On-farm Demonstration of Energy Generation and Phosphorus Recycling as an Alternative to Land Application of Poultry Litter

Written by FPPC
for
Eastern Shore of Virginia Resource Conservation & Development Council

Executive Summary:

This project involved demonstrating two different thermal manure-to-energy technologies at two locations. One project was located on a poultry farm in Cheraw, South Carolina and the goal was to demonstrate the generation of grid connected electricity on a farm by using poultry litter as the fuel source. The second project was located on a turkey farm in Port Republic, Virginia and the goal was to demonstrate an alternate method of heating a poultry house using turkey litter as the fuel source. Both projects employed thermochemical conversion technologies that utilized poultry litter generated on their respective farms.

The South Carolina project was a re-boot of a manure-to-energy project previously initiated by Farm Pilot Project Coordination, Inc. (FPPC), the Chesterfield County Resource Conservation & Development Council (RC&D) and the State of South Carolina (SC) on the Marc Marsh farm in Cheraw, SC under a SC State Energy grant. The farm owner raises pullets, roosters, and layers on a highly bio-secure facility. Yearly litter production on the farm is approximately 1,200 tons. The original project consisted of an on-farm gasification system, a heat exchanger, and an organic Rankine Cycle (ORC) electrical generator designed to consume 100% of the farm's litter for energy generation. The original gasifier was designed for 300 lbs/hr throughput that would produce enough thermal energy for the ORC generate 25 KWe. The reason for the re-boot was that the throughput and energy conversion in the gasifier was less than anticipated, and limited electricity generation. The ORC system would only operate for 5 minutes then shutdown due to lack of thermal energy. Based on performance testing in SC, grant partners recognized the measured limitations of BGP 6-auger gasification conversion component. FPPC recommended that additional investment support for deployment of a larger 12-auger BGP gasifier to the SC farm and a new more efficient boiler that could handle particulate matter in the flue gas. A new 12-auger BGP gasifier and a new boiler were installed to increase the energy output to the ORC unit.

The new 12-auger gasifier was installed during the summer and fall of 2014. All the material handling components along with new controls were redesigned to match the new gasifier. A new boiler was installed to address the fouling of the heat exchanger's surfaces on the old heat exchanger. The system was commissioned and tested in November 2014. Prior to connection with the ORC, evaluation of the new gasifier indicated that the gasifier successfully produce the design heat output load of 1,000,000 Btu/hr. This target output to the ORC was enough thermal energy to generate approximately 25 KWe according to the original ORC specifications. However, evaluation of the gasifier in conjunction with the ORC indicated that the design specifications for the ORC did not account for greater heat demand when the ORC system was operated at 25 KWe, which is half of the ORC's designed maximum output. Hence, the ORC failed to generate electricity as anticipated.

At this time, the system in SC is not currently being operated by the farmer, since it cannot continuously generate electricity. While the project did prove that electricity can be generated on a farm and connected to the grid, a critical lesson learned is the importance of ensuring that all the components are designed to meet the inputs and outputs with each components efficiency's taken into account.

The second project located on a turkey farm in Port Republic, VA utilized a Global Refuel (a division of Wayne Combustion) litter fired furnace to provide an alternate source of heat to a brooding house. Typically poultry farms use propane-fired burners in the houses for heat. Propane prices have seen many fluctuations in the past decade and one way to mitigate the price fluctuations is to use an alternate source of heat. Propane also generates moisture from the combustion process and moisture has become a problem in modern poultry houses. The Global Refuel litter furnace uses the heat from combustion to heat air circulated through the poultry house. This hot air from the furnace has the potential to provide other benefits besides fuel savings. One possible benefit is increased bird health by increasing the air quality in the houses. During the colder seasons and even during the summer for the first week of the flocks, farmers have to manage the fan run time and propane usage. Fans are used to circulate and exchange the air inside of the houses. These fans pull in fresh outside air and help remove moisture in the houses. However, they also bring in cold outside air and thus remove heat from the houses. The propane-fired burners will compensate for the heat loss. A farmer has to compromise between running the fans and burner runtime. The more fan runtime the better the air quality, but the more fuel is consumed. The Global Refuel system could provide a continuous source of heat to the houses by using on farm generated litter, which is a very inexpensive fuel.

The Global Refuel (GR) system was installed beside the farmer's turkey brooding house in March 2013. The turkey brooding house is stocked with young turkeys (poults) and therefore needs heat throughout the year for every flock. In the winter the house requires heat continuously. . The farmer needed 1,000,000 MBtu/hr of heat input for the house. A previously installed biomass boiler provides 300,000-500,000 Btu/hr of heat through a radiant heater floor. The GR system was designed to provide an additional 500,000 Btu/hour.

FPPC worked with the Virginia Department of Environmental Quality to secure a Biomass Test Air Permit, which allowed the unit to operate for testing purposes only. This permit allows for additional data collection needed to support the final permitting decision process.

The GR unit was designed to provide heat to the poultry house using an air-to-air heat exchanger with hot air delivered to the poultry house with one supply duct located in the center of the house. The existing air circulation system in the house would then be used to distribute the heat throughout the rest of the house.

However, the GR system failed to operate as designed. The system had mechanical problems with the material handling equipment. This caused the system to shutdown numerous times through the evaluation period. The system would operate for several days without problems, and then shutdown due to errors.

While initial emissions testing showed the system might need an abatement system for particulate matter, later results from a 3rd party testing company showed the system need more emissions work than anticipated. Global Refuel spent over a year trying to find the correct abatement technology to control the particulate matter, but decided that continuing to pursue the market for this technology was not in their company's interest. They have stopped working on the system, but will continue to support the farmers remotely if needed.

This project has shown that the Global Refuel system's concept of burning poultry litter and heating the poultry house through hot air via a central duct work system can work. However the combustion system needs more development to overcome its weaknesses.

South Carolina Project

Introduction and Background

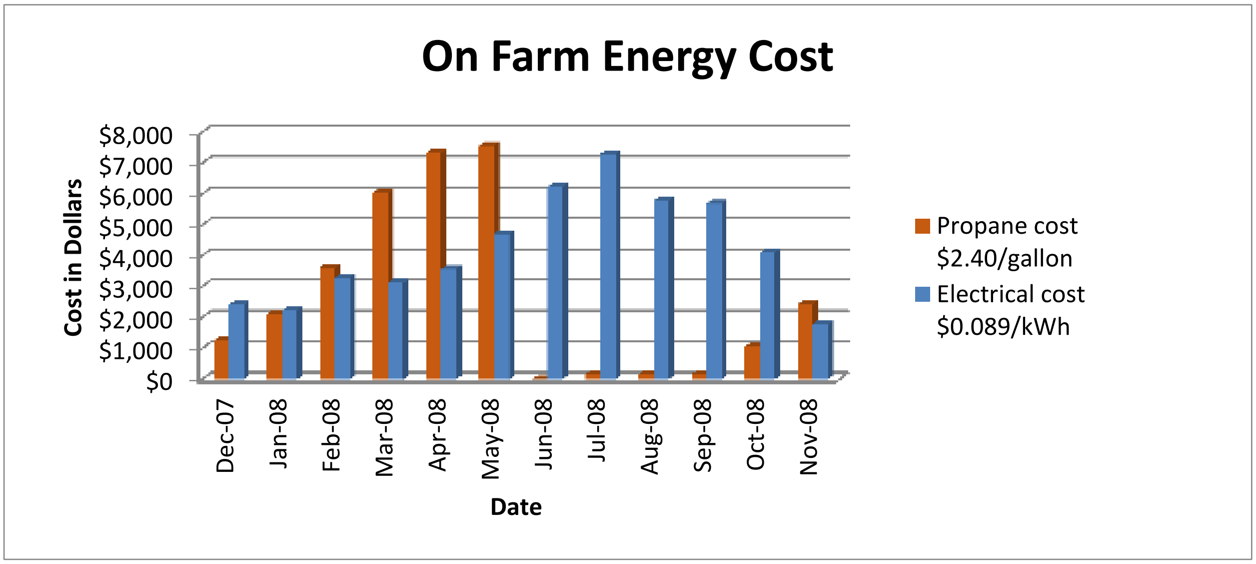
Project History

Since the project in South Carolina was a continuation of an existing project, the history of the original project will be provided so all the lessons learned from the entire project from start to finish is available.

The farm is a breeding poultry farm with 4 pullet houses, 4 rooster houses, and 4 hen houses that generate approximately 1,200 tons of poultry litter per year. A litter storage barn is located adjacent to the gasification system to provide easy access to the feedstock. Storing poultry litter is a normal operation for poultry farms and the buildings used for storage are approved for use by the NRCS.

From Figure 1, the use of propane and electricity both have peaks and valleys which correspond to the changing weather from hot to cool times of the year as well as when the houses are empty and when they are full. Electricity use in the summer increases because of large fans used to cool the poultry houses.

Figure 1



The proposed system was designed to provide a constant load of electrical power to the grid, thereby reducing the summer time peak demand and utility bills throughout the year.

Since the litter is collected once a year from the rooster and pullet houses and twice a year from the nest egg houses, covered storage was required to keep the litter dry. The amount of manure from each type of house varies with the nest egg houses producing 67% of the litter, the pullet houses producing 18%, and the rooster houses producing 15% of the litter (mass basis). It is well known that organic material can change with time and environment. The different litters were not mixed except for some crossover in the litter storage shed. These changes affected the energy content of the litter and this will be evaluated so the conditions of the litter feedstock going into the gasifier will be consistent and introduced at maximum efficiency for the system.

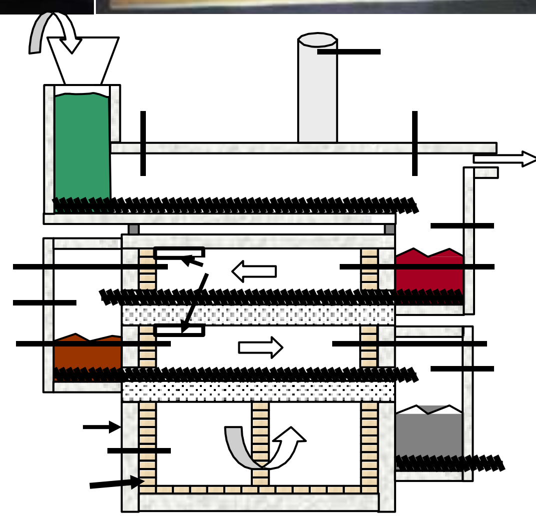
The choice of a BGP gasifier over other units was determined as a viable option from research and development efforts prior to the SC installation. BGP had worked in different areas around the world to develop their technology for animal disposal, hospital waste disposal, and energy generation with manure as a fuel. BGP introduced a batch unit located at North Carolina State University (NCSU) that could use animal manure as a fuel. This gasifier was set up by BGP and the equipment designer, David Brookes. Through testing of different waste streams (specifically pig manure), it was discovered that pig manure had enough energy to sustain the process if it was a semi-continuous or continuous system. The next unit was a small test unit with augers to continuously feed a waste stream through the unit for gasification without additional fossil fuels. At the same time, batch units were being developed for commercialization for on farm deployment to handle animal mortality. Informed by this research, BGP designed and successfully deployed a large mobile unit for mortality destruction.

The following photos depict of each of these systems below along with a simple diagram for the small batch and NCSU continuous systems. In all cases, the BGP gasifier was seen as a simple system that had been successfully deployed; however, the only fully successful deployment of a commercial version of the gasifier was and still is the small batch systems for animal disposal.

Left: BGP continuous research unit at NCSU. Right: BGP batch gasifier

System Design

For over twenty years, it was believed that manure could be gasified and the resulting syngas be used to produce liquid fuels or directly generate electricity in modified generators. Several of these gasifiers used traditional style gasifiers with fluidized beds updraft, or down-draft systems. These were proven technologies for traditional biomass and other products such as municipal solid waste and coal. Other companies worked with entrained flow systems and other non- conventional gasifiers. The problems encountered by these systems were primarily related to material handling, and the manure causing additional problems such as tars and other contaminates in the syngas. These contaminates could quickly destroy any engine unless the syngas was cleaned. On the small farm-level scale, the syngas contaminates were viewed as a costly problem. Research with biomass gasification can directly relate to manures; however manures tend to offer more challenges than woody biomass. For this reason most recent manure thermo-chemical technologies do not use traditional gasification methods or they directly combust the syngas.



Top left: mobile gasifier Top right: flow diagram of gases

Bottom: NCSU continuous gasifier schematic

The BGP gasifier was chosen as the vendor for the SC Marc Marsh project. They had a gasifier close to the commercial size needed to consume the farm's litter for the SC project. A throughput test and troubleshooting test were conducted to make sure the correctly- sized BGP gasifier needed for the farm could be specified. The prototype gasifier was located at Harsh International's fabrication shops in Eaton, CO which was running feedlot manure.

To achieve electrical generation using a gasifier fueled with poultry litter, FPPC considered two ways of generating electricity using combustion: 1) combust a fuel directly in a prime mover (reciprocating engine, gas turbine, etc.) or 2) indirectly by combusting a fuel and using a working fluid such as steam, or a refrigerant. Other possible pathways were not considered because they are not commercially available. These include the Stirling engine and the external Brayton cycle. On a small scale under 100kwe, it is more efficient to use a direct method such as a reciprocating engine (RICE) or a gas turbine (micro turbine). However, they both have challenges of their own.

The Electratherm ORC was the only choice at the time for electrical generation units. Previously, Infinity Turbine offered a possible unit, but the appropriately-sized model discontinued before the installation timeline. Both systems offered only one way to transfer heat to their system and that was with hot water. FPPC asked about directly heating the refrigerant. Both companies use hot water because oil in the refrigerant can degrade at higher temperatures. Also, direct heating would raise safety concerns since the pressure of the refrigerant could rise very quickly if overheated. Overall, the ORC systems are designed to use low-grade heat or waste heat.

FPPC was responsible for designing the system by combining somewhat off-the-shelf components: feeding mechanism, gasifier, ash handling system, heat exchanger, hot water plumbing, and the ORC. The original goal was to build a CHP (combined heat and power) system by generating electricity first and using the waste heat to heat the farm's poultry houses. Due to the high bio-security needs of the farm, and physical location of the gasifier site relative to the poultry houses, FPPC along with the farm partner decided not to proceed with heating the houses.

