external lab source (Figure 1.8), pile 1 was 310 ppm. In-house testing was 6.8 ppm. The percent difference is 4459%.

5.5. E. Coli

E. Coli is important within compost due to federal and state regulations and because human heath may be affected if the compost is over range and is being used for gardens. *E. Coli* must be under <1000 MPN(Most Probable Number)/g of dry weight compost [2] [8].

E. Coli was initially supposed to be tested under TMECC 7.01-A utilizing a stomacher. A stomacher is a sterile food pulverizer with no blades. However, the ENE Lab, does not have a stomacher. Therefore, the test was modified using HACH Method 8001 with 5 grams of compost added into the testing tubes. 10 ml of DI Peptone Water was added with 5 grams of ground compost. The slurry is added to Lauryl Tryptose broth and the sample incubated for two days at 35˚C inside an incubator (Hach portable, 12 VDC) in the dark. A drop of the broth was then added to EC (*E. Coli*) Medium with MUG (4-methylumbelliferyl-beta-D-glucuronide) broth tube.

This sample is incubated for two more days within the same incubator at 40˚C in the dark. The samples were then checked under a UV light to check for illuminations within the vials. No illuminations were found which indicates no *E. Coli* were present within the samples.

Compared to the external lab, none was detected as well. These results were shown to be accurate.

5.6. Ammonia

Ammonia is important because its presence indicates which stage of the process the compost is in. The amount of ammonia also indicates why the pH is either high or low.

If the compost is above 550 ppm, the compost is considered immature. If the compost is between 100ppm and 550 ppm, this indicates the compost is mature. If the ammonia is lower than 100 ppm, this indicates the compost is very mature [2] [8]. The tests that would have been used for testing are TMECC 4.02-C. Ammonia could not be tested within the EnE Lab due to the lab not being equipped with a working Ion-Selective Electrode.

The external lab results, shown in Figure 1.8, determined the compost to consist of 19 PPM. This is labeled as very mature.

5.7.Temperature

It is important to test for temperature periodically within compost. Temperature is also an indicator for what stage the compost is currently in. The compost must complete all stages (raw, immature, curing, and finished) to kill the bacteria, lower ammonia and pH, as well as obtain more nutrients [8]. The temperatures for raw compost are typically greater than 140˚F [2]. Compost that is finished is typically lower than 90˚F [2]. However, there isn't a required temperature. If the compost plateaus and maintains the temperature, even with steady turning, the compost would result in being finished [2]. The temperature results are tabulated below in Table 5.5 Temperature Results. Additional data are found in Appendix C: Raw Testing Data.

Table 5.5 Temperature Results

Date:	10/14/2019	10/31/2019	11/24/2019	Temp. Avg.	Determination: <90 [2]
Pile	**Temperature ° F**				
1.1	110	110	90	112 ± 9	High
1.2	128	112	106		
1.3	118	122	112		
1.4	113	106	114		
2.1	126	119	112	119 ± 8	High
2.2	126	120	117		
2.3	128	122	104		
2.4	127	122	108		
3.1	116	112	105	108 ± 8	High
3.2	116	108	98		
3.3	118	111	100		
3.4	113	110	90		

The compost sample piles have been analyzed to be mature by the external lab due to the sample being within state and federal limits for Salmonella and E. Coli [8]. The results indicate a temperature plateau between 113-128°F. Mature compost will typically cool off to less than 90°F. This is due to the organic decomposition in the compost pile being completed. Compost should maintain a temperature of 104°F for five days to kill off pathogens. This is found to be above the common range for mature finished compost. The compost piles temperatures measured were determined to be safe as long as the temperatures had previously plateaued within the compost piles.

The external lab could not collect temperatures since the compost was mailed to the lab. The external lab could indicate whether the compost was mature or not due to the other parameters.

5.8. Salmonella

Salmonella is important due to the federal and state regulations and *Salmonella* is used in the biosolid industries to determine adequate pathogen reduction [8]. *Salmonella* needs to be under 3 MPN/ 4g of dry weight equivalent compost. *Salmonella* is considered to be a toxic microbe.

Salmonella could not be tested at the EnE Lab at NAU because the lab does not have a stomacher and stomacher bags. Stomacher bags are used to keep each sample completely sterilized when placed inside the stomacher for pulverizing. The procedure that would have been followed is TMECC 7.02.

The external lab results, shown in Figure 1.8, determined the compost to consist of <3 MPN/g of dry weight compost. This indicates that the compost is within the EPA standards for *Salmonella*.

5.9. C:N Ratio

The C:N Ratio depicts the rate of decomposition of compost mixtures. C:N Ratios also accurately depict when ripeness has been reached within the compost [2] [8]. The C:N Ratio needs to be below 14 for the compost to be considered mature. The tests that would have been used are TMECC 4.02-A for Total Nitrogen and TMECC 4.01-A. The C:N Ratio could not be tested within the EnE Lab at NAU because the lab does not have an aluminum heating block for 500˚C and an 832 Series Sulfur/Carbon Determinator.

The external lab results, shown in Figure 1.8, determined the compost to consist of 11 ratio. This indicates that the compost is in standard.

6.0 Operations Analysis

The composting process at NAU is comprised into four sections, collection, composting, testing, and processing.

The collection of the materials that comprise the compost start with NAU's dining halls. NAU dining halls collect pre-consumer and post-consumer waste for the compost piles. The pre-consumer waste is comprised of vegetables trimmings, coffee grounds, and fruit peels. The post-consumer waste is everything leftover from the consumer, this includes food and meat scraps, napkins, and paper cups. The NAU dining halls then process the post-consumer waste inside of a Vortech 2000 emulsifier that steams and heats the waste to 220 degrees Fahrenheit, emulsifying it. From there, NAU facilities pick up the pre-consumer and post-consumer waste generated from the dining halls and transport it in 44 gallon round vented trash cans, to the composting site behind NAU Facilities. Several companies such as Arizona Public Service (APS) and local horse stables provide woodchips and horse manure without charge. The horse manure and woodchips along with pine needles and lawn clippings from NAU facilities comprise the bulking agents used to create the compost.

The type of composting process used is Aerated Static Pile Composting. The process starts with 6 cubic yards of horse manure, 3 cubic yards of woodchips, and 3 cubic yards of pine needles and lawn clippings, into a bed which NAU Facilities deposit 3 cubic yards of the pre-consumer and post-consumer waste from the dining halls. A medium wheel CAT loader is used to move the bulking agents and to turn the compost piles. Throughout the week the pile is covered with a mixture of the bulking agents to deter animals and reduce the smell. Once a week for 2 months, the pile is added to a pile that will serve as the first of 6 composting piles.

The piles are turned and mixed once every two months. The only moisture added to the composting piles are what the environment provides. Throughout the composting process the composting piles temperatures reach up to 140 degrees Fahrenheit; the pile's average temperature throughout the year is between 100-120 degrees Fahrenheit [12]. At the end of 12 months the pile is ready to be tested and then turned into usable amended soil.

After 12 months, a sample from the completed compost is sent it to Soil Control Laboratory, in Watsonville, California, for testing. The tests typically focus on testing for E-Coli and Salmonella, although periodically a detailed test for C:N ratio, Nitrite/Nitrate, pH, ash content, and heavy metals is performed. These tests are used to ensure quality compost that does not fall outside EPA regulations.

At the end of a 12-month period, the oldest compost pile is screened it through a 3in soil screen. Once the finished compost has been screened is it mixed in a mixing bowl with soil in a 1:4 volume ratio. The result is a soil that is comprised of 20% soil and 80% compost, this product is the pre-amended soil that NAU currently sells as compost. The composting process can be seen below in Figure 6.1 Compost Volume Balance as a block diagram.

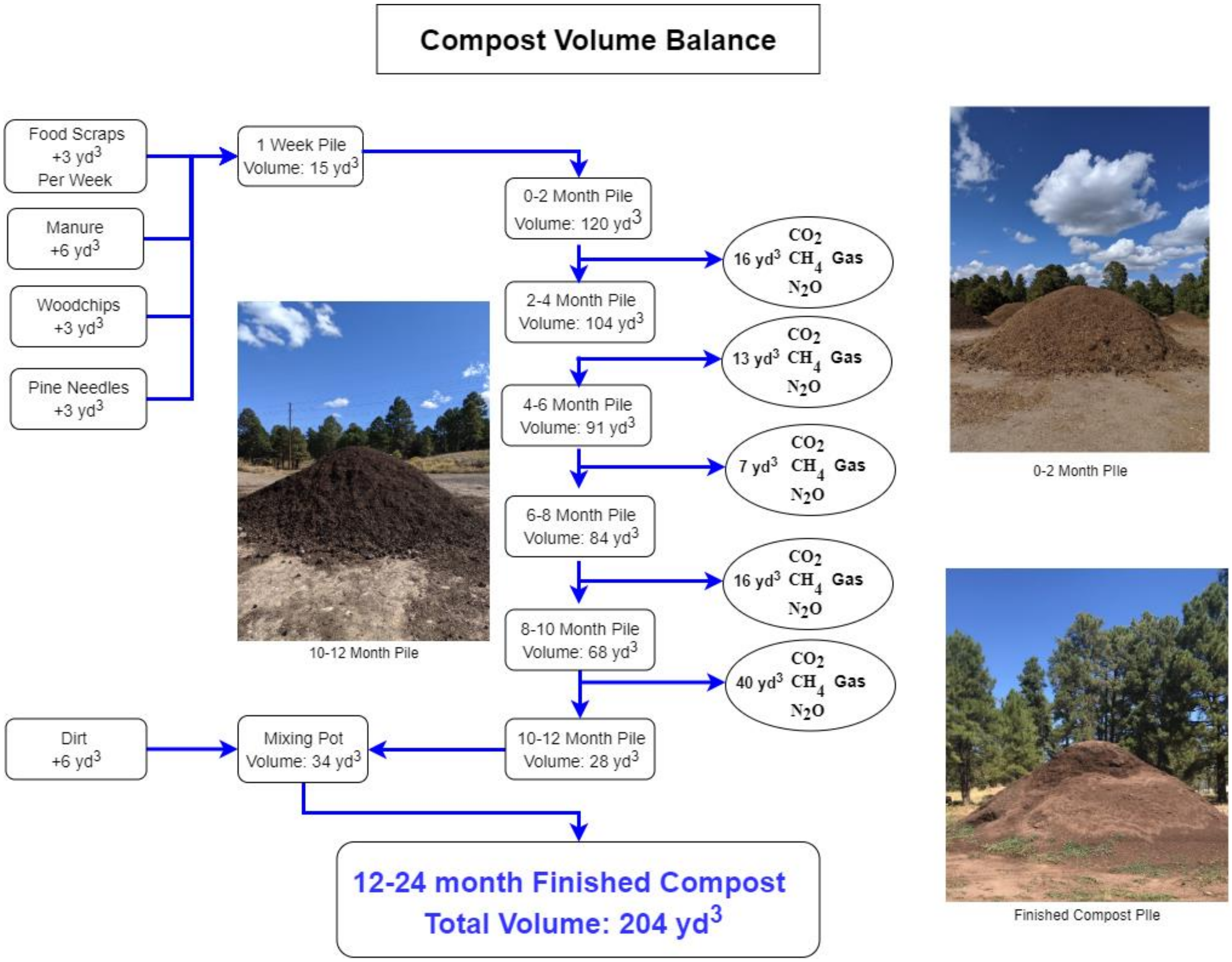

Figure 6.1 Compost Volume Balance

7.0 Economic Analysis

The economic analysis was based on a 20-year period due to lab equipment life expectancy. The present worth of in-house testing was compared to that of using an external lab. Piles are tested every two months, generating six samples a year. The comparison included equipment, materials, and lab rent. Table 7.1 below shows the cost of in-house testing at year 0. This table shows the initial cost of required materials for testing along with the cost of necessary equipment required for testing.

Table 7.1 Capital Cost at Year 0

Capital Cost at Year 0		
Method	**Materials**	**Cost for Item**
Organic Carbon TMECC	**Aluminum Oxide, 25lbs**	$63.04
	Sucrose, 500g	$16.60
	CaCo3, 500g	$10.75
Nitrogen TMECC	**Kjeltabs Cu-3.5,Foss 1000pk**	$251.00
	Salicylic Acid, 1 lbs	$9.67
	Sodium Thiosulfate, 4 lbs	$20.39
Salmonella TMECC	**lactose broth, 1 kg**	$29.22
	Brilliant Green Bile Broth 500 g	$79.00
	Idoine-Iodide solution 1L 5mg	$36.95
	Tetrathionate broth 500 g	$53.57
	Hektoen Enteric Agar, 500 g	$149.50
	Selenite F broth 500g	$74.30
	1-2 Test Kit, 48pk	$114.20
Ammonia TMECC	**deionized, ammonia-free water, 3500 mL**	$99.75
NItrate/Nitrite TMECC	**deionized, ammonia-free water, 3500 mL**	$99.75
***E.Coli* HACH**	**Lauryl Tryptose broth tubes, Qty 15**	$32.75
	EC Medium with MUG, Qty 15	$33.20
Method	**Equipment**	**Cost $ /Equipment**
Organic Carbon TMECC	**832 Series Sulfur/Carbon Determinator**	$35,000.00
	Furnace	$1,169.00
Nitrogen TMECC	**Microwave**	$2,653.00
	Aluminum Heating Block. 500C	$445.40
Salmonella TMECC	**Stomacher**	$5,606.50
	Strainer bag, Qty 1	$12.49
pH TMECC	**pH meter**	$12.99
	Glass Electrode	$50.70
	Stirring Rod	$3.00
	Centrifuge Extraction Apparatus	$1,312.00
Ammonia TMECC	**Ion -Selective electrode**	$884.00
	Manetic Stirrer	$317.19
Ash TMECC	**Balance**	$148.00
	Evap dish 525mL, Qty 1	$136.00
	Dessicator Cabinets 24"x18"	$131.00
Total Solids & Moisture Content TMECC	**Drying oven**	$399.00
NItrate/Nitrite TMECC	**Ion Chromatograph Dionex DX120**	$9,600.00
	Colorimeter AQ4000 Thermo Scientific	$1,279.00
***E.Coli* HACH**	**Incubator**	$299.00
	Alcohol burner	$7.99
	Incoulating loops	$101.00
	Pipet 10 mL	$197.00
	Pipete filler	$116.40
	Coliform tube rack	$115.00
Total Capital Cost for Year 0		
AT YEAR 0		**$61,169.30**

Table 7.2 below shows the comparison of the annual costs for in-house testing per year. The annual cost of in-house testing and it came out to be $3,987.95. However, using the external lab will cost $349 per one gallon of sample, and this amount should be paid six times a year which will be $2,094.

Table 7.2 Annual In-House Testing Cost

Annual Cost				
Method	**Materials**	**Pile 1- #Samples**	**Cost for Item**	**Cost/Test**
Organic Carbon TMECC	**Aluminum Oxide, 25lbs**	1	$63.04	$0.01
	Sucrose, 500g	1	$16.60	$3.32
	CaCo3, 500g	1	$10.75	$2.69
Nitrogen TMECC	**Kjeltabs Cu-3.5,Foss 1000pk**	1	$251.00	$0.25
	Salicylic Acid, 1 lbs	1	$9.67	$0.01
	Sodium Thiosulfate, 4 lbs	1	$20.39	$0.02
Salmonella TMECC	**lactose broth, 1 kg**	1	$29.22	$0.38
	Brilliant Green Bile Broth 500 g	1	$79.00	$6.58
	Idoine-Iodide solution 1L 5mg	1	$36.95	$0.37
	Tetrathionate broth 500 g	1	$53.57	$0.50
	Hektoen Enteric Agar, 500 g	1	$149.50	$12.46
	Selenite F broth 500g	1	$74.30	$6.19
	1-2 Test Kit, 48pk	1	$114.20	$2.38
Ammonia TMECC	**deionized, ammonia-free water, 3500 mL**	1	$99.75	$11.08
NItrate/Nitrite TMECC	**deionized, ammonia-free water, 3500 mL**	1	$99.75	$11.08
***E.Coli* HACH**	**Lauryl Tryptose broth tubes, Qty 15**	1	$32.75	$3.64
	EC Medium with MUG, Qty 15	1	$33.20	$3.69
NAU Lab	**$100/day for 6 days**	1	$600.00	$600.00
Total In-House Annual Cost				
Annual Cost				**$3,987.95**

Figure 7.1 below shows a present worth analysis for NAU testing over a 20-year period. The present worth analysis was calculated to be -$123,194, using an assumed interest rate i = 4%. Profits from selling compost were not included in the present worth analysis. The capital cost C

was taken from Table 7.1 above. The value A1 was taken from the annual cost Table 7.2. The value A2 is the annual cost of labor to perform testing on one compost pile. A2 is equal to 48 hours of labor times $12 per hour, equaling $576 per year.

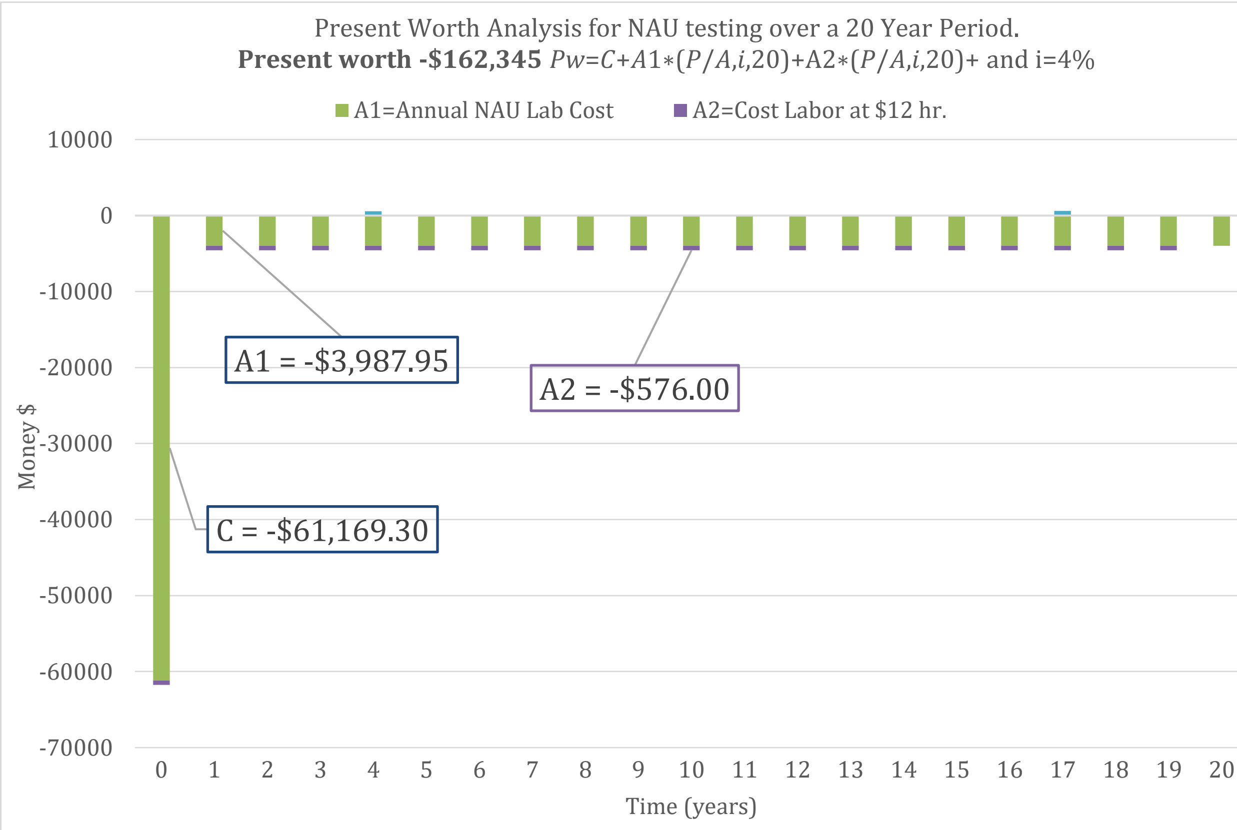

Figure 7.1 Economic Analysis for NAU Testing

Figure 7.2 shows the present worth analysis using Soil Control Laboratories testing services over a 20-year period. The present worth analysis was calculated to be -$28,458 per year, using an assumed interest rate i = 4% and an annual cost of $339 per test 6 times a year. The value A is the annual cost of Control Laboratories testing services, equal to -$28,458.

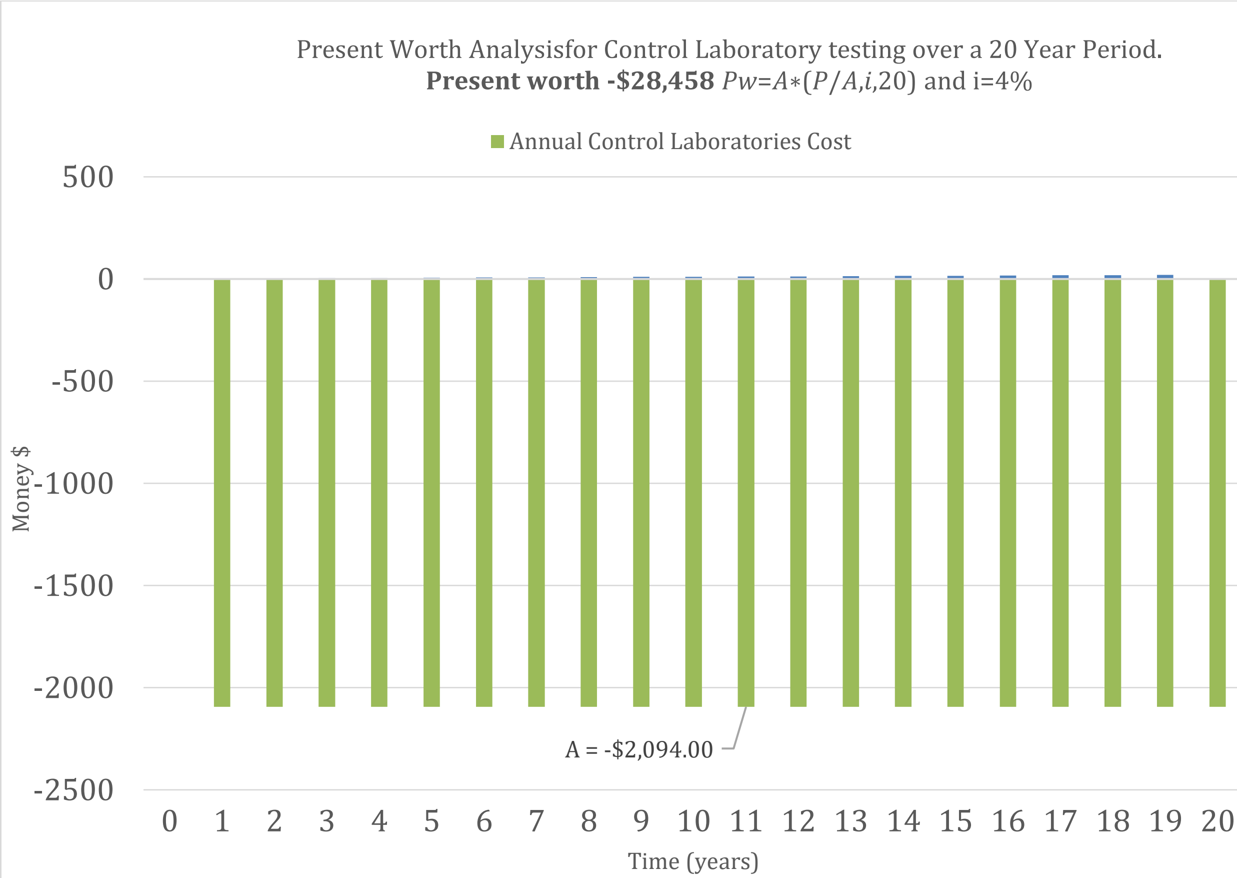

Figure 7.2 Economic Analysis for Control Lab Testing

Figure 7.1 and 7.2 compare the present worth of in-house vs external lab testing over a 20 year period at a 4% interest rate. In-house testing was determined to have a present worth value of -$162,345. External lab testing was determined to have a present worth value of -$28,458.