System Design and Operation Prior to the Start of this Project:

Assuming 24/7/350 operation (time taken out for maintenance and downtime) the feed rate was determined by dividing the total amount of litter on the farm by 365 and 24 to get an hourly feedrate (1200 tpy = 273lbs/hr). Since the amount of downtime was unknown a feed rate of 300lbs/hr +/- 50 was chosen. Each component was specified based on this feed rate criteria.

The gasifier was sized according to that feed rate with an assumed energy content of the litter. The energy output of the gasifier was specified within a certain range by the designer, David Brookes, who provided anticipated flow rates and temperatures. We specified the heat exchanger to match the output of the gasifier, considering flow rate, temperature, type of gases, water temperatures, and pressure drop across for the air side. Unfortunately, we could not size the ORC system as desired for 20-30 kwe generation. Electratherm offered one size (a larger 50 kwe unit), and they were not willing to deliver a specially-sized unit. As designed, this system would work assuming each component worked as specified. The 6-auger gasifier operated at about 1/3 to ½ its specified feed rate and failed to completely gasify the feedstock, thus failing to recover all the available energy.

Prior Performance Results for the BGP Gasifier 6-auger unit:

The 6-auger gasifier was the first major component in the system and was responsible for generating or extracting the energy from the chicken litter and delivering energy in the form of hot combustion gases to the HE. It was supposed to operate at a feedrate of 250-350 lbs/hr of as- is chicken litter. The 6-auger gasifier was only able to extract from the litter about 600,000 to 700,000 Btu/hr at its best without destroying the augers in one week run while keeping the primary chamber (PC) below 1600F. Below is the data collected in March 2012. This resulted in 624,670 Btu/hr being extracted from the feedstock.

Here is the energy balance:
Gasifier:

225lbs/hr * 0.23%M = 173 lbs/hr (dry feedstock)

173lbs/hr * 7,350 Btu/lb = 1,271,550 Btu/hr into the gasifier
173lbs/hr * 0.10 = 17.3 lbs/hr of ash

If carbon is 72% than the lbs/hr of "as is" ash would be 62.2 lbs/hr

62.2 lbs/hr * 10,400 Btu/hr = 646,880 Btu/hr left in the ash
Heat exchanger:

Water flow rate: 65 gpm
Water delta T: 15 F

Energy out in water: 65gpm*15F*500 = 487,500 Btu/hr

Energy extracted from manure = 624,700 Btu/lb
Efficiency of gasifier and HE = 487,500/624,700 = 78%

The 6-auger gasifier presented a challenge. It would produce a carbon rich ash that maintained a significant portion of the energy in the feedstock but the augers would not be damaged or we could extract more energy from the ash, but at the expense of damaging the augers.

The gasifier has three areas where it can lose energy: 1.) through the steel shell 2.) through the heat capacity of the ash (no carbon) 3.) the carbon left in the ash. BGP expected the efficiency of the gasifier to be 80%. To calculate the energy left in the mineral portion of the ash, the heat capacity of the ash was used to calculate that loss. If the mineral ash content of chicken litter was assumed to be 10% by weight (measured on Marc's farm) on a dry matter basis and the specific heat for the mineral ash is the same as coal fly ash (0.191 Btu/lb F) than at 300 lbs/hr feedrate at 20% moisture and the ash exiting at 1600 F than the Btu's lost with the ash would be 300*0.8*0.1*1600*0.191 = 7,334.4 Btu/hr. This assumes a 100% reduction in Carbon in the ash which is usually not the case even when the gasifier is running perfectly. Most of the heat generated by the hot ash is due to the residual carbon that is left in the ash that is still reacting with available Oxygen in the atmosphere. When there is abundant carbon in the ash, as there is in with the South Carolina project, the ash can have between 50-75% carbon by dry weight and can give off significant heat. The amount of carbon in the ash under optimal gasification should be by weight less than 15% and ideally around 5% or less by dry weight.

The gasifier was not extracting sufficient energy from the litter. Even at lower feed rates it was not performing. To extract the energy from the litter there are basic requirements: 1) external heat supply for start-up 2) oxygen, and 3) time. The external heat supply is used to start the thermochemical process; it dries the litter, drives volatiles from the litter, and helps the carbon cycle sustain itself. The oxygen helps break the strongly bonded carbon and speeds the process. Time is related to parameters such as feed rate, heat transfer rate in to the poultry litter, and rate of volatilization of all the organic molecules. Any one of these requirements and rates can affect the process.

Heat transfer: The heat under the hearth tile was measured and was sufficient to drive the reaction, but the rate of heat transfer through the hearth tile and into the litter was not known. It was observed that the litter piles up in a manner that is not conducive to rapid heat transfer. The installed hopper modifications were an effort to allow better control of the amount of litter entering into the primary chamber at a given time so that the heat transfer could happen more rapidly.

Volatilization: The litter had good volatilization, but it doesn't seem to occur fast enough. The carbon cycle was just starting when the ash was conveyed out of the primary chamber and droped into the ash box. It was unclear if this was due to the material not being conveyed correctly, its bulky character for the size chamber, the length of the chamber, or if there was insufficient heat transfer (above).

Oxygen: Typically the carbon cycle was the last phase of the gasification process and this was the time in which outside air was introduced into the primary chamber to react with the carbon bonds to help break them and allow the gasifier to fully extract all the energy from the manure. Typically this involved a good amount of flame which would die down considerably to almost no flame before the ash exited the primary chamber. A considerable amount of flame was observed just before the exit of the primary chamber which suggests that the process was not complete. If more air was added at this stage the temperature reached levels that damaged the auger (observed in a 3-day test run).

Problems and Solutions to the previous system

This project was focused on solving the problems from the first project. A complete engineering review of the previous system was undertaken and below were the results. These results were used to determine which changes were to be implemented to give the best chance of running the ORC 100% of the time. The original 6-auger unit did gasify poultry litter while it also generated ash and thermal energy. However it did not meet the design specifications of 300 lbs/hr and it did not produce enough energy reliably for the ORC to work continuous.

System Components

Feed Hopper: The feed hopper was the first part of the gasifier and it seemed to be work fine on the original 6-auger unit. The 6-auger unit relied on the main augers to pull material from the hopper at a rate governed by the speed and size of the auger. This concept would work if the residence time for the feed rate was known and designed into the gasifier with auger size and length. The 6-auger gasifier's feed rate and residence time were tied together and inversely proportional. The higher the feed rate the lower the residence time. The federate and residence will need to be separated with the 12-auger gasifier.

Main Augers: The augers in the primary chamber (PC) of the gasifier were the only moving parts inside the gasifier. The simplicity of this design was appealing, however, the type of metal, 304L SS (a low carbon 304 SS), used for the 6-auger gasifier was found not to be adequate under the desired operating conditions. This metal selection was made on the basis that it could handle temperatures of 1600 F, was readily available, and was a relatively cheap alloy. It was the material used in both the NCSU continuous gasifier and the small Colorado test unit. In both these test units the augers have maintained integrity and have not seen damage due to high temperatures. At first it was felt that the temperatures in the PC were controlled to be below 1600 F and it was not understood why the augers were failing under this temperature limit. It was considered a chemical attack; however, subsequent temperature measurements by looking at the material around the auger at the ash end of the primary chamber were higher than expected. Auger temperatures at the hot end ranged from 1500 F to 1800F which exceeded the limits of 304L SS. Research in the area of high temperature metals was reviewed and it was the belief that carbide precipitation was taking place. At higher temperatures chromium (which gives 304 SS its protection) attaches to the carbon in the steel and leaves the steel without the necessary chromium to provide protection. A simple test using a sample piece of 304L SS and 309 SS in a muffle furnace at 1600 F showed that 304 started showing a little bit of scaling and flaking but very small amounts. When the temperature was raised to 1800 the 304 had more substantial flaking and the 309 had no visible problems. These results mirrored what was seen with the augers. If the temperature can be kept to a low enough temperature than 304L SS would work, but if the temperatures exceed 1550 F than a better grade alloy such as 309, 310, or 330 is needed.

Top: damaged auger in 6-auger gasifier Bottom: 309 vs 304 muffle furnace test

It was not clear as to why this was not seen on the augers in the NCSU machine or the small CO test unit. The SC unit ran longer and the machine was fully heat soaked while the NCSU and CO units did not had long-term runs where the augers had possibly reached the higher temperatures. Another possibility was the high temperatures in the SC unit were due to the primary chamber being undersized and too much energy was present in a confined area, causing excessively high temperatures.

Another concern with the original auger design was their orientation. All the augers were right handed augers and all turned the same direction in a shallow trough and tended to push material towards one side of the PC. If the PC was flooded with feedstock, then the material did not have much of a chance to move from side to side because it had no place to go. However with a decreased feed rate, the litter would move from one side to the other as it traveled from the hopper to the ash box. At NCSU, when this phenomenon was observed, to improve mixing, a left handed auger was installed to push the material back.

Primary Chamber: The PC is where the chicken litter was gasified. The six main augers conveyed the fresh litter from one end of the gasifier to the other and during this time, heat was transferred from the hearth plate to the litter producing a syngas that was then drafted into the secondary chamber (SC). Each auger was identical with a 6" OD, a 2.5" schedule 80 pipe, and a 6" standard pitch. Each auger was constructed from 304L SS (a low carbon 304 alloy).

One idea was the PC was too small to be able to gasify 300 lbs/hr of chicken litter and more length, more depth (more augers) or more height in the PC ceiling was needed. All continuous feed BGP gasifiers have 6" OD augers, but the residence time varied due to length of the augers. Below is a chart of BGP continuous gasifiers and their auger length and lbs/hr and lbs/auger. A significant difference found was the lbs/auger which was high in the SC unit.

Unit location	# of augers	lbs/hr	lbs/auger	PC length ft
South Carolina	6	300	50	10
Colorado	4	125	32	8
NC State	3	90	30	13

Secondary Chamber: The SC was where the syngas was oxidized (combusted). When the syngases first entered into the secondary chamber, they were ignited and formed a flame front that carried through the secondary chamber and created the energy needed to heat the hearth tiles and to continue the thermochemical process. Only a small amount of heat was needed to continue the reaction while the rest of the energy traveled up the stack and into the Cain heat exchanger (CHE). This chamber was designed for a low velocity flow so that PM would not carried up the stack.

There were two problems with the secondary chamber. The first problem was with the hearth tiles cracking. Of the four tiles, the two on the burner side had major cracks running completely through them. These two tiles were repaired by placing another brick pier under the cracked area to give it more support. It was unclear as to why the tiles cracked but it was theorized this was a problem with heat and flame temperature. The South Carolina unit's propane burner was configured for an on/off mode with the controlling t/c placed before the exit. The burner was initially set at approximately 600,000 Btu/hr (burner's max is 1.2MBtu/hr) and mounted at a 10 degree offset angle. The burner was remounted to fire straight down. The combination of the offset firing angle with a Btu output that was too high and the controlling t/c placed too far away from the burner caused the cracking in the hearth tile by allowing the burner's flame to touch the hearth and have too high a temperature on the hearth tile. Note that the hearth was supposed to handle 3,000 F. When the gasifier was running on just litter with the outlet temperature at 1800 F, the temperature under the burner (near the first hearth tile) was approximately 1900 – 2000 F. However, when the propane burner was firing, higher temperatures in the range of up to 2300 – 2400 F were a result and the propane burner flame was more concentrated. The solution for the 12 –auger was to install a t/c closer to the propane burner that controled the burner using a modulating valve with a second t/c near the exit of the gasifier that controlled the system's temperature. An additional support pier was installed under the 12-auger's first hearth tile to provide additional support.

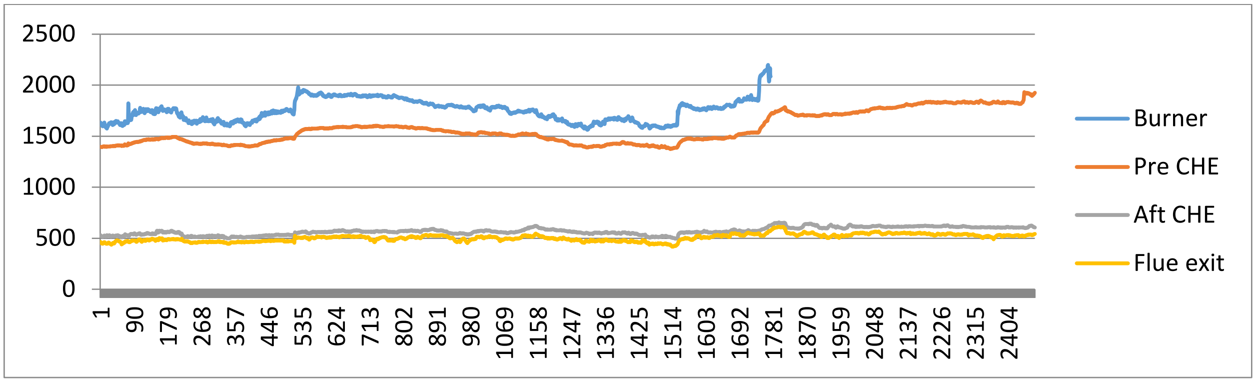
An additional concern was the burner box. When the 6-auger gasifier first arrived, the burner box was installed with no additional blowers. In this case the burner was expected to provide 200 scfm of air and the primary chamber was to provide 300 scfm of air. We also saw that insulation on the burner box was inadequate. The 12-auger unit had mounts placed for additional blowers and the box was insulated with blanket insulation.

Ash Box: The 6-auger gasifier's original ash box was not insulated when it arrived in South Carolina, but it was insulated before running the machine. The 6-auger's ash box was insulated many times because it was not properly insulated the first time. It was difficult to retrofit insulation in the field because the auger shafts go through the ash box making it difficult to work on. The ash box on the 12-auger unit was insulated before it is shipped.