8.0 Impacts

8.1. Social Impacts

The social impacts from NAU's composting operation are positive. NAU's composting project receives bulking agent donations from small and large businesses. These donations provide businesses with a free alternative to dumping their waste at the Cinder Lake Landfill. This relationship creates positive bonds between NAU and businesses looking to dispose of bulking agent waste. NAU's composting project produces compost that people will be able to purchase for local gardening needs and creates a greater sense of community. The production of compost by NAU improves the relationship between residents and the state school NAU, in that NAU is seen as trying to positively impact the environment.

8.2. Environmental Impacts

The environmental impact of the project is positive because instead of dumping the food scraps into a landfill, it is being reused as compost that helps the local gardeners. Compost decomposed the organic materials that are throw out in the compost from different sources, and it also helps the soil to hold the carbon dioxide which mean that emissions will be reduced. It is also an Eco-friendly safe product and will save more space in the landfill.

8.3. Economic Impacts

Northern Arizona University (NAU) can save more money over 20-year period if they use an external lab instead of in-house testing. Also, NAU can provide more funding by selling the compost for more projects in NAU facilities. Finally, all local companies will be able to avoid tipping fees for throwing out the waste because as mentioned in the operation part that every waste is being disposed in NAU Compost Facility for free.

9.0 Summary of Engineering Work

The project determined whether if NAU Compost facility is able to do in house testing using the Test Method Examination for Composting and Compost (TMECC), instead of sending the samples into an external lab.

Some of the required equipment are not available in the ENE labs. Therefore, what was done is that some of the testing parameters were removed from the list such as total nitrogen, organic carbon, and Salmonella and some others were modified. Tests such as *E. Coli*, and nitrate/nitrite were modified to HACH instead of following TMECC. Table 9.1 below shows the proposed staffing hours vs. the actual staffing hours. The following table shows a total of 461.5 hours for proposed hours and 416.5hours for the actual working hours. The difference between proposed and actual is 126.5 hours. The reason of having less hours is that some of the testing parameters were eliminated from the testing analysis task due to unavailability of the required lab equipment following TMECC. Some methods were modified to HACH, but as provided in the testing analysis part above, the modified methods failed.

Table 9.1 Estimated Working Hours vs. Actual Working Hours

Task	Estimated Working Hours			Actual Working Hours		
	Senior Engineer	Engineer	Lab Tech	Senior Engineer	Engineer	Lab Tech
Task 1.0 Research						
1.1 Regulations Research	2	4	8	0	6	0
1.2 Operations Research	3	7	3	0	10	0
Task 2.0 Work Plan	2	4	8	2	14	3
2.1 Sampling and Analysis Plan (SAP)	3	16	15	5	9	0
2.2 Health and Safety Plan (HASP)	3	22	22	1	3	3
Task 3.0 Sampling	16	22	20	1	6	1
Task 4.0 Testing and Analysis	24	40	65	3	4	78
Task 5.0 Operations Analysis	14	15	4	1.5	8	0
Task 6.0 Economics Analysis	22	35	0	5	13	4.5
Task 7.0 Impacts	3	15	12	1	2	0
Task 8.0 Project Management	2	4	3	0	0	0
8.1 Meetings	3	3	3	8.5	28.5	25
8.2 Team Management	8	9	5	9	28	16.5
8.3 Deliverables	7	15	4	0	0	4
8.3.1 Milestone	6	13	3	0	0	0
8.3.1.1 30% Report and Presentation	3	7	2	4	7	0
8.3.1.2 60% Report and Presentation	3	8	2	7	17	2
8.3.1.3 90% Report and Presentation	3	6	1	2	10	5
8.3.1.4 Final Presentation	1	1	1	8	6	6
8.3.1.4 Final Report	1	2	1	3	2	0
8.3.2 Meeting Memo Binder	0	8	8	4	18	0
8.3.3 Website	3	10	0	0	12	0
Total	**588**			**416.5**		

10.0 Summary of Engineering Costs

Examining the purposed and actual cost of engineering services, the actual cost is less. The purposed total personnel was predicted to be $56,546. The actual total personnel was predicted to be $55,804. The purposed total supplies cost was predicted to be $13,196. The actual supplies cost was $13,119. Overall, the purposed engineering services cost was predicted to be $69,742. The actual engineering services cost was $55,804. There was a difference of $13,938. The breakdown of the purposed and actual cost of engineering services are shown below in Table

10.1 Purposed Cost of Engineering Services, and Table 10.2 Actual Cost of Engineering Services.

Table 10.1 Purposed Cost of Engineering Services

Proposed Cost of Engineering Services				
1.0 Personnel				
Classification	**Hours**	**Rate, $/hr**	**Cost $**	
SENG	123	200	24600	
ENG	241	74	17834	
LAB	224	63	14112	
Total Personnel	**588**	**N/A**	**$56,546**	
2.0 Supplies				
Item	**Cost/unit $**	**Unit**	**Quantity**	**Cost $**
NAU Lab Rental	100	120	1	12000
E.coli Broth Glass Ampules, pk/20	56	1	20	56
m-ColiBlue24 Broth, Plastic Ampules, PK/50	130	1	50	130
Total Organic Carbon (TOC) Reagent Set, HR	489	1	1	489
Nitrogen-Ammonia Standard Solution, 50 mg/L as NH3-N, pk/20 - 2 mL PourRite™ Ampules	54	1	20	54
NitriVer® 3 Nitrite Reagent Powder PIllows, 10 mL, pk/100	43	1	100	43
Nitrate TNTplus Vial Test, LR (0.2-13.5 mg/L NO3-N)	47	1	1	47
Phosphorus (Reactive and Total) TNTplus Vial Test, LR (0.15 to 4.50 mg/L PO4)	59	1	1	59
Potassium Reagent Set	210	1	1	210
Salmonella EPA Test Broth pk/15	108	1	15	108
Total Supplies	**$13,196**			
Total	**$69,742**			

Table 10.2 Actual Cost of Engineering Services

Actual Cost of Engineering Services				
1.0 Personnel				
Classification	Hours	Rate, $/hr	Cost $	
SENG	81	200	16200	
ENG	228.5	74	16909	
LAB	152	63	9576	
Total Personnel	**416.5**	**N/A**	**$42,685**	
2.0 Supplies				
Item	Cost/unit $	Unit	Quantity	Cost $
NAU Lab Rental	100	120	1	12000
Buffered Peptone Water	89.9	1	1	90
Lamp, Ultraviolet, Portable	78.69	1	1	79
EC/MUG without Durham Tubes, Package of 15	33.2	1	1	33
Lauryl Tryptose Brother MPN Tubes, Concentrated, pk/15	32.75	1	1	33
Ion Selective Electrode for Ammonia	884	1	1	884
Total Supplies	**$13,119**			
Total	**$55,804**			

11.0 Conclusion

SAS Engineering has concluded that the NAU Compost Facility Analysis project should not do in-house compost testing at NAU. If compost were to be tested at NAU, there would be a loss money. Equipment and materials would need to be bought in order to sustain testing. The HACH modifications for testing did not work as well as TMECC, which must be followed for testing.

12.0 References

[1] P. Pfeifer, M. Gallo and B. Marbury, "NAU Composting Pilot Study Research Report, 2011-2012", *Cvcompost.com*, 2013. [Online]. Available: https://www.cvcompost.com/NAU-Compost-Research-Project.pdf. [Accessed: 14- Feb-2019].

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[12] Facilities Supervisor, Howard Cowell, interview, Oct. 2019.

Appendix A: Work Plan

NAU Compost Monitoring Program Work Plan

SAS Engineering

Abdulrahman Almehmadi, Scott Bearchell, Sara Page

December 10, 2019

GI: Dr. Bridget Bero

TA: Adam Bringhurst

1.0 Introduction

1.1. Project Objectives

The purpose of this project is to create a comprehensive management plan for Northern Arizona University's (NAU) composting piles, including analysis required to determine if the soils can be sold at Flagstaffs Community Market. The following sections detail the Work Plan for the NAU compost project. The Work Plan includes a Sampling and Analysis Plan (Appendix A), and a Health and Safety Plan (Appendix B) for the Compost project.

1.2. Project Scope

The project scope includes:

- 1.0 Research
    - 1.1 Regulations Research
    - 1.2 Operations Research
- 2.0 Work Plan
    - 2.1 Sampling and Analysis Plan (SAP)
    - 2.2 Health and Safety Plan (HASP)
- 3.0 Sampling
- 4.0 Testing and Analysis
- 5.0 Operations Analysis
- 6.0 Economical Analysis
- 7.0 Impacts
- 8.0 Project Management

1.3. Work Plan Schedule

The SAS Engineering will initiate sampling on September 16th and complete by September 24th, 2019. Following the sampling, lab analysis will be conducted from September 25th through October 29th, 2019. The Schedule will follow the Gantt chart located in Section 3.0 Scheduling in the project proposal.

2.0 Project Management

2.1.Project Management Approach

To properly manage the NAU Compost project, SAS Engineering will conduct weekly team meetings for keeping members on schedule and to create a well-organized team that will follow all the deadlines outlined in the project proposal. In addition to weekly team meetings SAS Engineering will meet with the grading instructor, Professor Bridget Bero, once a week to review project deliverables and progress. Client meetings will also be conducted throughout the project to address client questions or concerns. Biweekly meetings will be held with the technical advisor for guidance in soil testing and compost-related technical questions and project progress. Abdulrahman Almehmadi will be the designated client contact.

2.2. Project Procedures

Team meetings will be scheduled at least three days prior to a deliverable to ensure that any corrections can be made before submittal. SAS Engineering will schedule meetings with the Technical Advisor a week in advance to allow time for preparation by both the team and the advisor to fully understand the task deliverable being reviewed. A meeting agenda will be emailed prior to meetings. This agenda will cover the topics of discussion, dates and, time of meeting. Throughout the meeting one member of SAS Engineering will be selected to document the discussion and notes. These documents will be compiled into a meeting memo binder delivered to Professor Bridget Bero at the completion of the project.

2.3. Quality Management

To ensure the highest quality data is being recorded and analyzed SAS Engineering will follow appropriate Quality Assurance (QA) and Quality Control (QC) methods. QA/QC procedures for project management include meetings with the project technical advisor, team review of each task deliverable, and maintenance of the project schedule. Field sampling and analysis QA/QC methods are in section 2.2 of the Sampling and Analysis Plan in Appendix A. If it is determined that additional QA/QC methods are needed to maintain the integrity of the project, new methods may be developed and added to this Work Plan.

3.0 Site Background Information

3.1. Site Location

The site is located within the City of Flagstaff next to Interstate 40 as shown in Figure 3-1 Project Location.

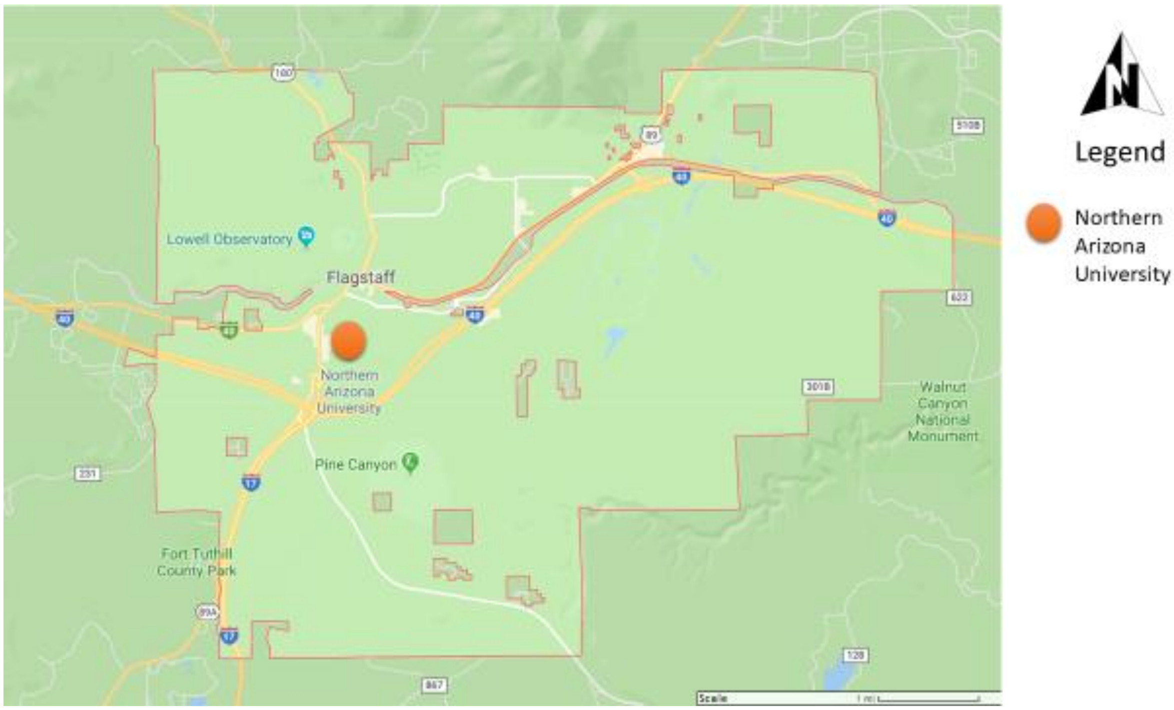

Figure 3-1 Project Location Map within the City of Flagstaff [1]

The compost piles are located on NAU's south campus adjacent to Interstate 40 and S Lone Tree Rd. as displayed in, Figure 3-2, and 3-3.

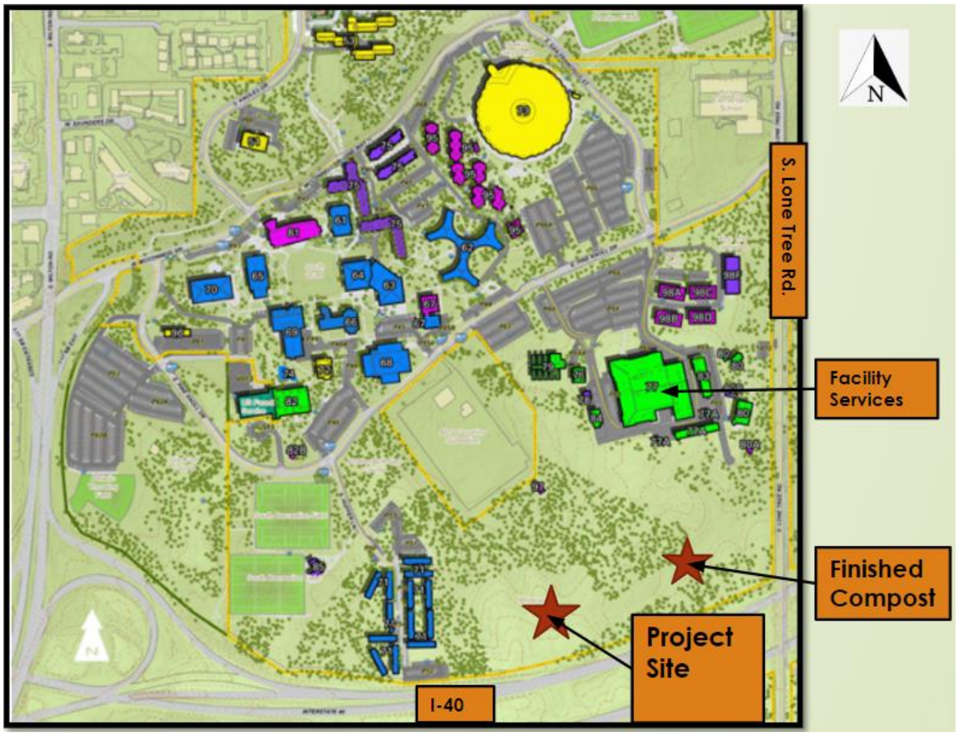

Figure 3-2 Northern Arizona University Site map [1]

Figure 3-3 Site Located, North of Interstate 40 and West of S Lone Tree Rd. [1]

A preliminary site visit was conducted on February 6th of 2019 shown in Figure 1.4. At that time of the site visit, 12 piles were observed at various stages of composting.

Figure 3-4 NAU Compost Piles February 6, 2019 [2]

3.2.Previous Operations and Investigations

NAU's composting program was created on April 30, 2012 [1]. Shortly after the composting program's creation, a composting study that spanned a year and a half, 2011-2012, was conducted by a former forestry student in coordination with NAU to develop the most effective means of composting on a large scale in Flagstaff [1]. According to an email exchange mentioned in the report from the City of Flagstaff Community Sustainability Specialist, McKenzie Jones, the amount of organic material deposited into Flagstaffs Cinder Lake Landfill made up ~28% of the City's waste stream [1]. The organic material being disposed into the landfill that could be turned into compost was estimated to be ~60,000 tons per year [1]. To combat the constant increase of waste produced per year, NAU created a compost recycling program that is intended to reduce the amount of total waste put into Flagstaff's Cinder Lake landfill. As a result, from this program, the NAU compost piles processed 10,000 lbs. of composted material per week during the 18-month study period. At the production rate of 10,000 lbs. per week, NAU is projected to produce a maximum of 520,000 lbs. per year or 260 tons of composted soil [1].

The feedstock used in NAU's composting program consists of food scraps from the following locations along with horse manure and carbon-based material such as tree trimmings and grass clippings. From NAU, the compost pile accepts food scraps from NAU dining, operated by SODEXO, pine needles, grass clippings, and woody material from tree trimmings. From Flagstaff, the compost pile accepts food scraps from the Flagstaff Medical Center (FMC) Hospital, Mother Road Brewery, and horse manure from nearby stables [1]. Currently the NAU compost piles are being operated by a NAU Facilities Employee, Howard Cowell, who manages and turns the compost piles daily.

The piles are organized into different stages of composting on the site. The process consists of Howard Cowell mixing 24 yd^3 of food scraps and 24 yd^3 of bulking agents, consisting of wood chips and horse manure, into a pile every week. This continues for two months then a new pile gets started. When a new pile gets started, the older piles are turned once a week for a year. This phase is called curing, and the compost needs to be well aerated, the temperature is checked once every other week. After curing for a year, the pile gets moved across the facility to the finished compost site. The compost is then utilized throughout campus and sold. The compost is currently sold to Flagstaff citizens who come to the compost site and buy the compost by volume at $24-28 per yd^3.

The Composting Pilot Study Research Report [1] examined the sources of feed to be used for a composting pile at NAU. The study also researched and tested the ideal range for soil nutrients in cured composted soil along with the various effects different types of composting methods have on the soil. The study selected the best method for composting in Flagstaff, turned piles with minimal watering. The Composting Pilot Study did not test for harmful bacteria such as e-coli and salmonella and the data graphs for thermophilic and mesophilic testing are unreadable because of missing axis labels.

The condition of the three completed compost piles as of September 20, 2019 can be seen below in Figures 1.5-1.7

Figure 1.5: NAU Finished Compost Pile 1. September 20, 2019 [3]

Figure 1.6: NAU Finished Compost Pile 2. September 20, 2019 [3]

Figure 1.7: NAU Finished Compost Pile 3. September 20, 2019 [3]

All three finished compost piles appeared to be well matured compost. The piles are located in safe locations away from potential contamination sources.

The constrains and limitations of the Compost Project moving forward are as follows:

- Scheduling
- Acquiring scheduled lab access time
- Acquiring required testing materials
- Testing results

As of September 20, 2019 the compost sampling is completed and weather is no longer a limitation for the success of the project.

4.0 Investigative Operations and Approach

The following sections will discuss the objectives and general approach that will be used by SAS Engineering in order to create a comprehensive management plan for NAU's composting piles.

4.1. Site Investigation Objective

The objective for the Compost project site investigation is to ensure that sampling and analysis can be conducted by NAU personnel and tested according to State and Environmental Protection Agency's (EPA) standards.

4.2. Site Investigation General Approach

SAS Engineering will follow Test Method for the Examination of Composting and Compost (TMECC) guidelines for compost sampling and collection [4]. Samples will be collected from NAU's completed compost pile from various locations around the pile at a 4ft height above the ground. The lab analysis will be conducted in NAU's Environmental Engineering lab. Samples will be transported in plastic Ziplock bags as outlined in Section 5.0. Disposal of compost samples can be found in Section 6.0.

5.0 Deviations from the Work Plan

If any problems are identified, deviations from the work plan will be approved by the Tech Advisor or Grading Instructor prior to taking action. Deviations from the Work Plan will be addressed by SAS Engineering and reported to the client.

6.0 References

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[7] *HASP Template*. EPA, 2019.

Appendix A: Sampling and Analysis Plan

1.0 Introduction and Project Management

NAU has a collective compost program on campus. SAS engineering will be collecting compost samples to analyze for any contaminants that may exceed the parameters identified by the EPA and ADEQ. This will be done and compared to a recent compost analysis to show that in house testing may be performed and would be accurate.

1.1. Project Organization Table

Table A1.1 shows the title, name, contact information, and responsibility for the completion of the project.

Table A1-1 Project Organization

Title	**Name**	**Phone Number** **Email Address**	**Responsibility**
SAS member	Sara Page	520-245-2394 sep259@NAU.edu	Project Manager/Client Correspondent
SAS member	Abdulrahman Almehmadi	928-221-0532 aaa625@nau.edu	QA/QC Officer
SAS member	Scott Bearchell	928-864-7193 Sb2639@nau.edu	Safety Officer
NAU Compost Representative	Adam Bringhurst	adam.bringhurst@nau.edu	Supervise work/ Approve changes to work plan

1.2. Project Sampling Details

The site is located within the City of Flagstaff next to Interstate 40. The compost piles are located on NAU's south campus adjacent to Interstate 40 and S Lone Tree Rd. All the samples will be collected from the finished compost pile. Further descriptions of the sampling methods are discussed in Section 3.2.

2.0 Project Data Quality Objectives

2.1. Project Objectives and Problem Definition

The purpose of this project is to create a comprehensive management plan for Northern Arizona University's (NAU) composting piles, including analyses required to determine if the soils can be sold at Flagstaffs Community Market. Through these testing's, NAU would also be able to provide in house testing of compost through EPA and ADEQ requirements.