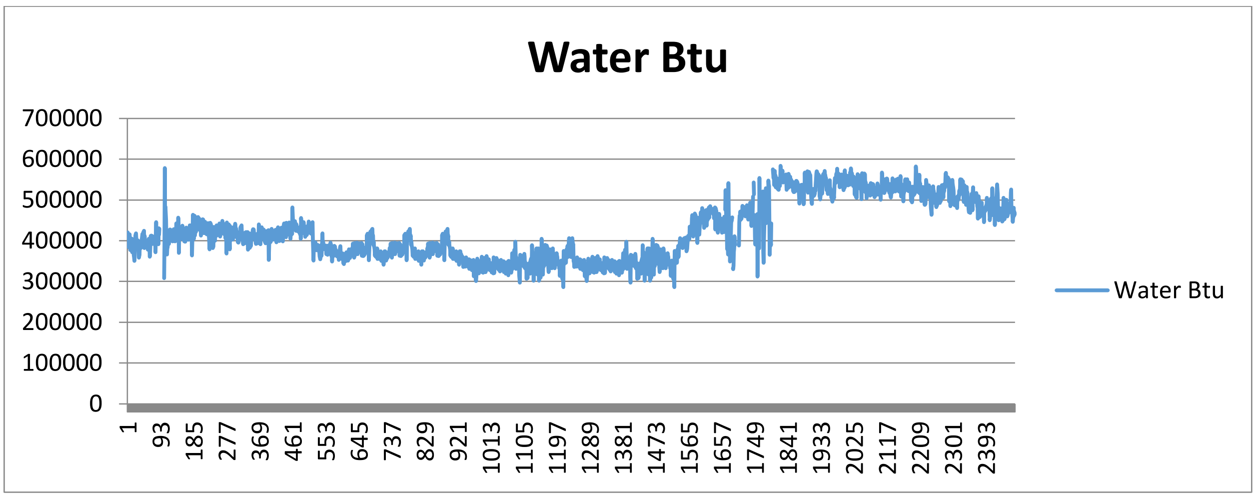
Cain Heat Exchanger (CHE): The CHE was not properly specified due to incorrect flue gas flow information given to FPPC. The second problem was with particulate matter fouling the heating transfer surface. The CHE was not specified with a soot blower or any way of cleaning the heat exchange surface while the unit was operating. All solid fuels generate PM and the boiler industry has figured out how to keep their boilers clean and operating efficiently. Other companies that have successfully demonstrated the ability to combust biomass fuels and generate hot water have used more traditional heat exchangers that are off the shelf boilers that have soot blowers to remove the particulate matter from the heat exchanger surfaces.

Electratherm ORC: We were assured by the company that we could run their system at lower outputs given the amount of energy we could supply; 1,000,000 Btu/hr. No changes were planned for the ORC unit.

Graph 1: temperatures of the gases in the gasifier and the CHE.



Graph 2: Calculated Btu going into the ORC from the CHE



Graph 2 is a calculation of the Btu/hr from the 60-auger system going to the Electratherm from the CHE in the form of hot water. The Btu/hr was fairly consistent and then we fired the burner to get more energy. After we fired the burner for a couple of hours, we turned off the burner and the temperature of the gasifier maintained the 1800 F to the CHE for the rest of the run time of over 12 hours. This data is from a Tuesday till Thursday.

These are the temperatures measured in the secondary chamber in the 6-auger gasifier. The temperatures are fairly constant and stable so the gasifier is working but it was not able to process the 300 lbs/hr needed. It was also not recovering all the energy from the manure and putting out a clean ash when operated at higher feedrates.

Ash handling: The ash was conveyed out of the gasifier with an auger. From there, the original ash system comprised of a 30' 9" auger at about a 30-degree angle. The augers were in a standard "U" trough. It was conveyed in a large metal container. The metal container was part of a dump trailer system. The dump trailer worked well, but it is a bit cumbersome to operate especially by only one person. A different, easier to use system was needed for the redesigned system.

Summary of the original 6-auger unit

Even though the 6-auger gasifier in combination with the CHE and the ORC did produce grid connected electricity, the system did not do so continuously. The 6-auger was severely underperforming which resulted in the system not sustaining electricity generation. The BGP gasifier's design was sound in principle, but it needed engineering and modifications to realize its potential. The Cain heat exchanger seemed to be working, but it was not equipped to handle particulate matter and was not working up to its potential. The ORC worked, but again, the match of components depended on full performance from each of the major components and the entire system could benefit from engineering review of component compatibility.

4.) Use the 6-auger machine to produce biochar. This option would involve minor modification to the existing gasifier to make it more robust (such as replacing the augers with a higher grade alloy).

Current South Carolina Project

All the knowledge and lessons learned were taken from previous experience in South Carolina and reviewed to find the best path forward. The decision was made to utilize a 12-auger BGP gasifier that was already partially built and install a new heat exchanger (standard boiler) to replace the CHE. Some modifications were made to the 12-auger gasifier to improve performance. Below were the modifications made to the 12-auger gasifier.

1.) **Hopper:** Harsh increased the height of the existing hoppers 12-18" and then mounted a 9" transverse auger to the hoppers. The auger and trough was mild steel with standard flighting and pitch. The last 12" of flight (opposite end of the inlet to the transverse had reverse flighting. This transverse hopper was removable. It had a single inlet that was feed by the current feed auger in SC. A removable lid will also be included for ease of inspection

2.) **Hopper shaft seal:** The feed hopper was modified so the shaft exit point was square and not angled. This helped seal around the shaft to prevent excessive dust and rogue air from entering the PC.

3.) **Hopper stir mechanism:** The 6 auger gasifier's stirring mechanism worked very well, however the gear motor was underpowered. A new gearbox that has slower RPM's and more torque, but not more HP was installed.

4.) **Alternating augers:** To better spread the litter across the PC so that it did not pile up and create problems the use of left and right hand augers were used. The unit had 12 right hand augers currently before modifications. Six left hand augers were installed by Harsh with alternating design of L-R-L-R, etc. The augers were made from the current metal of 304 SS.

5.) **Bypass flue stack:** Harsh designed a good method for bypassing the flue stack gases. This method was used for the SC project instead of having all the flue gases going through the heat exchanger all the time. This required the gasifier's exit to be modified where the flue gases come out the back of the unit instead of the top.

6.) **Feedrate:** An adjustable scalloped restrictor plate in the hopper was installed to control the feedrate. This restrictor plate was manually controlled by using a wrench to lower or raise it.

7.) **Auger shafts:** The main auger shafts on both ends were keyed so air can could be used to pull heat away from the augers.

8.) **Ash box:** The ash was originally setup to have two different exit points. This was modified so all the ash was conveyed through one exit. This entailed changing the auger to either left or right where it did comprise of both. The connection between the ash boxes used a round tube instead of a trough so rogue air was restricted and the temperature could be controlled in the PC. The exit trough was changed to a round tube to again restrict air from entering through the ash box.

9.) **Support pier:** A support pier was installed under the first hearth tile. This was the same spot where the SC support pier was added for the hearth tile repair.

10.) **Ash box seals:** A better type of shaft seal was used instead of insulation to seal around the shafts as they exit the ash box. The more it was sealed, the easier it was to control rogue air from entering the PC. The ash box was insulated from the factory by using appropriate insulation materials

11.) **Burner box insulation:** A new burner box was built that was at least 12" taller to allow more room for the flame from the burner and it used blanket insulation instead of cast ceramic insulation.

Installation of the new 12-auger gasifier and the new boiler

All the old equipment was removed from under the 40’ x 40’ shed. The only remaining equipment was the ORC system. Everything was relocated and moved including gas lines, controls, electrical lines, and plumbing because of the new gasifier’s size and the connection to the new boiler.

Old system

Arrival of new system of new system on truck

New system ready for inspection before installation

Top: Gasifier Installation Bottom: new boiler installation

Testing

The first test fire was conducted in November 2014. The test fire was only with the gasifier. The boiler was not completely connected to the gasifier and was not plumbed to the ORC. One of the modifications was to install a 100% bypass stack. After the flue gases left the gasifier, a diverter plate would divert the hot gases to the bypass flue stack which vented to the atmosphere or to the boiler. This was done not only for testing purposes but also for safety. This equipment in normal conditions would not have an operator at all times. Instead someone from the farm would check on the unit a few times a day along with filling up the hopper and emptying the ash bin when needed. Unlike most combustion systems that can ramp up and down quickly, this system acts like a large thermal flywheel that stores energy in its refractory insulation. This helps maintains the system temperature when the feedstock varies, but it also can damage the boiler during a malfunction since it will continue to deliver heat to the boiler several hours after the fuel has been shut off to the system.

The gasifier was first heated up with only propane for 3 days to finish curing and drying out the refractory. The system was slowly heated up to 1,000 F over a 36 hour time period, then slowly cooled down over the next 24 hours. The first test fire with litter followed the next week. The federate was kept low to allow observation of the system to try and find any problems before the system was pushed to its typical operating limits. The federate was kept to about 100 lbs/hr. Below is a picture of the PC.

Primary Chamber with feedstock

The first picture was approximately the middle of the PC. The second picture was about ¾ of the length of the PC, closer to the ash end. This was the hottest part of the PC. During this test run, the PC temperatures never exceeded 1400 F even when air was added to the PC. The litter was spread evenly across the entire chamber, something that did not happen in the 6-auger unit. The litter also was below the auger pipe as seen the second picture. In the 6-auger unit, litter was usually covering the auger which was believed to help cause the overheating because the material was exothermic at this stage and it also acted as insulation and trapped heat around the auger.

The next test was after the boiler was installed and all the plumbing was completed so that the entire system could be tested. The system was started and everything slowly brought up to temperature which took 2 days. On the third day, the hot water was diverted to the ORC. After several failed attempts to start the ORC, the water was diverted away from the ORC and Electratherm was contacted for troubleshooting. It was discovered a solenoid valve that is a safety bypass valve for the refrigerant had a bad seal. The replacement valve was replaced 4 weeks later. During this test, the gasifier produced 800,000 Btu/hr output of the boiler. Even though this was not the target output, the federate was kept at just over 200 lbs/hr until the ORC was operational.

After the valve was replaced, the system was restarted. The system was up to temperature and the ORC was ready to turn on in 48 hours after the gasifier was started. The ORC still would not operate. After working with Electratherm, it was determined there were a two problems. The refrigerant level indicator in the overflow tank needed to be reset. The second problem was the contactor to the grid had a bad connection not allowing the generator to connect to the grid. Both were fixed and the ORC would operate. The gasifier's federate was set to 250 lbs/hr which provided 1,000,000 Btu/hr output of the boiler. Based on the efficiency provided by the Electratherm, the electrical gross output should have been 23.4 KWe output. The ORC would start out at above 30 KWe due to its algorithm that operates the system. The ORC didn't measure the amount of energy going into the system via usual methods such as temperature and water flow rates. Instead it used ambient temperature and the hot water inlet temperature to calculate how much electricity the generator should be able to generate. This presented a problem when the ORC is not provided the amount of energy close to its maximum input. After discussing the issues with Electratherm, they offered some suggestions on how to manipulate the system in order to run at a lower KWe output. After several attempts to keep the ORC running continuously, system was shut down to allow everything to cool down in a controlled manor.

Data was gathered and sent to Electratherm to see if there was anything that could be done to continuously run the ORC with the amount of energy the gasifier could generate. It was discovered that the ORC's efficiency would steadily decline when not operating at the maximum output. The efficiency at the conditions that were used to run the system were in the 4% range. At 4% efficiency and 1,000,000 Btu/hr input to the ORC, the expected gross KWe was around 11.7 KWe. Electratherm again offered some suggestions to manipulate the controls so the system would run at this lower output the entire time the ORC was running. Unfortunately, the project was over at this time and this was the final attempted run for the system.

After the entire system was shutdown, a thorough inspection of the entire system was completed. It was discovered that there was some damage to the last three feet of the main augers in the gasifier due to excessive temperatures. During the last run, the temperatures in the PC near the ash of the chamber were in excess of 1600 F during the last 24 hours of operation. While this temperature range was known to cause damage, the focus at the time was to operate the ORC and keep it running.

Emissions

The emissions were not tested using a 3rd party company as originally planned. The emissions were checked periodically using a portable electronic emissions monitor. The monitor could check Oxygen, Carbon Monoxide, and NOx. The concentration of CO were always under 50 ppm while the NOx ranged from 50 to 125 ppm. These are not EPA methods and should not be used for anything other than a way of checking to make sure the system is operating within its designed operating parameters. Although the amount of particulate matter was not measured, the particulate matter was visible and that could lead to permitting issues in some states. j

Conclusions

The BGP gasifier is a unique manure to energy system. The BGP system uses a portion of the heat from combustion to drive the process allowing it to utilize wetter and less energy dense feedstocks. Most systems use air to drive the oxidation reaction of the fuel, but this can be problematic with wet manure and manures that are dense where the air cannot sustain combustion or the air cannot lift the dense manure. The augers in the main PC offer a good way of conveying the manure through the system as augers are used to convey materials in many industries. The augers can handle bulky, dense, fine, and course materials. However these benefits have also proven to be the weak point in the gasifier. In order to keep the temperatures down in the PC, the gasifier must have a large footprint or the manure is not taken to complete ash and as a result a high amount of carbon is left in the ash. There are possible solutions to this problem such as using a higher grade alloy for the augers, redesigning the system to keep the augers cool, using an alternate conveying system, or redesigning the system to reduce the temperature in the PC.

The BGP gasifier was seen as a simple design that was robust and inexpensive in both capital cost and operation, however this has not been supported by the South Carolina project. Some of the problems encountered have been resolved and others will be addressed in subsequent efforts.

There is only one commercial ready technology that can utilize heat from combustion to generate electricity under 100 KWe and that is an ORC. There are two commercial ready ORC technologies on the market; Electratherm and Infinity Turbine. Infinity Turbine offers a 10 KWe and a 50 KWe unit. Electratherm offers three sizes ranging from 38 KWe to 120 KWe. The problem with small systems is the cost per KWe and the low efficiencies. However, the gasifier produces high grade heat. A future option would be to work with companies to take advantage of the high grade heat available from manure gasification and modified combustion systems. A modified ORC system could show promise and offer greater efficiencies than is currently available. There are other technologies that could be developed to operate at the farm scale that use a different type of technology. These technologies include the Brayton cycle, the Stirling engine, and a small steam turbine.

Manure to energy systems are still in the development stages and manure to electricity for on farm use is not commercially ready. More work should be focused on making systems able to handle a wide range of manures, able to run automatically with minimal operator time, low maintenance, work on emissions controls, increase efficiency of the electrical generator, and to reduce the price.