2.2. Data Quality Objectives (DQO) and Quality Control

The data quality objectives are to obtain data of sufficient quality for use in comparison to EPA Compost Standards. Quality control (QC) is discussed below in section 2.2.1.

2.2.1. Field Quality Control

The QA/QC officer will be responsible for making sure that the QA/QC procedures are followed in the field during sample collection. Abdulrahman Almehmadi is the designated QA/QC officer. To ensure liability is avoided from SAS engineering, Abdulrahman will observe SAS is following the proper sampling procedures. The proper sampling procedures include proper sample labeling and storage. Of all these procedures will be checked again by Scott Bearchell, the designated Safety Officer.

2.2.2. Lab Quality Control

The testing and analysis quality control will be conducted by following the procedures for each parameter with the guidance EPA and the TEMCC manual. This ensures accuracy and consistency for each test of the samples. All equipment utilized will be calibrated and used accordingly as per the manual. All SAS members will be trained on all equipment utilized. This ensures quality control as well as safety control.

2.2.3. Data Quality Control

The data analysis will be conducted with accordance to EPA and TMECC manual standards and procedures. The results will be documented manually through a lab notebook, will be checked, as well as being uploaded to an Excel spreadsheet for organization, representation of the findings, and for easy sharing of the results. The

Excel data will be safe by being kept on a flash drive in the care of the project manager, Sara Page.

2.2.4. Cross-contamination Precautions

2.2.4.1. In Field

Within the field, the different finished piles will be sampled individually and will be bagged accordingly. The samples will be labeled to avoid confusion. The samples will be collected 4 feet above the ground to avoid contamination from the surface ground dirt. All the equipment utilized within the field will be washed with soap and water to decontaminate prior to each use between sampling piles.

2.2.4.2. In Lab

To ensure accurate and qualitative results, cross-contamination will be minimized. Prior to use of all equipment and lab surfaces, the surfaces will be cleaned. Gloves will be changed after every parameter test. The samples will be stored appropriately and will be restored in the same location.

2.3. Data Review, Validation and Management

Throughout the testing and analysis phase, the data will be reviewed by the QA/QC officer, Abdulrahman Almehmadi. This will minimize errors and identify major outliers in the results. All results will be documented and discussed in the lab notebook and the Excel spreadsheet.

3.0 Field Methods and Procedures

The following methods and procedures will be followed by all SAS engineering team members in the field. Information on the field equipment and compost sampling procedures are discussed.

3.1. Field Equipment

SAS Engineering will prepare for field sapling by obtaining and preparing the field equipment listed below.

- 160 Heavy duty gallon Ziplock bags
- 1 clean augers
- Soap
- Water bottles
- 1 long rod temperature thermometer
- 1 Sharpie
- 1 Shovel
- 1 Field logbook per person
- Work Plan
- PPE/Decontamination equipment- trash bags, gloves, paper towels, goggles, face masks etc.
- 4, 5-gallon buckets.
- Measuring Tape

3.2.Field Sampling

The compost samples at the NAU Composting site will be collected following EPA and TMECC [4] guidance. All samples will be taken using a clean, decontaminated auger. Samples will be obtained from the finished pile most recently tested (May 2019) by the external lab. Two additional finished piles will be sampled also.

3.2.1. Sampling Containers

Samples will be composited in 5 gallon buckets then stored in double-bagged gallon Ziplock bags.

3.2.2. Sample Locations

The samples will be taken four feet above the ground with the auger. The auger will be pushed horizontally into to pile as far as it will go and take out approximately a pint of compost. This will be done at 8 locations within each pile. Below the Figures A3-1 and 2 show the side view and top view of the finished compost pile and the sampling locations. The black dots represent the auger dig points.

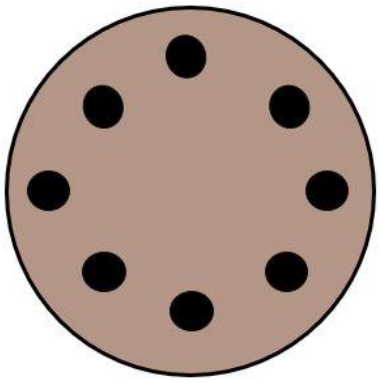


Figure A3-1: Top View of Compost Pile

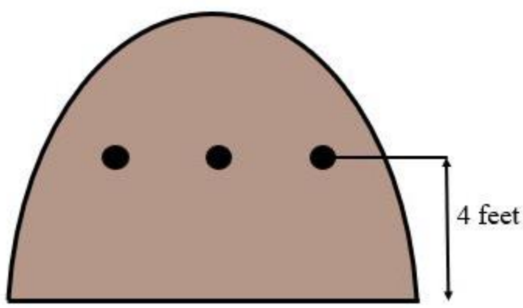


Figure A3-2: Side View of Compost Pile

3.2.3. Sample Methods

All 8 samples will be placed in a 5-gallon bucket and mixed. Once the finished compost is mixed it will be placed into doubled Ziplock baggies. The Ziplock Baggies will be labeled according to section 7.2.1 in Appendix A. This will be repeated for each finished compost pile samples. The equipment will be cleaned with soap and water in between sampling the different piles [5]. The temperature of each compost pile will be obtained numerous times throughout the next two months to record fluctuation.

4.0 Lab Testing and Analysis

Testing and analysis follows set procedures from the TMECC [4] per test. SAS engineering will be conducting 8 different parameter tests with 3 replicate samples per test. The parameters are C: N Ratio, *E. Coli*, pH, nitrite/nitrate, ammonia, *Salmonella*, percent ash, and heavy metals. The test methods are discussed below.

4.1. C: N Ratio

This test follows the Total Nitrogen TMECC 4.02-D and Total Carbon TMECC 4.02-D. Parameters must be between 25:1 and 40:1, respectively.

4.2. E. Coli

This test follows the TMECC 7.02-C. Parameters must be under 1000MPN (Most Probable Number) per 1g of dry compost.

4.3. pH

This test follows the TMECC 4.11-A. The pH must be between 5.5- 7.5.

4.4.Nitrite/Nitrate

This test follows the TMECC 4.02-B. Parameters for nitrate/nitrite are greater than 75 ppm, shows high concentrations, which indicates mature compost.

4.5.Ammonia

This test follows the TMECC 4.02-C. Parameters must be under 15% of Total Nitrogen.

4.6.Salmonella

This test follows TMECC 7.02-A. The testing parameters must be under 3MPN per 4mg of dry compost.

4.7. Percent of Ash

This test follows the TMECC 3.02-A. The testing parameters are less than 50%.

4.8. Heavy Metals

This test follows ASTM D5381-93. The testing parameters are between 0.5- 400 depending on the element. This will be subcontracted out to a NAU grad student using the XRF.

5.0 Sample Preservation, Packing and Shipping

After field sampling, SAS engineering will be transporting the compost samples securely back to the NAU Environmental Engineering Lab. The lab location is approximately a mile away from the field location. No preservation is required. Chain of custody will be enforced to ensure proper documentation regarding the handling of the compost samples. The samples will be stored in a refrigerator at 39 degrees Fahrenheit conditions. To keep samples secure, SAS engineering will be utilizing the NAU Environmental Engineering Water Quality Lab and the NAU Civil Engineering Material Lab for testing and analysis.

6.0 Disposal of Residual Materials

Throughout the NAU Compost project, waste will be generated and will need to be disposed of properly. Disposable PPE will be placed in the trash and disposed through dumpsters located at NAU. Reusable PPE will be decontaminated, washed and placed back properly within the lab. Waste created within the lab will be disposed of with direction from the lab managers. The waste includes solids and liquids. Potential waste that will be disposed of within the labs are tested waste involving chemical broths and reagents. Potential hazardous waste may be created, lab managers instructions will be followed.

7.0 Sampling Documentation and Shipment

7.1. Field Notes

7.1.1 Field Logbooks

Each member working in the field for SAS engineering will record the information taken in the field in a logbook. The logbook will contain the following information for each field event:

- Location
- Team members and their responsibilities

- Other personnel on site
- Deviations from sampling plan
- Location and description of each sample
- Date and Time
- Equipment Used
- Sampler
- The weather on the day of sampling (temperature, conditions)
- Sketch of site
- Notes and observations

The log entries shall be written in non-smearable black ink, the pages will be consecutively written in the corner, and be signed by the one taking the notes.

7.1.2 Photographs

Photographs will be taken at the field sampling site, throughout the procedures, of the samples, and other areas of interest. Each photograph will be recorded in the log notebook with the following information:

- Time and date
- Location
- Weather Conditions
- Description of what is being photographed
- Name of the photographer

7.2. Sample Identification and Labeling

All samples will be labeled in a clear manner for identification purposes in the field and in the lab. The sample labels at a minimum will included the information below:

- Project Name
- Date

7.2.1 Labeling System

Each sample will be labeled using the following layout: [Project_Pile #_ Date].

Example label: COM_Pile1 _8/20/2019

7.3. Sample Chain-of-Custody Forms and Custody Seals

The samples will require a chain-of-custody whenever the possession of the sample is switched between different members, labs, and other parties. A form will be sent with the sample for the party to fill out the details of the handling. A record will be maintained to ensure security and integrity of the sample. The details included within the chain-of-custody include date, time, relinquished by, and accepted by. Examples of the chain-of-custody form and chain-of-custody seal [6] are shown below in Figures A7-1 and A7-2.

<table>
<tr><th colspan="3">Chain of Custody Record</th></tr>
<tr><td>Project No.</td><td rowspan="3">Project Title</td><td rowspan="4">Organization

Contact

Address</td></tr>
<tr><td></td></tr>
<tr><td>Shipping
Container No.</td></tr>
<tr><td colspan="2">Field Samplers: print signature</td></tr>
</table>

Date	**Time**	**Site/Location**	**Sample Type**	**Sample ID**	**Remarks**

Relinquished by (*print and signature*):	Received by (*print and signature*):	**Comments**

Figure A7-1 Official Chain of Custody Seal

Chain of Custody Seal

Sample Name/ID Number:	Sample # ___ of **3**
Company:	
Signature:	Date/Time:

Figure A7-2 Official Chain of Custody Seal

8.0 Deviation from Sampling Analysis Plan

All decisions to deviate from the SA Plan will be made by Adam Bringhurst. Any changes made will be documented in the final report.

Appendix B: Health and Safety Plan

1.0 Job Name and Location

The site is NAU Compost facility analysis and it is located within the city of Flagstaff next to the interstate 40, the compost piles are located on NAU's south campus adjacent to Interstate 40 and S Lone Tree Rd.

2.0 Safety and Health Administration

NAU health and safety requirements will be followed.

3.0 Hazard Assessment

Any field and lab work may have hazard risks, and these could be divided into chemical, physical, and biological hazard.

3.1. Physical Hazards

Physical hazards are considered to be falling or tripping in the field, the exposure potential during work will be low. Table B3-1 below shows the physical hazard during the field work.

Table B3-1 Physical Hazards

Physical hazard		
Type of physical hazard	**Exposure potential during work**	**Control**
Tripping, fall	low	Closed toed shoes, gloves.
Control measures		
Work practices	NAU field safety training	
PPE	Closed toed shoes, gloves	

3.2. Chemical Hazards

The SAS Engineering team will use different chemicals when testing and analyzing the pile samples. Table B3-2 below shows chemicals that will be used during lab work.

Table B3-2 Chemical Hazards for Lab

Chemical Hazards in Lab				
Chemical Hazard	**Characteristics**	**State/Concentration**	**Exposure Potential During work**	**Control**
Sulfuric acid	solution	Liquid	Low	Use of masks, gloves, lab coats, safety glasses, use in fume hood
Salicylic acid	Solution	Liquid	Low	Use of masks, gloves, lab coats, safety glasses, use in fume hood
Sodium Thiosulfate	Solution	Liquid	Low	Use of masks, gloves, lab coats, safety glasses, use in fume hood
Buffer solution	Solution	Liquid	Low	Use of masks, gloves, lab coats, safety glasses, use in fume hood
Additional Control Measures				
Work Practices: Northern Arizona University chemical hygiene training, and Biohazard safety.				
PPE: Gloves, eyewear, closed toed shoes, proper lab clothing				

3.3. Chemical Hazards

According to the report that was provided by the client, there are no biological hazards.

4.0 Training Requirements

To make sure that SAS Engineering team is safe, each member of the team should have the following training certificates prior to the work: NAU Field Safety Training, Chemical Hygiene Training, and Biohazard training. SAS Engineering has completed these trainings.

5.0 Personal Protective Equipment

SAS Engineering team has all of the required PPE to be able to do their work. The required PPE are closed toe shoes, gloves.

6.0 Site Control and Operating Procedures

The Safety Officer, Scott Bearchell, will make sure that each member is following the sampling protocol. Since the samples will be taken from one pile at a time, the communication between each member will be easy if anyone needs help.

7.0 Decontamination Procedures

The decontamination procedure will be the same for equipment, and hands. It will be basically washing hands and equipment with water and soap.

7.1. Personal Decontamination

The personal decontamination is the first step that should be done after the sampling event. The first thing is removing all PPE and dispose them in the trash. Clean hands with soap and cold water to remove any contaminants.

7.2. Equipment Decontamination

All equipment will be rinsed with soap and water to prevent any contaminants on the surface of equipment, using wipers if needed in order to make sure that equipment is cleaned and rinsed carefully.

7.3. Waste Disposal

All waste will be disposed as per EPA and OSHA requirements. Some equipment that will be used could be decontaminated such as the sampling tools, but most of PPE will be disposed and placed in the trash.

8.0 Emergency Response Procedures

For any emergency situations that could be encountered during either lab or field work, 911 will be contacted if there is a serious injury, but if not, it could be by using the first aid and/or driving to the nearest hospital. The section below shows the nearest hospital location from the engineering building where all the lab work will be there. Also, this hospital is the closest hospital to the compost site where all the field work will be done in. Figure B8-1 shows the transportation map from NAU Labs to the closest hospital.

Closest Hospital to Lab- Flagstaff Medical Center

Phone: [(928) 779-3366](tel:9287793366)

Address: 3118, 1200 N Beaver St, Flagstaff, AZ 86001

Transportation Route: Take Beaver Street North from NAU Campus to Flagstaff Medical Center

Image:

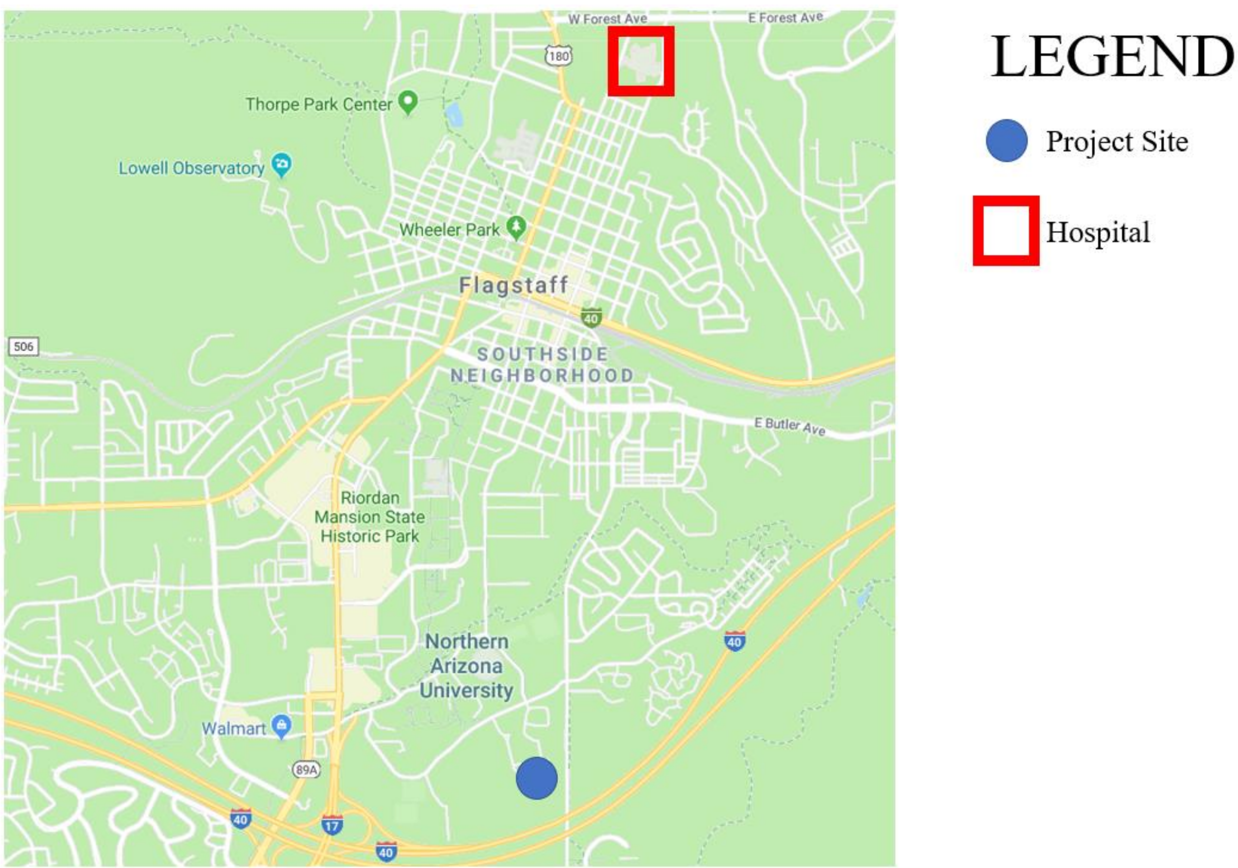


Figure B8-1 Map of Hospital

Table B8-1 below shows the emergency contact information for SAS engineering team members.

Table B8-1 Emergency Contact Information for SAS Team Members.

Team Member	**Emergency Contact Name**	**Emergency Contact Phone Number**	**Relationship to Team Member**
Sara Page	Colleen Page	520-271-4938	Mother
Scott Bearchell	Craig Bearchell	928-637-3609	Father
Abdul Almehmadi	Mohammed Fakkeh	213-841-5287	Friend

Appendix B: Sampling Event Information

Figure B.1 Pile 1

Figure B.2 Pile 1 Sampling

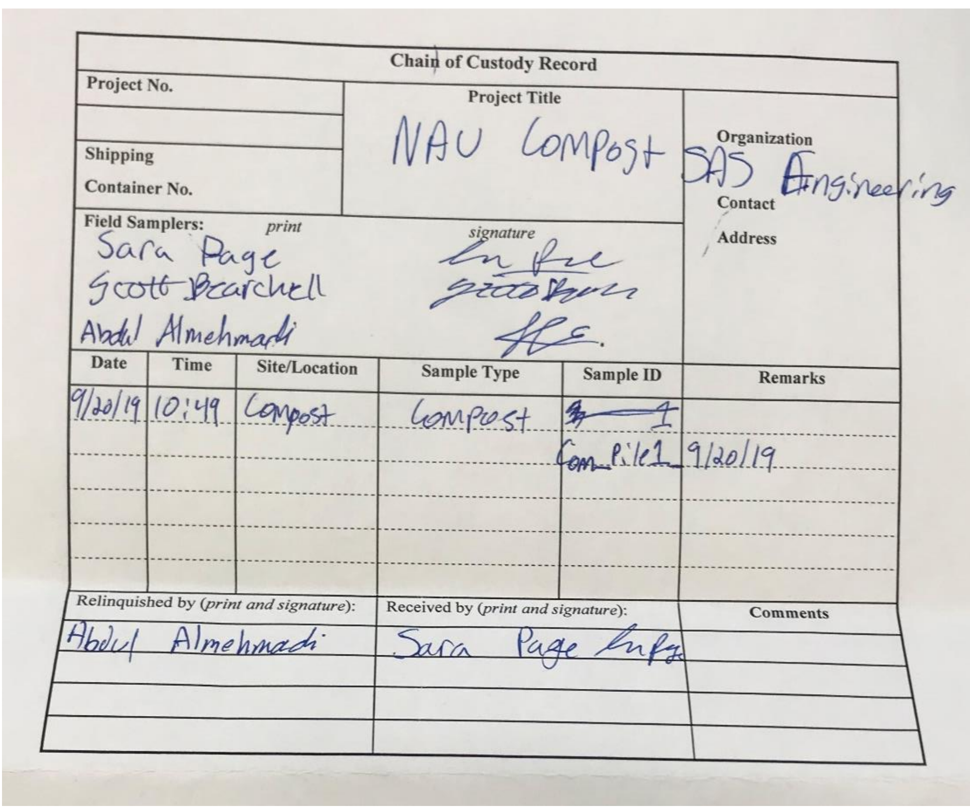
Figure B.3 Pile 2

Figure B.4 Pile 2 Sampling

Figure B.5 Pile 2 Auger Hole

Figure B.6 Pile 2 Sampling Auger

Figure B.7 Pile 3



Chain of Custody Record

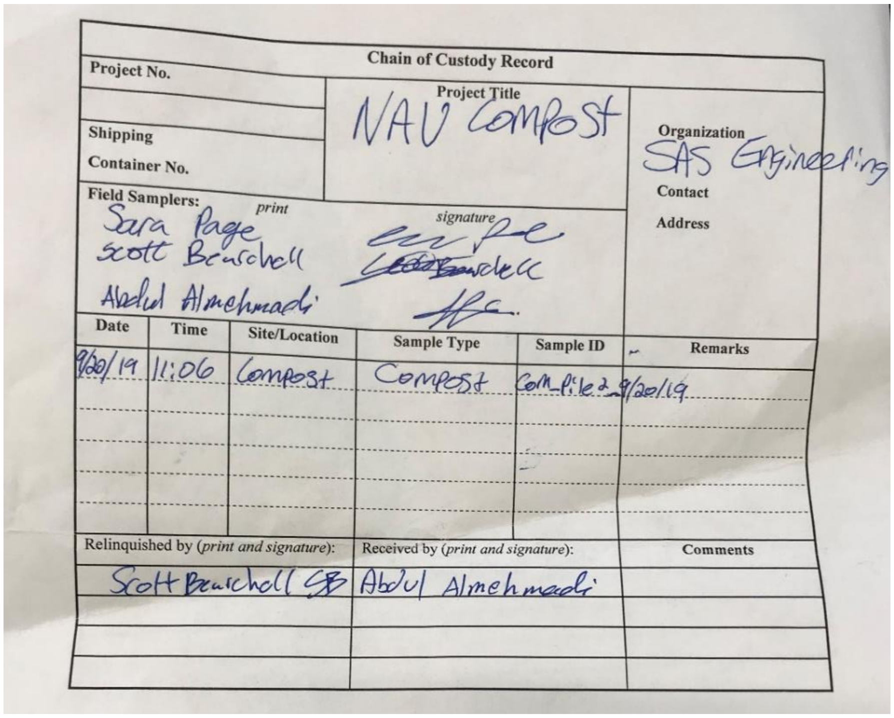
Project No.	Project Title	Organization
Shipping Container No.	NAU Compost	SAS Engineering
		Contact
		Address

Field Samplers: print	signature
Sara Page	[signature]
Scott Bearchell	[signature]
Abdul Almehmadi	[signature]

Date	Time	Site/Location	Sample Type	Sample ID	Remarks
9/20/19	10:49	Compost	Compost	~~3~~ 1	
				Com Pile1 9/20/19	