Port Republic, VA Demonstration of the Global Refuel system

Introduction

The Global Refuel (GR) system was chosen for this project due to its success on a poultry farm in Indiana. The system operated for over a year at this farm and was seen as a success. The GR system was also a relatively inexpensive manure to energy system designed for small farms with only 1-2 houses.

The Global Refuel poultry litter to energy system was located at the Riverhill poultry Farm in Port Republic, VA was the second installation of its kind in the country, and served as an opportunity for the technology provider, Global Refuel (a division of Wayne Combustion Systems), to fine tune performance of the technology in a real-world, farm scale setting.

The Global Refuel technology was selected for demonstration by FPPC and the Eastern Shore RC&D because they were one of the few vendors with technologies available commercially that also had data on air emissions available for review by the project team and air permitting agencies. These preliminary emissions data indicated that criteria pollutant emissions from the Global Refuel system would meet Virginia's permitting requirements.

Installation

The installation of the GR unit was done during February and March of 2013. The unit was installed on a 30' x 30' concrete pad a few feet from the poultry house. The unit was positioned at the midpoint of the length of the poultry house so that the duct work would enter on the side wall at the middle of the house. The poultry house does whole house brooding and this was considered the best place to ensure even heating across the poultry house from the GR unit. The unit was first fired in **March** 2013.

GR unit being set in place on the concrete pad

Installation of the duct work into the poultry house

Duct work from the combustion unit to the poultry house

Obstacles to finish construction

GR installation completed

How the system works

The WC system is a two stage combustion system designed for poultry litter as the fuel source. The system was comprised of two chambers: 1.) the combustion chamber (CC) was the inner chamber and was mainly comprised of mild steel. 2.) The second outer chamber (OC) was the heat exchanger. The CC was a rectangular box (almost square) that sat inside the OC. A large HVAC fan blew air around the outside of the CC thus heating the air. The air was directed around the around the CC via baffles and ultimately exited through duct work to the poultry house. The return air came from the poultry house. The WC system was designed for 180 lbs/hr max federate which is approximately 900,000 Btu/hr input with the poultry litter having 5,000 Btu/lb (LHV). This number was high for this farm. This farms poultry litter had a moisture content of 24 % and a LHV of 4,030 Btu/lb. Wayne Combustion claimed the GR system could handle raw poultry litter straight from the houses with a maximum moisture content of 35%.

The material handling system comprised of a large bulk hopper that used a drag chain to move the litter into a horizontal transfer auger. The bulk hopper had a series of “beaters” that were used to delump the litter before it exited the hopper and into the transfer auger. The transfer auger took the litter from the bulk hopper into an inclined belt conveyor that was mostly enclosed. The belt conveyor conveyed the litter to a cone shape surge hopper located on top of the combustion unit. Another delumper was located between the belt conveyor and the surge hopper. The surge hopper had a material sensing switch that controlled all prior material handling components in an on/off fashion. When the surge hopper was empty, the material handling components were energized and stayed energized until the surge hopper was full.

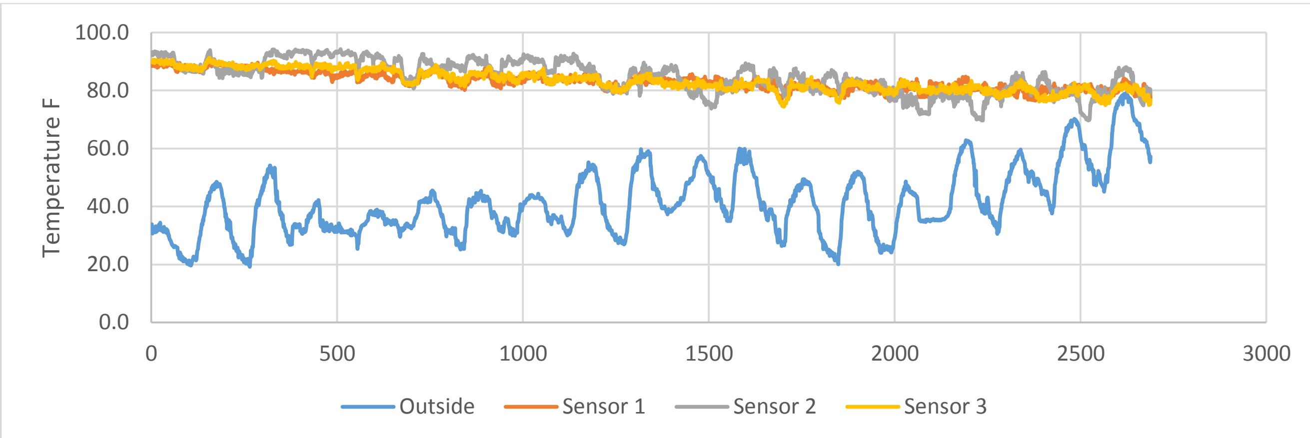
The surge hopper had a rotating assembly inside to keep the litter from bridging. An auger was used at the bottom of the surge hopper to meter litter from the surge hopper onto the top distribution plate inside the combustion chamber. The surge hopper acted as an airlock as long as litter was inside. The top plate had a sweep arm that rotated inside of the top plate. The top plate was designed with holes in it so that the litter was dried/pyrolyzed before it fell through the holes and onto the main combustion grate centered 2-3' below. Another stir arm was used to keep the litter moving on the bottom combustion grate. The concept that GR was hoping for was that the litter would combust quickly as it fell from the top plate to the bottom plate with little residence time on the bottom plate. The bottom plate acted as an air distribution grate and ash removal system. The bottom combustion grates consisted of two plates that were slotted. The bottom plate remained stationary while an air cylinder was used to "shake" or rotate the top bottom grate a few degrees in a back and forth motion to shake the ash through the holes in the grates and allow the ash to fall through the grates into an "ash pan" below. The ash pan also had a shake mechanism to keep the ash moving. The ash pan had 2 separate 3" flexible augers that were perpendicular to each other. They were used to remove the ash from the system. The combustion air came from a blower that blew air through the bottom combustion grate slots.

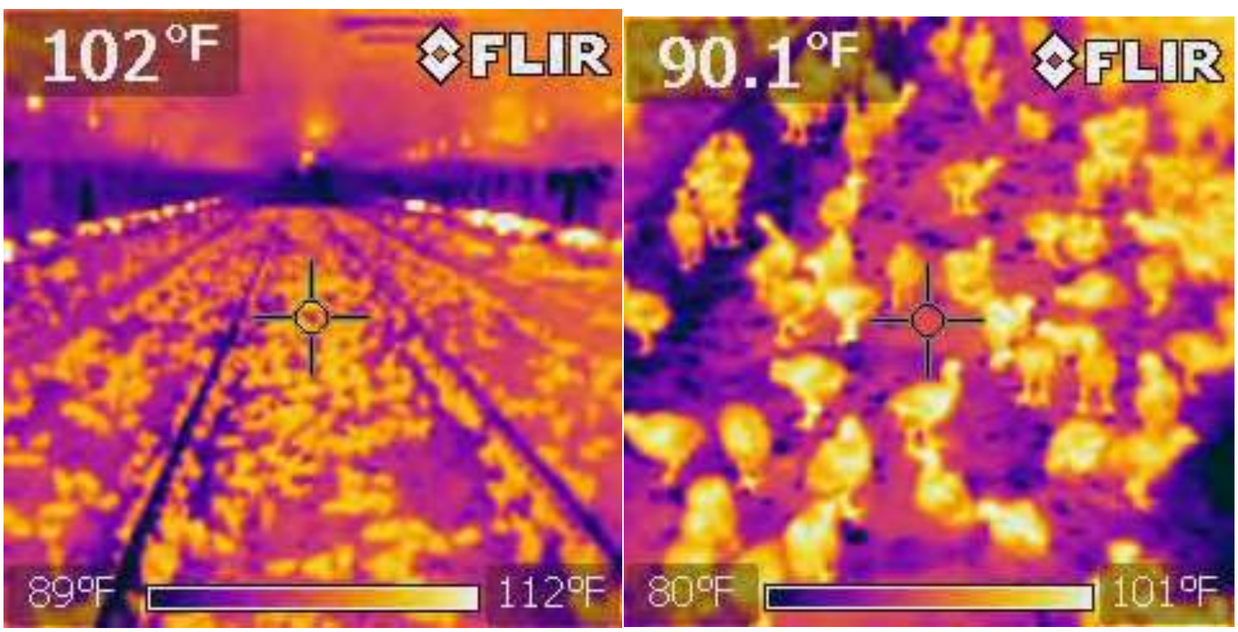
The CC was roughly square and the combustion grates were round. The bottom grates were surround by one layer of firebrick approximately 12" in height. These bricks were used to keep heat inside the combustion zone and keep ash inside the grate. The combustion air would blow vertically upwards through the grate where it would come in contact with the litter and off gasses from the litter. The heat from combustion would transfer through the CC's mild steel walls. On one side of the combustion chamber was a vertical steel wall that separated the combustion zone from the flue stack which was located at the top on one side of the chamber

The control system utilized a PLC to control the entire system. It was mainly an on/off system. The federate was feed in increments of a few seconds on and a few seconds off. The combustion air was manually adjusted. There was no draft control on the system. The ash system was on/off which was timed using the federate to set the time interval. The HVAC fan was set at one speed. It used one thermocouple in the system located a few inches above the top combustion grate for control. It used a propane fired burner to start the system. Once the system reaches a certain temperature, it starts feeding litter. This usually took 30-45 minutes. It did have a startup program where it limited the federate until the system had reached a certain temperature. It had safety features with limit switches on motors and access doors and a high limit temperature alarm for the CC.

Performance

The GR unit was initially commissioned and the unit was able to combust poultry litter and generate usable heat for the poultry house. The unit only ran for a few days at a time due to a variety of malfunctions in the system. During this first period of operation, three temperature sensors were located in the poultry house. An additional sensor was placed outside. All three sensors were placed in the middle of the house, width wise. Along the length of the house, one was placed in the middle, the other two were placed equal distance between the middle and the ends of the house. The Graph below shows that the temperatures in the house. The house was also used radiant hydronic floor heat powered by a wood fired boiler. Pancake style propane heaters were also used to provide supplemental heat when needed. The GR did not run constantly due to several problems. The lesson learned here is that the sensors did not indicate when the GR system was on or off. This indicates that using a single point entry for a heat source such as hot air from the GR system can be done so that the heat is evenly distributed throughout the house and that it can be integrated with other heating systems to keep the house at the correct temperature despite the fluctuating outside temperatures. The GR system was tested several times since the initial test in March 2013. In some tests, the system ran for a few days before failure while others, it required constant maintenance to keep it going for a single day. Each test concluded that the system does provide heat to the houses and can combust poultry litter, however it had several problems that kept it from operating continuously.





Infrared camera images of the poultry house with the WC unit running

Nice and dry around the watering lines thanks to the extra heat from the WC unit

Problems:

The GR unit had several problems that prevented it from operating continuously. These problems are listed below.

- Belt conveyor jammed
- Bulk hopper not moving
- Surge hopper sensor not working correctly
- Severe corrosion on top distribution plate
- Bottom grates becoming stuck and shake mechanism not able to move grates
- Ash augers frequently jamming
- HVAC duct work louver jamming
- Combustion temperatures too low
- Dust problem on litter handling equipment
- High CO and PM emissions
- Visible emissions from stack
- Not efficient heat exchange
- Ash having too much remaining carbon
- Foreign objects like rocks jamming combustion stir arm

Solutions:

Hopper: The current hopper had a lot of moving parts that could be eliminated such as the beater mechanism inside the hopper. A standard manure spreader does not require such a mechanism to operate and is built specifically for poultry litter. The controls would operate the same and the safety would improve with only one moving part (the drag chain) which moves at similar speeds to the existing WC hopper drag chain. Another benefit is having the ability to increase the size of the manure spreader by simply ordering a larger size. They come in different lengths which could be an option to farmers.

Conveyor: The belt conveyor used in the GR system allows dust from the poultry litter to build up on the surrounding equipment and floor. This could be a problem in an enclosed building. The belt conveyor also uses more horse power then an alternate conveying method, a screw auger. The screw auger has been successfully used with poultry litter as long as a "U" trough is used and not a round tube. Screw augers are very reliable and are readily available with many suppliers. If the industry standard components are used, than various manufactures of augers can be used in the same unit without any problems. An auger would also completely eliminate dust because it can be sealed.

Surge Hopper: The surge mechanical parts of the hopper worked, however the level sensor should be changed to a mechanical rotary bin level switch. Also the connection between the conveyer belt (or an auger) will need modification to prevent a pinch point where litter can bridge and jam.

Feedrate: The feeding system and the stirring mechanism needs to be driven by separate gearboxes that are independently controlled. This will allow more control of the federate and the stir arm. Currently they use the same gearbox and the same shaft. The federate needs to be a continuous system instead of the current on/off control.

Combustion Chamber: The GR unit has a small combustion zone and would benefit from making this zone larger. The key to combustion is time, temperature, and turbulence. The GR utilizes the steel shell of the combustion box to transfer heat to the surrounding air. This heat transfer stops combustion and limits the combustion to the area inside the ceramic bricks. The height of the bricks could be increased around the combustion zone. The combustion gases could also be rerouted to pass back through the combustion zone before exiting through the stack. In future designs the height of the combustion chamber might need to increase by a couple of feet to allow for a higher combustion zone to be lined with refractory (brick).

Air Handling: To reduce the horsepower of the HVAC fan, the duct work around the combustion box could be changed to reduce the resistance of the air flow. Fins could also be added to the outside of the combustion box in order to increase heat transfer.

Stack Draft: The draft in the system was not being controlled. Draft is used to measure the flow of gases in the system. If the draft is too high then the air could be moving too fast and vice versa for the draft being too low. An exhaust fan where all the flue gases go through the fan or a barometric damper could be used to control the draft.

Ash components: All ash components need to be constructed from stainless steel to provide corrosion resistance. The bottom of the chamber should be designed to have one ash auger and this auger should have a rigid shaft in order to handle rocks which are present in litter.

Startup propane burner: The startup burner needs to be modulating instead of on/off. Currently it is set to fire at 400,000 Btu/hr. This has caused uneven heating on the combustion grates which are cast and they tend to crack due to the uneven heat.

Combustion air: The combustion air fan should be changed to a fan with a motor controlled by the PLC so it can easily change to accommodate changing operating conditions in the system.