Relinquished by (*print and signature*):	Received by (*print and signature*):	Comments
Abdul Almehmadi	Sara Page [signature]	

Figure B.8 Chain of Custody Pile 1



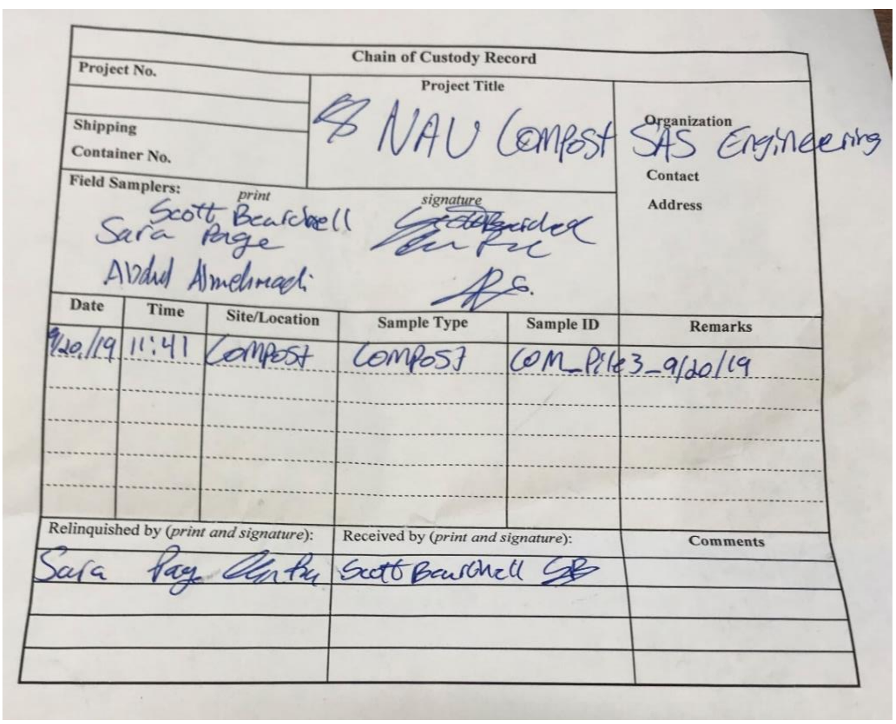
Chain of Custody Record

Project No.	Project Title: NAU Compost	Organization: SAS Engineering
Shipping Container No.		Contact
Field Samplers: (print) Sara Page, Scott Bearchell, Abdul Almehmadi	(signature)	Address

Date	Time	Site/Location	Sample Type	Sample ID	Remarks
9/20/19	11:06	Compost	Compost	Com_Pile2_9/20/19	

Relinquished by (print and signature):	Received by (print and signature):	Comments
Scott Bearchell SB	Abdul Almehmadi	

Figure B.9 Chain of Custody Pile 2



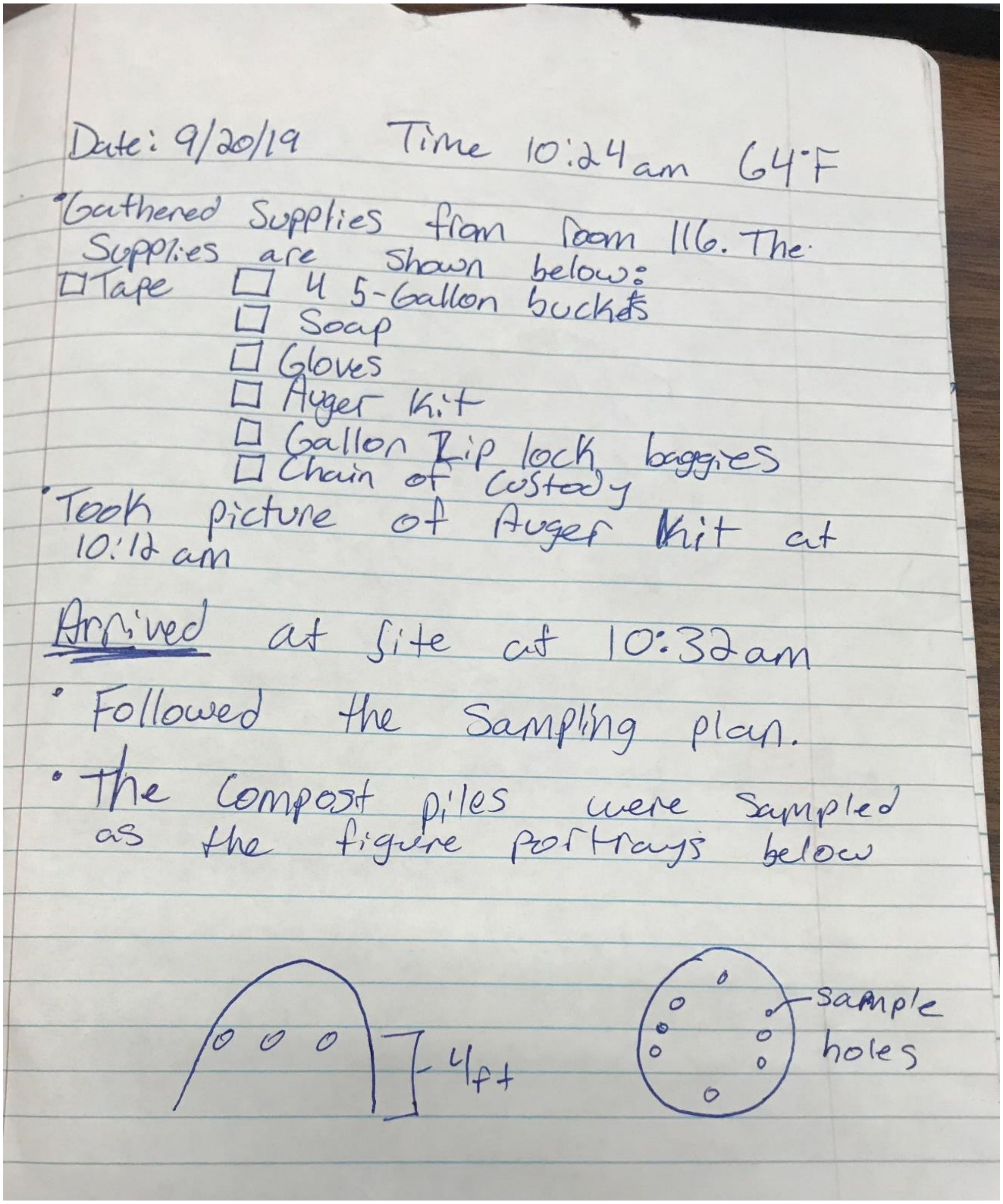
Chain of Custody Record

Project No.	Project Title: NAU Compost	Organization: SAS Engineering
Shipping Container No.		Contact
Field Samplers: (print) Scott Bearchell, Sara Page, Abdul Almehmadi	(signature)	Address

Date	Time	Site/Location	Sample Type	Sample ID	Remarks
9/20/19	11:41	Compost	Compost	COM_Pile3_9/20/19	

Relinquished by (print and signature):	Received by (print and signature):	Comments
Sara Page	Scott Bearchell SB	

Figure B.10 Chain of Custody Pile 3



Date: 9/20/19 Time 10:24 am 64°F

- Gathered Supplies from Room 116. The Supplies are shown below:

☐ Tape ☐ 4 5-Gallon buckets
☐ Soap
☐ Gloves
☐ Auger Kit
☐ Gallon Zip lock baggies
☐ Chain of Custody

- Took picture of Auger Kit at 10:12 am

Arrived at site at 10:32 am

- Followed the Sampling plan.
- The compost piles were sampled as the figure portrays below

Figure B.11 Log Book Page 1

Date 9/20/2019

- 1st Sample came from pile that was tested may 2nd.
- Sampling of the 1st pile: Started: 10:38am
  Finished: 10:49am
- 1st pile Sampler: Abdul
- Used Sara's steps for consistancy of pile auger locations. Each location was 5 steps away.
- Total spots of auger per pile are 8
- Abdul Relenquished custody to Sara.
- Sara bagged the sample at 10:54am

Second Sample:

- Sampler: Scott Time: 11:01 am
  Finished: 11:06 am
- Both piles look dark brown,
- felt soft & moist. Not compacted
- Bagger: Abdul

Third Sample: 8 steps around pile, 8 samples

- Sampler: Sara Time: Start: 11:29
  Finish: 11:40
- Bagger: Scott

Figure B.12 Log Book Page 2

Appendix C. Raw Testing Data

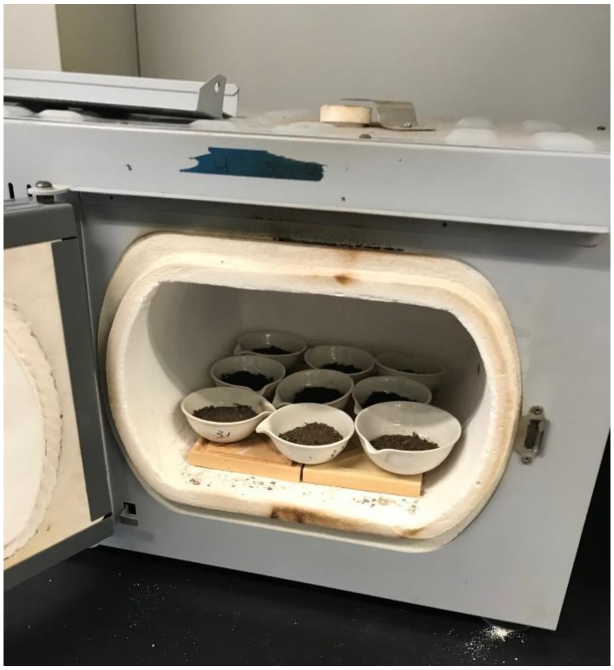
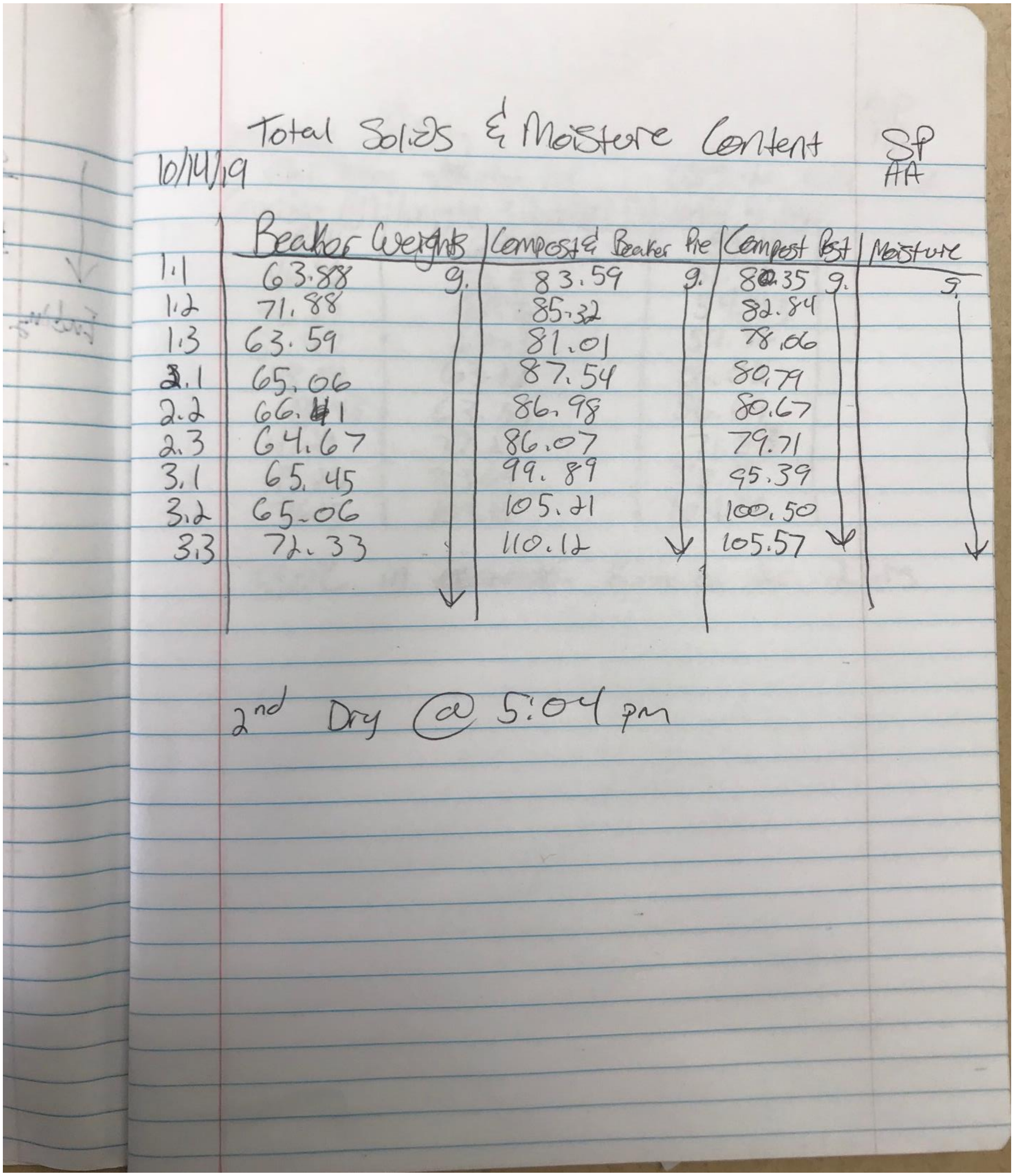