Emissions controls: Particulate matter emissions will need to be addressed with future GR units. Emissions testing from a 3rd party tester at GR's facility in Indiana have shown that the system has particulate matter emissions that would prevent it from being permitted in some states in the Chesapeake Bay Watershed.

Summary:

The Global Refuel system did provide heat to the poultry house as designed. A small manure to energy system like GR's system can combust poultry litter that was generated on the farm. However, the many mechanical problems prevented it from being a useful tool for the farmer to provide an alternate source of heat for his poultry house and concentrating the raw poultry litter to ash. Also visual indications along with 3rd party emissions testing emissions controls will be needed.

It was also learned that reacting poultry litter thermochemically is somewhat unique at each farm. The composition of the poultry litter (including moisture content), the retention time and temperature of the process, and heating chamber geometry are all factors affecting thermochemical reactions.

It is one of the few systems that has proven to some extent to be able to combustion poultry litter and provide useful energy to the farmer. The system is relatively easy to use, easy to maintain, easy to fix, and inexpensive when it was operational. Small farmers (4 houses and smaller) need a system this size for their farms. While the GR unit does have its problems, the concept is unique in that it delivers the heat to the poultry houses with relatively inexpensive duct work while all other systems use hydronic systems that require expensive plumbing and in house heaters.

ROI Chart for Poultry Litter to Energy Projects

Overview

This chart is for overall ROI calculations for on farm poultry litter projects. The numbers are just place holders since exact figures are not available to generate a complete ROI. Each farm is very different and in cases of organic farms the expenses can be significantly higher for propane and bird mortality with the ROI being potentially better. There are only a few systems using poultry litter as fuel in the US on farm and the complete financial picture is not fully understood.

There are two types of farms: regular commercial birds and organic birds. an "*" is used in the categories that would have a significant change for organic birds vs. regular. System costs include installation costs.

Existing Farms costs	Costs	System costs and New farmer costs	Costs	Potential savings	Savings; assume a 4 house farm
*Propane per house/year	5,000 – 10,000	Gasifier 300 lbs/hr	200,000	60-100% of propane costs	20,000 to 40,000 /year
Electricity per house/year	3,000	Material handling equipment	50,000	0-200 % of costs, depending on grid connection and contract with utility	12,000 to 24,000/year
Ammonia Litter treatment per house	2,500	Water Boiler	50,000	50-100% reduction in use of litter treatment if houses heated	Up to 10,000/year
*Mortality costs farmers money in payout reduction		Plumbing to heat houses/house	30,000	Unknown, but the healthier the birds the less mortality and that means more money per flock	?
*Increase in feed/gain ratio		Emissions equipment**	30,000	Reduces the amount of feed used during flock which increases farmers pay	?
*Faster growth of birds		Electrical generator; ORC	260,00	Less time on farm which means more flocks which means more money	?
Ash or biochar sales; 150/ton with 120 tons/year	18,000	Grid connection	15,000		
		System building	30,000		
		Maintenance and operation time: 2 hours /day = 730 hrs/year	10,000		

		***Lost revenue of selling litter at $15/ton with 1200 tons/year	18,000		
		Parasitic loads; propane to start and electricity to run/year	5,000		

- *Organic would add to this cost
- ** If needed
- *** Getting rid of litter could become a cost in certain states in the CBW in the next few years.

On-farm Demonstration of Energy Generation and Phosphorus Recycling as an Alternative to Land Application of Poultry Litter on the Delmarva.

Mark S. Reiter, Associate Professor of Soils and Nutrient Management, Virginia Tech, Painter, VA

1.1 INTRODUCTION

Despite being drier than other livestock manures, a significant problem with PL is bulkiness (Sharpley et al., 2007; Lynch et al., 2012). Poultry litter bulkiness makes transportation problematic. The bulkiness imposes economical limits from a nutrient value standpoint, often making it infeasible to ship out of the watershed; which leads to the PL application to fields for agronomic production near its source (Figure1.1 and Figure 1.2). The 5-year price average of nutrients N, P, K, and S were computed using the fertilizer price list compiled by USDA-ERS (2014) and equaled $1.26 per kg N based on urea, $1.50 per kg P_2O_5 based on TSP, $1.17 per kg K_2O based on KCl, and $0.84 per kg S based on ammonium sulfate. Using the shipping costs per loaded km of $1.55 (Weaver, 2015) and $2.48 (DeVuyst and Burton, 2008) and the total value of the fertilizers (N-P-K-S) the distance per metric ton (Mg) was calculated (Table 1.1). When factoring in the average load weight allowed on a commercial tractor trailer in Virginia, approximately 21.79 Mg, the added value of the ash co-product becomes clear (Table 1.2) (VDOT, 2015). When graphed against a map of the United States PL is only economical transported to the Ohio/Indiana boarder and the PLA can feasibly be shipped anywhere in North America.

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1.3 Tables

Table 1.1: Fertilizer worth versus transport distance for PLA†, fresh PL‡, and standard fertilizers.

	Fertilizer Worth§	High Mileage Estimate¶	Low Mileage Estimate#
	$ Mg^{-1}	---------------------km Mg^{-1}--------------------	
PLA	384.98	248	155
PL	58.46	37.6	23.5
KCl	700.44	451	282
TSP	688.98	444	277

†Based on average nutrient concentrations of PLA (Lynch et al., 2013).
‡Based on average nutrient concentrations of PL (Bolan et al., 2010).
§Based on 5-year price average of nutrients computed using fertilizer use and price list compiled by USDA-ERS (2014).
¶Calculated using the shipping costs per loaded km of $1.55 (Weaver, 2015).
#Calculated using the shipping costs per loaded km of $2.48 (DeVuyst and Burton, 2008).

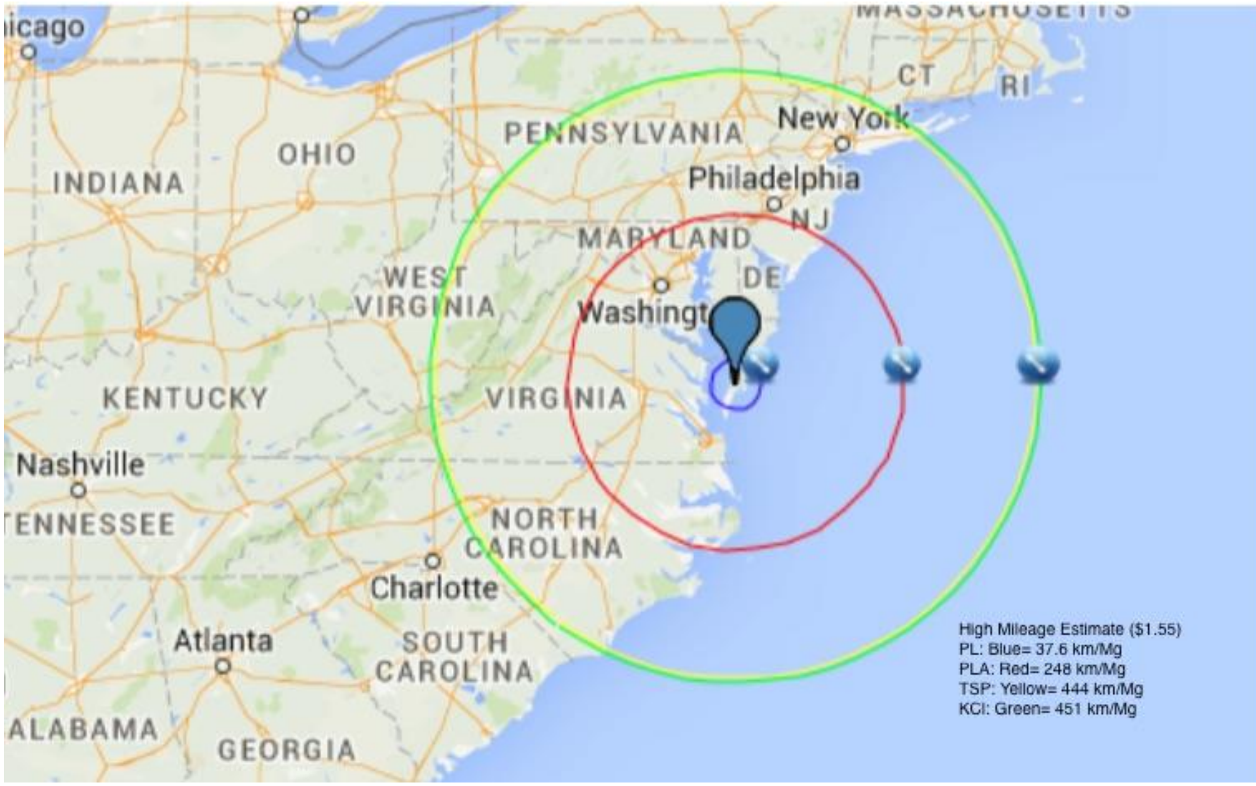
Table 1.2: Fertilizer worth versus transport distance with trucking estimation for PLA†, fresh PL‡, and standard fertilizers.

	Fertilizer Worth§	Fertilizer Worth per truck load¶	High Mileage Estimate#	Low Mileage Estimate
	----------$ Mg^{-1}--------	--------------------$ $load^{-1}$------------------	----------------------------------km $load^{-1}$--------------------------	
PLA	384.98	8388.71	5412	3383
PL	58.46	1273.84	822	514
KCl	700.44	15262.59	9847	6154
TSP	688.98	15012.87	9686	6054

†Based on average nutrient concentrations of PLA (Lynch et al., 2013).
‡Based on average nutrient concentrations of PL (Bolan et al., 2010).
§Based on 5-year price average of nutrients computed using fertilizer use and price list compiled by USDA-ERS (2014).
¶Calculated using the average load weight allowed on a commercial tractor trailer in Virginia of 21.79 Mg (VDOT, 2015)
#Calculated using the shipping costs per loaded km of $1.55 for high mileage (Weaver, 2015) and using the shipping costs per loaded km of $2.48 for low mileage (DeVuyst and Burton, 2008).

1.4 Figures

Figure 1.1: High distance estimate transport radius map based on average nutrient (N, P, K, and S) concentrations of PLA†, fresh PL‡, and standard fertilizers§



†Based on average nutrient concentrations of PLA (Lynch et al., 2013).
‡Based on average nutrient concentrations of PL (Bolan et al., 2010).
§Calculated using the shipping costs per loaded km of $1.55 (Weaver, 2015). Based on 5-year price average of nutrients computed using fertilizer use and price list compiled by USDA-ERS (2014) and .the average load weight allowed on a commercial tractor trailer in Virginia of 21.79 Mg (VDOT, 2015).

Figure 1.2: Low distance estimate transport radius map based on average nutrient (N, P, K, and S) concentrations of PLA†, fresh PL‡, and standard fertilizers§

†Based on average nutrient concentrations of PLA (Lynch et al., 2013).
‡Based on average nutrient concentrations of PL (Bolan et al., 2010).
§Calculated using the shipping costs per loaded km of $2.48 (DeVuyst and Burton, 2008). Based on 5-year price average of nutrients computed using fertilizer use and price list compiled by USDA-ERS (2014) and the average load weight allowed on a commercial tractor trailer in Virginia of 21.79 Mg (VDOT, 2015).

2. Characterization of Poultry Litter Ash Co-Products

2.1 Materials and Methods

A study was initiated to evaluate the chemical characteristics of PL co-product sources (Table 2.1) compared to triple super phosphate (TSP) and muriate of potash (KCl). The fertilizers were arranged in a randomized complete block design (RCBD) with 4 replications.

2.2.1 Elemental Analysis

Fertilizer samples (0.5 g) were digested in nitric acid and hydrogen peroxide using method 3050B (USEPA, 1996), and then analyzed using ICP-OES (Spectro Analytical Instruments, Kleve, Germany) at the Virginia Tech Soil Testing Laboratory (Maguire and Henkendorn, 2011). Using dilute salt and water extraction testing protocols for 0.1M $CaCl_2$ (Aslyng, 1964), 1:10 water (Olsen and Sommers, 1982), and 1:100 (van Diest, 1963) the correct ratio of sample to solution was placed in 60 ml straight-walled plastic extracting beakers. The samples were shaken for 1 hour on a reciprocating shaker (Eppindorf, Enfield, CT, 06082) set at 200 oscillations per minute (opm). The extracts were filtered through Whatman no. 2 filter paper into plastic vials and then analyzed using ICP-OES (Spectro Analytical Instruments, Kleve, Germany) at the Virginia Tech Soil Testing Laboratory (Maguire and Henkendorn, 2011). A total N, C, and S combustion procedure was conducted for the samples using the Dumas method with a Vario EL Cube (elementar Americas, Mt. Laurel, NJ, USA) (Bremner, 1996).

2.2.2 Balance Comparison

Balance comparisons of the poultry litter going in and ash coming out of poultry litter burners took place as litter burners began running at the farm locations. Each thermo-conversion system was unique to the farm location in its physical construction, operating conditions; residence time and initial feedstock (PL) (Table 2.2); individual system sampling methods are listed below. Samples were tested for percent moisture (Wolf and Haskins, 2003), calcium carbonate equivalent (CCE) (Wolf and Haskins, 2003), and elemental concentration using the EPA method 3050B. Densification was calculated by taking the ash nutrient concentration percentage and dividing by its corresponding feedstock PL nutrient concentration percentage. (Times Concentrated= Ash nutrient %/ PL nutrient %)

Wayne Combustion Global Refuel (Port Republic, VA): ASH3

Samples were taken at three sampling locations in accordance to the residence time of the system: fresh PL going in, the main bulk ash auger, the fly ash auger from the side at the heat exchanger. The residence time was observed to be 30 minutes from the start to the main bulk ash auger and the fly ash auger. The time and temperature of the combustion chamber was recorded for each sampling.

2.2.3 Total Carbon Content

Total carbon content of the ash co-products were determined using a total N, C, and S dry combustion procedure was conducted for the samples using the Dumas method with a Vario EL Cube (elementar Americas, Mt. Laurel, NJ, USA) (Bremner, 1996).

2.3.4 Statistical Analysis

Statistical analysis was conducted using analysis of variance (ANOVA), SAS PROC MIXED procedures and Fisher's LSD with an alpha level of 0.10 using SAS 10.1 statistical software (SAS Institute, 2007).