Figure C.1 Ash Analysis

Figure C.2 pH Analysis, Shaker Table

Figure C.3 pH Analysis

Figure C.4 XRF Preparation



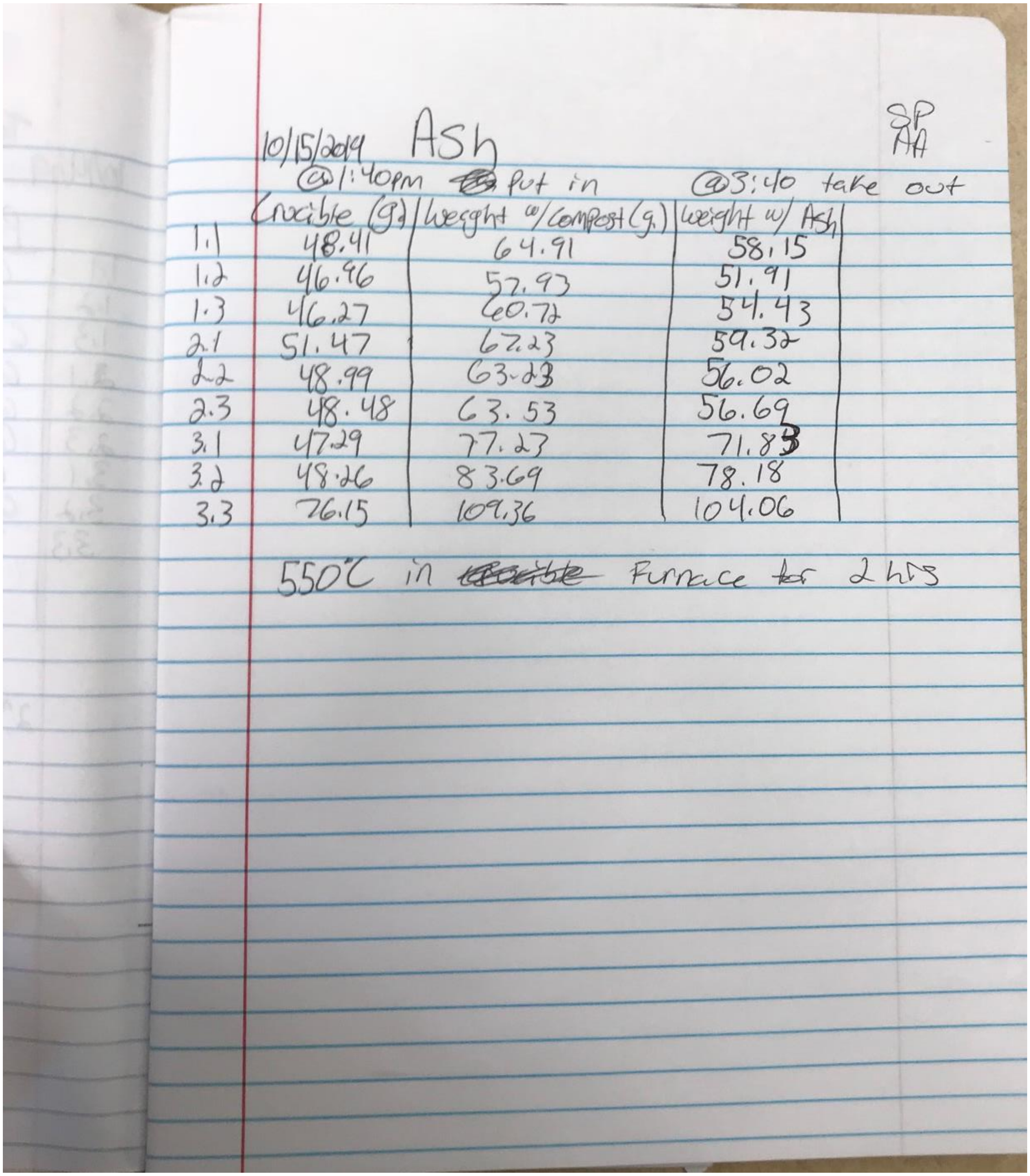
Total Solids & Moisture Content SP AA

10/14/19

	Beaker Weights g.	Compost & Beaker Pre g.	Compost Post g.	Moisture g.
1.1	63.88	83.59	80.35	
1.2	71.88	85.32	82.84	
1.3	63.59	81.01	78.06	
2.1	65.06	87.54	80.79	
2.2	66.41	86.98	80.67	
2.3	64.67	86.07	79.71	
3.1	65.45	99.89	95.39	
3.2	65.06	105.21	100.50	
3.3	72.33	110.12	105.57	

2nd Dry @ 5:04 pm

Figure C.5 Lab Notebook Moisture Content



10/15/2019 Ash

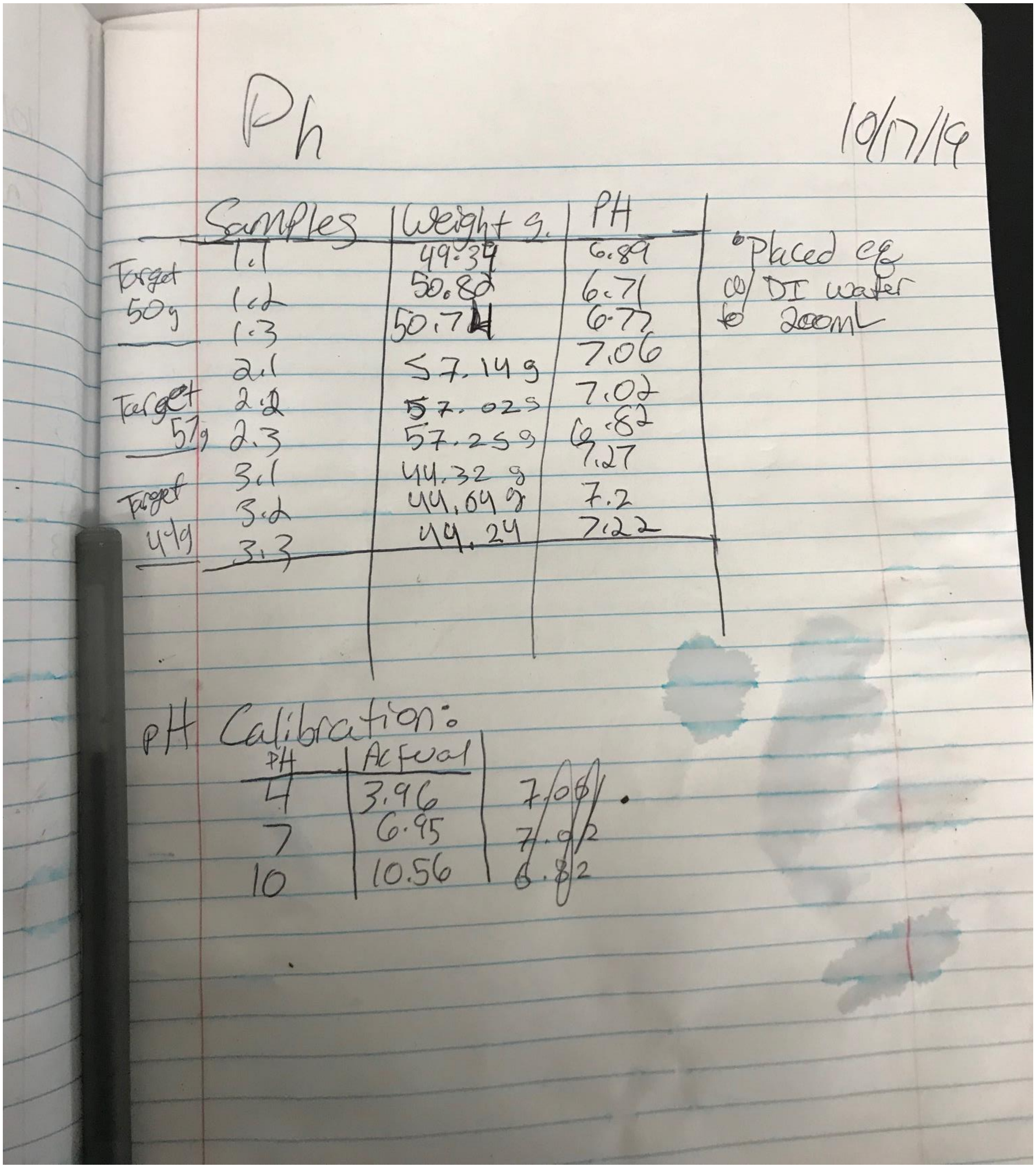
SP AA

@1:40pm ~~put~~ put in @3:40 take out

	Crucible (g)	Weight w/compost (g)	Weight w/ Ash
1.1	48.41	64.91	58.15
1.2	46.96	57.93	51.91
1.3	46.27	60.72	54.43
2.1	51.47	67.23	59.32
2.2	48.99	63.23	56.02
2.3	48.48	63.53	56.69
3.1	47.29	77.23	71.83
3.2	48.26	83.69	78.18
3.3	76.15	109.36	104.06

550°C in ~~crucible~~ Furnace for 2 hrs

Figure C.5 Lab Notebook Ash Content



Ph 10/17/19

	Samples	Weight g.	PH
Target 50g	1.1	49.34	6.89
	1.2	50.82	6.71
	1.3	50.74	6.77
Target 57g	2.1	57.14 g	7.06
	2.2	57.02 g	7.02
	2.3	57.25 g	6.82
Target 44g	3.1	44.32 g	7.27
	3.2	44.09 g	7.2
	3.3	44.24	7.22

• Placed eq w/ DI water to 200mL

pH Calibration:

pH	Actual	
4	3.96	~~7.08~~
7	6.95	~~7.02~~
10	10.56	~~6.82~~

Figure C.6 Lab Notebook pH