2.3 Results and Discussion

2.3.1 Elemental Analysis

Acid Digestion

The nitric acid/hydrogen peroxide digestion is a complete elemental digestion that quantified the total concentrations of elements (Table 2.3a; Table 2.3b). The industry standard

TSP had the highest P concentration (201.81 g kg^{-1}) and a significant concentration of Ca (168.22 g kg^{-1}). The KCl had the highest K concentration (493.11 g kg^{-1}) as expected.

When compared to the industry fertilizer standards no co-product was similar to TSP for P concentration (Table 2.3a, 2.4, 2.5, 2.6). For K concentration, no co-products were similar to KCl, but all co-products had concentrations greater than or similar to the fresh PL standard (Table 2.3a, 2.6). For S concentration, the fresh PL had the greatest concentration, and all co-products had significant less S (Table 2.3a).

Micro nutrients or trace elements were present in all of the co-product samples (Table 2.3a; Table 2.3b) and were below the level of environmental concern according to the fertilizer law (USDA-NRCS, 2015). Micro-nutrients such as boron (B), manganese (Mn), Copper (Cu), and Zinc (Zn) are vital to health growth in plants, in highly managed and high yielding farming systems farmers are looking to supplement these nutrients to crops. By using a PL co-product, these farmers will get the extra benefit of these nutrients not normally found in inorganic fertilizers.

Dilute Salt and Water Extractions

While there is no single recommended protocol for measuring WEP, we analyzed our sources using three of the most recommended protocols (Kleinman et al., 2007). The dilute salt extraction is used in place of water to obtain a clearer filtrate, but the amount of soluble P will be smaller due to Ca^{2+} ions enhancing P sorption in the soil (Aslyng, 1964). Our results found known significant differences between the three extractions for P concentration. There was a significant difference for K concentration; the 1:100 water extractions produced higher concentrations than the others. Trends show that although no significant differences were produced from our data the 1:10 $CaCl_2$ extraction concentrations (Table 2.4) were tended to be slightly less than the 1:10 water extract concentrations (Table 2.5).

2.3.2 Balance Comparison

The composition of poultry litter varies greatly from location to location depending on the practices of the individual poultry producer (Bolan et al., 2010; Kelley et al., 1996; Tasistro et al., 2004). Thus, the resulting ash from the different thermo-combustion systems is influenced by not only the unit, but by the starting material (Table 2.7). The literature states that the typical concentration factor is 6 or 7 times that of the original feedstock nutrients (P, K, and S) of the PL (Bock, 2004). Our study found that this varied between systems based on moisture, but falls well within our range of 4-10 concentration for P (Table 2.9). The systems tested in our balance comparison trials were not equipped with cyclones or bagging units, so the majority of K and S escaped the systems through the exhaust (Kelleher et al., 2002) and resulted in lower concentrations 2.5-5 for K (Table 2.9), and 2-3 for S (Table 2.9).

2.3.3 Ash Co-Product Carbon Content

The carbon content of PL co-products also varies greatly on the thermo-conversion system and the initial PL feedstock (Table 2.10).

2.4 Conclusion

Our study found that nutrient densification for P concentration fell within a range of 4-10 times concentrated, K concentration ranged 2.5-5 times concentrated, and S ranged 2-3 times concentrated. Our comparisons between total nutrient digestions and water soluble extractions found that the ash products were significantly less plant available than the standard fertilizers (TSP and KCl). A greater amount of the co-products will have to be applied to meet the same nutrient availability of the standards. Overall, if all ideal combustion criteria are met (ie. 700-1000ºC; 25% moisture), then poultry litter co-products are feasible to use a fertilizer sources, but will need to be individually analyzed for nutrient content before making application recommendations. More research into balance comparisons are needed to be able to identify stronger relationships within the nutrients.

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2.6 Tables

Table 2.1: Descriptions of PL co-product sources used in all studies.

Source	Co-Product Type	Farm Name	Thermo-Conversion System
Ash3	Bulk Ash	RHO	Combustion

Table 2.2: Source information and background information for poultry litter co-product thermo-conversion systems.

Source	Location	System	Burn Temp	Residence Time	Mode of Energy Dispersal	PL Type	Co-Product Type
ASH3§	Port Republic, VA	Wayne Combustion Global Refuel	593ºC in chamber	30 min	Forced Air	Turkey	Ash

§Thermo-Conversion systems used in the balance comparison study.

Table 2.3a: Total elemental concentration of ash co-products, fresh PL and standard fertilizers.

	P	K	S	Ca	Mg	Mn	Na	Fe	Al	B	Zn	Cu
	----------g kg^{-1}----------									----------mg kg^{-1}----------		
ASH3	104.90b	129.77d	28.42b	162.58a	36.59b	4.60a	25.24c	16.88b	2.15f	220.56d	2888.41a	3429.68a
KCl	0.03j	493.11a	0.25b	0.72g	0.88i	NDi‡	15.01g	0.22g	0.07h	0.73h	0.15g	0.16j
PL	12.51i	29.06g	370.92a	23.64f	174.73g	1.39h	9.38h	0.04g	1.02g	43.66g	588.35f	519.43g
TSP	201.81a	1.70h	247.95a	168.22a	4.54h	0.11i	3.03j	2.55fg	3.08e	643.96a	425.41f	22.56ij
$LSD_{0.10}$	3.44	9.62	166.85	8.44	1.84	0.14	1.13	3.96	0.77	16.84	173.78	79.84

† A different letter within the column designates significance at the 0.10 level.

‡ ND= Non-detectable, below the detectable limit of the instrumentation (<.0001 mg L^{-1}).

Table 2.3b: Total elemental concentration of ash co-products, fresh PL and standard fertilizers.

	As	Be	Cd	Co	Cr	Hg	Mo	Ni	Pb	Sb	Se	Si
	--mg kg^{-1}--											
ASH3	13.51c	0.12h	NDc	8.97d	15.45d	ND	48.84a	50.00cde	5.58d	1.07de	4.59b	35.04bc
KCl	0.27fg	NDi	NDc	0.04i	0.05d	ND	NDh	0.24f	NDf	NDf	NDf	19.64cdef
PL	NDg	0.14gh	NDc	1.25hi	4.83d	ND	1.19h	3.35f	2.02e	NDf	0.67ef	NDf
TSP	5.99d	1.59a	8.28a	1.71h	159.13b	ND	4.57g	26.58ef	3.08e	2.53b	NDf	81.92a
$LSD_{0.10}$	2.81	0.03	0.67	1.50	69.94	---------	1.59	38.17	1.25	0.65	0.92	25.59

† A different letter within the column designates significance at the 0.10 level.

‡ ND= Non-detectable, below the detectable limit of the instrumentation (<.0001 mg L^{-1}).

Table 2.4: Weak Salt (0.1 M $CaCl_2$) Extraction of ash co-products, fresh PL and standard fertilizers.

	P	K	S	Mg	Mn	Zn	B
	----------g kg^{-1}----------			----------mg kg^{-1}----------			
ASH3	0.08b	72.81d	30.06c	646.97e	0.17c	NDc	21.10e
KCl	0.28b	483.89a	0.27j	563.96e	0.28c	NDc	0.90i
PL	0.82b	26.07h	13.11f	567.07e	21.43b	79.93b	25.00d
TSP	219.57a	1.64j	3.09i	5138.78a	112.70a	443.26a	38.74b
$LSD_{0.10}$	16.56	3.89	1.13	250.89	8.07	20.65	3.29

† A different letter within the column designates significance at the 0.10 level.

‡ ND= Non-detectable, below the detectable limit of the instrumentation (<.0001 mg L^{-1}).

Table 2.5: Water Extraction (1:10) of ash co-products, fresh PL and standard fertilizers.

	P	K	Ca	S	Mg	Mn	Zn	B
	---g kg^{-1}--------------------------------------- ---				---------------------------------------mg kg^{-1}------------------------------------			
ASH3	0.27c	70.31d	0.12c	25.23c	167.43e	0.29d	0.05d	20.85e
KCl	0.02c	516.14a	0.30c	0.23j	503.46c	0.03d	NDd	1.49j
PL	0.82c	22.52h	0.48c	10.94f	346.69d	16.78b	77.39b	23.50d
TSP	209.68a	1.80j	132.40a	3.37h	4158.25a	108.80a	294.95a	38.96b
$LSD_{0.10}$	5.23	5.40	3.40	1.24	109.58	4.41	3.90	1.17

† A different letter within the column designates significance at the 0.10 level.

‡ ND= Non-detectable, below the detectable limit of the instrumentation (<.0001 mg L^{-1}).

Table 2.6: Water Extraction (1:100) of ash co-products, fresh PL and standard fertilizers.

	P	K	Ca	S	Mg	Mn	Zn	B
	------------------g kg^{-1}------------------ -				------------------mg kg^{-1}------------------			
ASH3	1.97d	86.56cd	0.35c	28.40bc	1063.69c	2.94de	NDe	25.26d
KCl	0.06f	479.70a	0.41c	0.23g	571.76de	0.67e	0.28e	1.06h
PL	3.55c	27.23i	0.85c	11.44e	990.78c	25.93b	74.21b	22.08de
TSP	190.42a	1.54j	133.86a	12.01e	4571.50a	118.17a	359.51a	43.20b
$LSD_{0.10}$	1.25	16.53	3.40	4.27	344.82	4.40	13.28	5.09

† A different letter within the column designates significance at the 0.10 level.

‡ ND= Non-detectable, below the detectable limit of the instrumentation (<.0001 mg L^{-1}).

Table 2.7: Characterization of fresh poultry litter sample feeding the combustion unit.

	Moisture	CCE†	N	P	K	S	Mg	Ca	Na	Fe	Al	Mn	Cu	Zn	B	K_2O‡	P_2O_5‡
	%								mg kg^{-1}							%	
ASH3	22.56	0.29	4.58	1.70	2.19	0.88	0.59	2.64	5696	678	116	749	616	620	57	2.02	3.04

† CCE- Calcium Carbonate Equivalent.

‡Available fertilizer equivalent.

Table 2.8: Characterization of Poultry litter ash samples.

	Moisture	CCE†	N	P	K	S	Mg	Ca	Na	Fe	Al	Mn	Cu	Zn	B	K_2O‡	P_2O_5‡
	%								mg kg^{-1}							%	
ASH3	0.20	22.54	0.30	10.70	11.04	2.32	3.83	17.68	33980	10320	1806	4102	3262	2170	261	13.26	24.50

† CCE- Calcium Carbonate Equivalent.

‡Available fertilizer equivalent.

Table 2.9: Concentration of nutrients from the densification of poultry litter entering the thermo-conversion unit and poultry litter ash exiting the unit from four different units in the Mid-Atlantic.

	N	P	K	S	Mg	Ca	Na	Fe	Al	Mn	Cu	Zn	B	K_2O	P_2O_5
	Times Concentrated†														
ASH3	0.07	6.41	5.04	2.63	6.62	6.93	5.98	22.93	15.71	5.54	5.36	3.52	4.61	6.55	8.26

†Times Concentrated= Ash nutrient Concentration %/ Feedstock PL nutrient concentration %).

Table 2.10: Differences in carbon content of PLA and fresh PL by thermo-conversion system.

	Bulk PLA	Fresh PL
	C	
	%	
ASH3	5.30b	37.95b

3. Incubation of Poultry Litter Co-Products for Phosphorous and Potassium Availability

3.1 Materials and Methods

3.1.1 Experimental Design

A non-leached aerobic incubation study was conducted with a Bojac sandy loam soil (Table 3.1) (Coarse, loamy, mixed, semiactive, thermic, Typic Hapludult) (USDA-NRCS, 2012) with a bulk density of (1.14 g cm^{-3}) (Table 3.2) to evaluate the P and K mineralization characteristics of PL co-products. To evaluate the P and K mineralization of PLA (ASH3) compared to TSP and KCl applied at a rate of 85 mg P kg^{-1} and the amount of K applied per source was recorded. The fertilizers were arranged in a randomized complete block design (RCBD) with 4 replications and incubated for 0, 3, 7, 14, 28, 56, 84, 112, and 140 days as described by (Reiter et al., 2014). The Fertilizers were mixed in 50 g of air-dried soil in 500 ml plastic bottles. Bottles were then raised to approximately 60% water-filled pore space (0.15 g water g $soil^{-1}$; Schomberg et al., 2011) with double de-ionized water. Final weights were taken so the water content could be adjusted on an as needed basis. Uncapped bottles were placed into incubation chambers at 80% humidity and 25°C.

3.1.2 Sample Analysis

At each sampling day, four replications were extracted per treatment source. For extraction, each bottle was filled with 500 mL of 0.01 M $CaCl_2$ solution (Aslyng, 1964) and shook for 1 hour at 200 opm (Kuo, 1996). The suspension settled for an hour and the supernatant was decanted and filtered through Whatman 42 filter paper into 25 mL scintillation vials and stored at 4°C until analyzed. Samples were analyzed for P and K concentration using ICP-OES (Spectro Analytical Instruments, Kleve, Germany) at the Virginia Tech Soil Testing Laboratory (Maguire, R. O. and S. E. Henkendorn, 2011). The P and K concentrations of the untreated control soil samples were averaged and subtracted out. The percent remaining in the sample was calculated by the concentration of the sample divided by the original amount of fertilizer added and multiplied by 100. ($\frac{\text{Sample Concentation}}{\text{Original Amount Added}} \times 100 = \%\ \text{remaining}$).

3.1.3 Statistical Analysis

Statistical analysis was conducted using analysis of variance (ANOVA), SAS PROC MIXED procedures and Fisher's LSD with an alpha level of 0.10 using SAS 10.1 statistical software (SAS Institute, 2007).

3.2 Results and Discussion

Overall availability of soil P from fertilizer sources was low due to the acidic nature of the soil. Water pH readings from the incubation soil averaged 5.4 (Table 3.2); which would decrease overall recoverable P. Phosphorous fixation occurs rapidly in the acidic pH ranges reacting with Al, Fe, and Mn ions and oxides to form insoluble compounds that are not plant available (Brady and Weil, 1996). When comparing the percentage P recovered/ P fertilizer applied over time for each fertilizer source (Figure 3.1), a significant P interaction between fertilizer source and incubation sampling day (Table 3.5) was observed. As expected the standard fertilizer TSP was initially the most available and water soluble at 0 d (55.50%), followed by fresh PL (9.13%). Triple super phosphate became less available over time as Fe-oxides and Al-oxides in the soil absorbed P (Sims et al., 1998; Brady and Weil, 1996). Fresh PL decreased in availability until day 28 (4.35%) and began significantly increasing in availability, 56 d (6.36), until peak availability at 112 d (7.19%). The increase in availability over time is likely from microbial activity, as the fresh material releases the P from PL organic matter (Sharpley et al., 2007). Fresh PL was found to be far less available (9.13%) than the 60-100% bioavailability range the literature field studies suggested (Slaton et al., 2013; Barbazan et al., 2009; Sneller and Laboski, 2009)

The ASH3 co-product remained at a consistent solubility across time and had a range of around 2-4% available P; which was lower than the TSP and fresh PL standards.

When comparing the percentage K recovered/ K fertilizer applied over time by each of the sources (Figure 3.2) a significant K interaction between fertilizer source and incubation sampling day (Table 3.6) was observed. Fresh PL had the greatest initial K availability at 0 d (97.99%). Our results for K availability were closer to the estimated availability in the literature; which stated that K should be highly soluble and should be 100% plant available (Jackson et al., 1975; Slaton et al., 2013). At 56 d there was a significant increase in K availability for ASH3 (54.54%). Fresh PL was by far the highest supplier of water soluble K, which was expected as the standard unprocessed material.

3.3 Conclusion

The industry inorganic standard fertilizer (TSP) and fresh PL had the greatest initial availability for P and K. Further ash research will be needed for each thermo-conversion system and feedstock as the burning process significantly alters the overall nutrient water solubility over time.

3.4 References

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3.5 Tables

Table 3.1: Mehlich-I background analysis of nutrients of the Bojac sandy loam soil (coarse, loamy, mixed, semiactive, thermic, Typic Hapludult) used in the incubation studies.

	P	K	Ca	Mg	Zn	Mn	Cu	Fe	B
	-----------------------------kg ha^{-1}-------------------------				-------------------------------------mg kg^{-1}---------------------------------				
Soil	194	146	832	95	1.4	25.4	1.3	25.0	0.2

Table 3.2: Chemical and physical properties of the Bojac sandy loam soil (coarse, loamy, mixed, semiactive, thermic, Typic Hapludult) used in the incubation studies.

	pH	Buffer Index	Estimated CEC†	Bulk Density	Acidity	Base Saturation
			---meq 100 g^{-1}---	g cm^{-3}	----------------------%-------------------	
Soil	5.4	6.14	3.9	1.136	39.5	60.6

†CEC- Cation exchange capacity

Table 3.3: Nutrient content of PL co-products, fresh PL and standard fertilizer for P and K incubation study.

Source	N	P	K	S
	--%---			
ASH3	0.280	10.39	11.25	2.29
PL	3.55	1.08	1.91	1.10
TSP	0.00	20.09	0.00	0.00

Table 3.4: Phosphorus availability as a percentage of total P recovered or total P applied over a 140 d incubation study with a Bojac sandy loam soil (coarse, loamy, mixed, semiactive, thermic, Typic Hapludult) for PL co-products and fresh PL and standard P fertilizer.

	----------Incubation Day----------								
	0	3	7	14	28	56	84	112	140
	----------% P Recovered----------								
ASH3	2.44	3.40	3.24	2.72	2.72	3.12	3.75	3.95	3.45
PL	9.13	4.50	5.21	4.64	4.35	6.36	6.65	7.19	5.25
TSP	55.50	15.12	12.32	11.31	11.36	7.43	6.68	5.25	5.88

† Phosphorus source x incubation time interaction $LSD_{0.10}$=1.99%.

Table 3.5: Potassium availability as a percentage of total K recovered or total K applied over a 140-d incubation study with a Bojac sandy loam soil (coarse, loamy, mixed, semiactive, thermic, Typic Hapludult) for PL co-products and fresh PL.

	-------Incubation Day-------							
	0	3	7	14	56	84	112	140
	-------% K Recovered-------							
ASH3	41.29	53.59	51.17	39.48	54.54	62.74	61.77	57.59
PL	97.99	88.58	88.36	87.94	88.19	93.24	92.75	87.73

†Potassium source x incubation time interaction $LSD_{0.10}$=8.99%.

3.6 Figures

Figure 3.1: Phosphorus availability as a percentage of total P recovered or total P applied over a 140 d incubation study with a Bojac sandy loam soil (coarse, loamy, mixed, semiactive, thermic, Typic Hapludult) for PL co-products and fresh PL and standard P fertilizer.

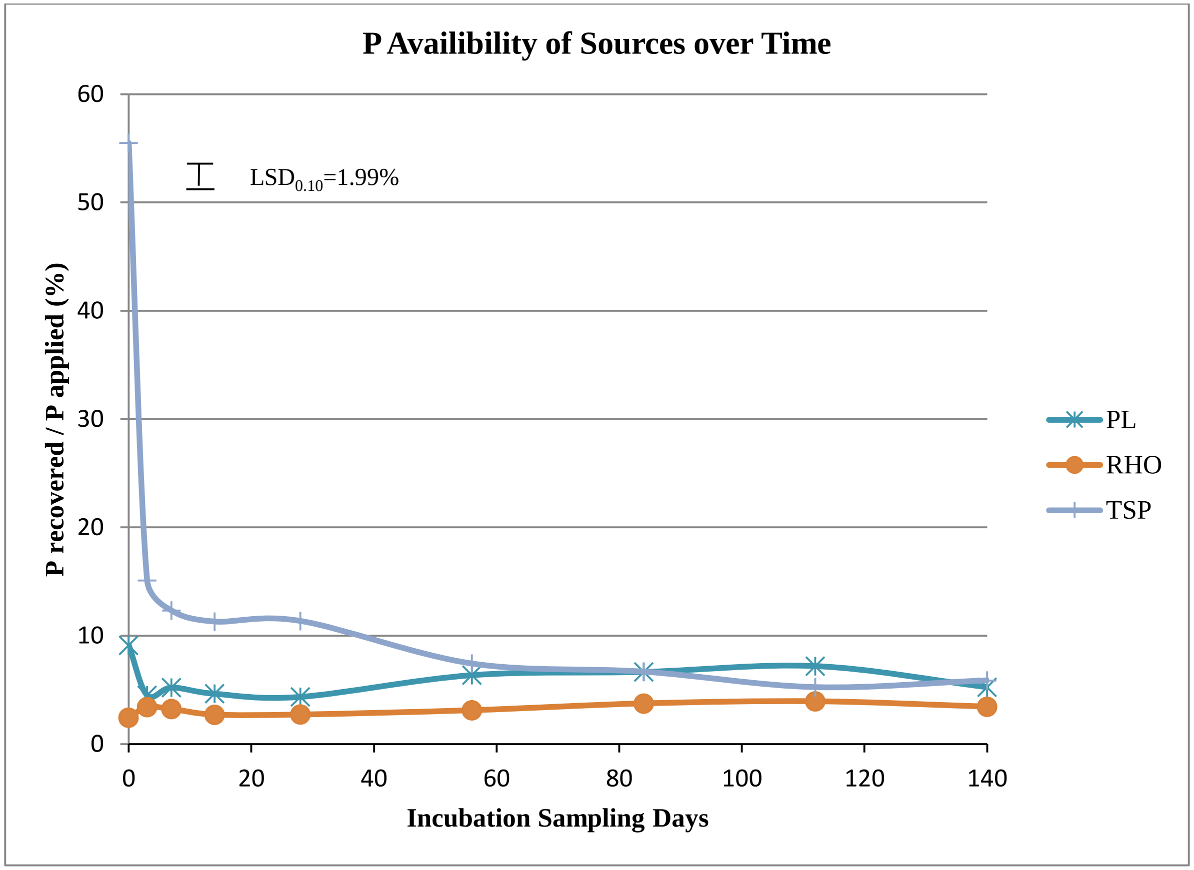
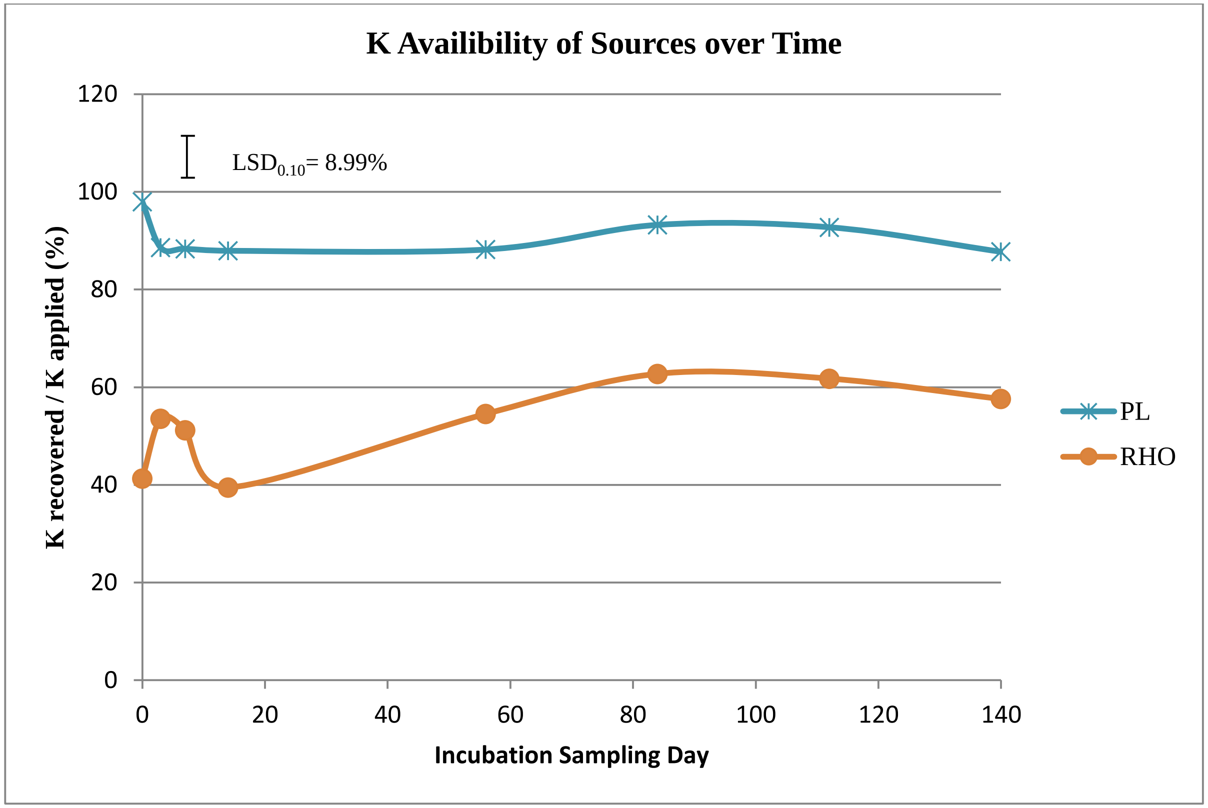


Figure 3.2: Potassium availability as a percentage of total K recovered or total K applied over a 140 d incubation study with a Bojac sandy loam soil (coarse, loamy, mixed, semiactive, thermic, Typic Hapludult) for PL co-products and fresh PL.



4. Nutrient Availability of Poultry Litter Co-Products in Field Trial Applications

4.1 Materials and Methods

4.1.1 Experimental Design

We initiated a study on sandy loam soils (Table 4.1) to test P and K availability from poultry litter ash (PLA) on corn, soybean, and wheat. Overall, three corn P studies, two full-season soybean K studies, three double-crop soybean K studies, three wheat P studies, and three wheat K studies were conducted.

Corn studies were conducted at the Virginia Tech Eastern Shore Agriculture Research and Extension Center (AREC) in Painter, Virginia (2013, 2014) and at the Virginia Tech Tidewater AREC in Suffolk, Virginia (2014). Studies consisted of 4 replications and 25 total fertilizer treatments arranged in a RCBD. The ASH3 was surface broadcast applied at 3 P rates (22, 44, and 88 kg P_2O_5 ha^{-1}). Potassium was applied with a balanced application using KCl to ensure all plants had identical total K rates. Poultry litter co-products were compared to a no-fertilizer control and inorganic P (TSP) fertilizer at similar rates.

Full-season soybean studies were conducted at the Virginia Ag Expo location in the Land of Promise, Virginia (2013) and Lottsburg, Virginia (2014) (Table 4.1). Double-crop soybean studies were conducted on the Eastern Shore of Virginia at 2 sites in Accomack County (2014) (Table 4.1). The studies consisted of 4 replications and 10 total fertilizer treatments arranged in a RCBD. ASH3 was surface broadcast applied at one K rate (67 kg K_2O ha^{-1}) and P was applied with a balanced application using TSP. Poultry litter co-products were compared to a no-fertilizer control and K (KCl) fertilizer at similar rates.

Phosphorus wheat studies were conducted at three locations on the Eastern Shore of Virginia in Accomack County (2014) (Table 4.1). The studies consisted of 4 replications and 13 total fertilizer treatments arranged in a RCBD. One PLA product (ASH3) (Table 4.2) was surface broadcast applied at 4 P rates (34, 67, 101, and 134 kg P_2O_5 ha^{-1}) and K was applied with a balanced application using KCl. Poultry litter co-product was compared to a no-fertilizer control and inorganic P (TSP) fertilizer at similar rates.

Potassium wheat studies were conducted at three locations on the Eastern Shore of Virginia in Accomack County (2014) (Table 4.1). The studies consisted of 4 replications and 13 total fertilizer treatments arranged in a RCBD. One PLA product (ASH3) (Table 4.2) was surface broadcast applied at 4 K rates (34, 67, 101, and 134 kg K_2O ha^{-1}) and P was applied with a balanced application using TSP. Poultry litter co-product was compared to a no-fertilizer control and inorganic K (KCl) fertilizer at similar rates.

4.1.2 Sample Analysis

Yield, grain moisture, and grain test weight were collected at the time of harvest. Grain weight was captured in field by the combine’s software (ALMACO Seed Spector LRX, Nevada, IA). Sample moisture and grain test weight was collected using a GAC® 2100 Agri DICKEY John Moisture Tester (Churchill Industries, Minneapolis, MO). Yield was corrected for percent moisture to industry bushel standards: 25.4 kg (56 lbs) per bushel for corn at 15.5% moisture, 27.2 kg (60 lbs) per bushel for soybeans at 13% moisture, and 27.2 kg (60 lbs) per bushel for wheat at 13.5% moisture (Murphy, 1993).

Plant tissue samples were dried until a constant weight at 55°C. Samples (corn ear leaf, corn grain, soybean tissue at V3 and V5, soybean whole plant at R2, soybean grain, wheat whole plant prior to bloom, and wheat grain) were coarse ground to pass a 2 mm sieve. Ground samples (0.5 g) were digested in nitric acid and hydrogen peroxide using method 3050B (USEPA, 1996), and then analyzed using ICP-OES (Spectro Analytical Instruments, Kleve, Germany) at the Virginia Tech Soil Testing Laboratory (Maguire and Henkendorn, 2011) for P and K.

Mehlich-I extractable nutrients were analyzed with ICP-OES (Mehlich, 1953). Soil samples were taken pre-fertilization at 3 depths: 0-15 cm, 15-30 cm, and 30-60 cm and at harvest at the 0-15 cm depth. Soils were air-dried and ground using a hammer mill to pass through a 2 mm screen. Using the Mehlich-I soil testing protocols, 8 grams of soil were extracted with 40 ml of Mehlich I solution (1:5 soil to extractant ratio) in 60 ml straight-walled plastic extracting beakers. The samples were shaken for 5 minutes on a reciprocating shaker set at 180 opm. Extracts were filtered through Whatman no. 2 filter paper into plastic vials and was then analyzed by ICP-OES for nutrient concentration.

To estimate P currently available in soil solution, 4 grams of soil were extracted with 40 ml of 0.01 $CaCl_2$ solution (1:10 soil to extractant ratio) in 60 ml straight-walled plastic extracting beakers (Aslyng, 1964; Olsen and Sommers, 1982). The samples were shaken for 1 hour on a reciprocating shaker set at 200 opm. Extracts were filtered through Whatman no. 2 filter paper into plastic vials. The solution was analyzed by ICP-OES for nutrients.

Soil organic matter samples were determined using the Loss-On-Ignition (LOI) Method as described by Ben-Dor and Banin (1989). The sample was air-dried at 105°C for 24 hours, cooled in a desiccator and weighed. The sample was then placed in a muffle furnace and ignited at 400°C for 16 hours, cooled in a desiccator and weighed. Organic matter is assumed to equal the % LOI. The LOI was determined by the equation % LOI = ($Weight_{105}$ - $Weight_{400}$ / $Weight_{105}$) x 100 (Ben-Dor and Banin, 1989).

4.1.3 Statistical Analysis

Statistical analysis was conducted using analysis of variance (ANOVA), SAS PROC MIXED procedures and Fisher's LSD with an alpha level of 0.10 using SAS 10.1 statistical software (SAS Institute, 2007).

4.2 Results and Discussion

4.2.1 Corn

There were significant differences between site year so data is presented separately and the P source x P rate interaction was not significant. For the P rate main effect, yield increased in a linear relationship with P rate in the first year (Painter 2013) (Figure 4.1), averaged across P fertilizer sources. Phosphorus was limited in this experiment because a plateau was not reached due to the initial low P testing soil (9 mg kg^{-1}). Yield increased linearly in the second year (Suffolk 2014), until it reached a plateau at 22 kg ha^{-1} (Figure 4.1). After this point, no further benefit to P fertilizer was realize due to high initial soil P concentrations (29 mg kg^{-1}). Yield data from Painter 2014 was omitted due to significant deer damage across all replications.

Overall, for P source, Suffolk 2014 data indicated that PL was significantly the highest yielding source (7891 kg ha^{-1}), averaged over P rate. We speculate that heavy rains during the early growing season leached or denitrified significant amounts of N fertilizer and the slow release N from PL was available to the corn crop and gave a significant yield advantage. The PL ash co-products were similar to TSP but higher than the no P fertilizer control (Table 4.3). Overall, our data agrees with Slaton et al. (2013)

who, found that PL provided an additional yield benefit above that of commercial fertilizer at one of their eight responsive sites and similar yields at the other sites. The cause of the yield benefit was unknown and could not be attributed to another essential nutrient present in the PL but not in the commercial fertilizer (Slaton et al., 2013). The Painter 2013 site was not significant and the average yield was 4565 kg ha^{-1}.

When averaged by site year and P fertilizer source, corn grain moisture had a significant linear response to P rate. Moisture increased with P rate at Suffolk 2014 ($y = 0.0049x + 13.5$; p=0.0640) and the no fertilizer control had the lowest grain moisture (15.85%). No fertilizer plots matured more quickly with lower yields and lower available nutrient concentrations, resulting in lower grain moisture concentrations at harvest.

There were no observed significant differences of P concentration in the corn ear leaf. The ear leaf concentrations averaged (2.2 g kg^{-1}) across all treatments and site years; which is below the optimal range of 2.5-.5.0 g kg^{-1} for tissue P (Bryson et al., 2013). Averaged across site year, grain P concentrations varied with P rate and P source. For P rate, the highest rate 88 kg ha^{-1} had the greatest concentration; which increased linearly ($y = 1.589x + 2129$; p= 0.0578). For P source, the standard, TSP (2.33 g kg^{-1}) had the highest grain P concentration.

4.2.2 Soybeans

Full Season Soybeans

Full season soybean yield, moisture, and test weight varied only with location and K fertilizer source was not significant. The Promise 2013 (2858 kg ha^{-1}) location had a statistically lower yielding crop than Lottsburg 2014 (5115 kg ha^{-1}).

The Lottsburg 2014 had statistically higher moisture concentrations (15.8%) than

Promise 2013 (13.1%). The Lottsburg 2014 grain test weight (1839 kg m^{-3}) was statistically denser than Promise 2013 (709 kg m^{-3}). Therefore, the fertilizer ash co-products were tested under variable growing conditions around Virginia, but source did not matter. Similar data and results were seen in other Virginia studies conducted during these same years at the same locations as ample growing conditions did not necessitate additional K fertility (Stewart, 2015).

All V3 tissue concentrations averaged across all treatments and site years (27.0 g kg^{-1}) were above or within the optimal range of 17.0-25.0 g kg^{-1} for tissue K (Bryson et al., 2013). Tissue K concentration of V5 and R2 tissue varied with location. Lottsburg 2014 (21.0 g kg^{-1} and 25.0 g kg^{-1} for V5 and R2, respectively) had statistically higher concentrations than Promise 2013 (19.0 g kg^{-1} and 14.0 g kg^{-1}, respectively). All V5 and R2 tissue concentrations were within the optimal range of 18.0-25.0 g kg^{-1} for V5 tissue K and 15.0-22.5 g kg^{-1} for R2 tissue K (Bryson et al., 2013). The only significant result from K fertilizer source occurred at the Promise 2013 site location for grain K concentration. All ash co-products were statistically similar to the fresh PL and TSP standards.

Double Crop Soybeans

The ASH3 was similar to applying no fertilizer at all (Table 4.6). The R2 tissue K concentration averaged across location, Willis Wharf B site had significant differences between K sources. Poultry litter had the highest tissue K concentration at R2 (28.0 g kg^{-1}) than other co-products. All other co-products were similar to the no-fertilizer control. However, all R2 tissue concentrations were within the optimal range of 15.0-22.5 g kg^{-1} for R2 tissue K (Bryson et al., 2013). Muriate of potash (18.4 g kg^{-1}) had the highest grain K concentrations.

4.2.3 Wheat P

Overall, there were no major differences between ash co-products for wheat yield. Average yield by location for Gospel Temple was 4133 kg ha^{-1}, Cheriton was 3722 kg ha^{-1}, and Quinby was 3360 kg ha^{-1}. Grain moisture was only significant at the Cheriton site in P rate main effect, averaged over P source. Grain moisture content increased linearly with P addition (y= 0.0025x +13.8; *p*= 0.0100). Similarly, grain test weight decreased linearly with the addition of P (y= -0.0712x + 766; *p*= 0.0351).

For tissue P concentration averaged across P rate, the Gospel Temple site had a significant P source effect. The co-product ASH3 (2.5 g kg^{-1}) was statistically similar to TSP (2.8 g kg^{-1}), but had lower concentrations than PL (3.0 g kg^{-1}). However, all tissue P samples were within the range of 2.0-5.0 g kg^{-1} for tissue P (Bryson et al., 2013). Codling et al. (2002) found that PLA treatments produced higher tissue P concentrations than the standard, although their concentrations were below the optimum range due to initial low soil P concentrations. Overall, there were no major differences between ash co-products grain P concentration and averaged 3.9 g kg^{-1} for Quinby, 3,8 g kg^{-1} for Gospel Temple, and 3.7 g kg^{-1} for Cheriton.

4.2.4 Wheat K

Averaged across location and K fertilizer rate, PL was statistically the highest yielding (3744 kg ha^{-1}). Muriate of potash and ASH3 were similar to the no fertilizer control treatments (3398 kg ha^{-1}) (Table 4.7). Therefore, the PL provided additional yield benefit just as in a soybean study by Slaton et al. (2013) although; the source of the additional benefit was unknown. Moisture exhibited similar results to yield when averaged over K rate, as PL (13.8%) was statistically the driest source and KCl and ASH3 were statistically similar to each other and drier than the control plot (14.3%) (Table 4.7).

The tissue K concentration increased linearly with increasing fertilizer rate ($y= 21.29x + 13051$; $p= 0.0017$) (Figure 4.2); which is indicative of K availability and plant uptake from the fertilizer sources. Averaged across location and K rate, tissue K concentration from fresh PL (16.2 g kg^{-1}) was statistically higher than KCl and ASH3 (Table 4.6). Only the PL source had tissue K concentrations within the optimal range of 15.0-30.0 g kg^{-1} for tissue K (Bryson et al., 2013). Quinby had a significant difference between K fertilizer sources, averaged across K rates. The ASH3 co-product (4.3 g kg^{-1}) was statistically similar to PL (4.3 g kg^{-1}) and had higher grain K concentrations than KCl (4.1 g kg^{-1}) and the control plot (4.1 g kg^{-1}) Therefore, the co-product was equally plant available compared to the standard sources.

4.2.5 Soil Mehlich-I and Soil Organic Matter

Following harvest, the P and K concentrations in the soil increased linearly with rate of fertilizer application, averaged over fertilizer source. Soil P concentrations increased linearly with the addition of fertilizer at the Painter 2014 corn location ($y= 0.0549x + 3.8$; $p= 0.0115$) (Figure 4.3) and soil K concentration for the wheat K locations ($y= 0.1873x + 81.7$; $p= 0.0088$) (Figure 4.4).

For the Gospel Temple site year P source main effect, PL (32.5 mg P kg^{-1}) had higher P concentrations than the TSP standard (29.7 mg P kg^{-1}) most likely due to its greater residual P although not significantly different than the ASH3 ash co-product (29.7 mg P kg^{-1}) or no fertilizer control (27.7 mg P kg^{-1}).

The vast majority of micro elements increased linearly with increasing rate of fertilizer application and was observed with Al, Ca, Cu, B, Mg, and Zn. The overall Fe concentration in the soil made it difficult to see an Fe response from the application of the fertilizers. Overall, Zn tended to be less concentrated in the soil fertilized by ash co-products leading us to believe that Zn is more plant available in the ash form. Soil B concentration trended to be higher following PL applications. Soil Cu concentrations tended to be higher following PL and ash, as Cu is typically absent from inorganic fertilizers. None of the soil applied elements exceeded concentrations that would cause environmental concern based on comparison of background concentrations in US soils according to the elemental limit recommendation charts from the USDA-NRCS (2015).

4.3 Conclusion

Overall, PL ash sources derived from PL are suitable and comparable P and K fertilizer sources for crops on sandy loam soils in the Mid-Atlantic. If all ideal combustion criteria are met, then PL co-products are feasible to use as fertilizer sources, but will need to be individually analyzed for nutrient content before making application recommendations. In our study, we found that the combustion systems seemed to have those ideal conditions and produced co-products that were highly plant available. A greater amount of the co-products will have to be applied to meet the same nutrient availability of the standards due to their lower availability. Fresh PL tends to be the better fertilizer due to its added N content, which is lost in thermo-conversion systems and would have to be supplemented with the ash co-products. More research using the water soluble availabilities instead of the total concentration nutrients of the co-products are needed to be able to identify stronger relationships with standard fertilizers.

4.4 References

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4.5 Tables

Table 4.1 Locations, soil types, and soil characterization for all field trial site locations.

Year	Location	Crop	Texture	Classification	CEC†	pH	P	K	Ca	Mg
					--meq 100 g^{-1}--		------------mg kg^{-1}----------			
2013	Painter, VA	C‡	SL§	Typic Hapludults	5.6	5.7	9	71	641	92
2014	Painter, VA	C	SL	Typic Hapludults	5.4	6.1	5	60	686	95
2014	Cheriton, VA	W	FSL	Typic Hapludults	4.2	6.3	37	87	460	117
2014	Quinby, VA	W	SL	Typic Hapludults	4.8	5.6	36	109	473	71
2014	Willis Wharf, VA	SB/W	SL	Typic Hapludults	6.0	5.3	86	128	646	49
2014	Gospel Temple, VA	W	SL	Typic Hapludults	5.3	5.7	31	143	592	63
2014	Keller, VA	SB	LS	Typic Hapludults	4.2	6.0	14	102	569	55
2013	Land of Promise, VA	SB	L	Typic Hapludults	8.6	5.8	48	54	958	145
2014	Suffolk, VA	C	LS	Typic Hapludults	2.8	5.0	29	94	247	51
2014	Lottsburg, VA	SB	FSL	Aquic Hapludults	5.9	6.6	84	108	783	207

† CEC- cation exchange capacity

‡ C-Corn, W- Wheat, SB- Soybean

§SL- sandy loam, L- loam, FSL- fine sandy loam, LS- loamy sand

Table 4.2: Nutrient content of Ash and Biochar Treatment Sources for field studies.

Source	N	P	K	S
	---%--			
ASH3‡	0.280	10.39	11.25	2.29
PL	3.55	1.08	1.91	1.10
TSP	0.00	20.09	0.00	0.00
KCl	0.00	0.00	53.57	0.00

‡ Combustion

Table 4.3: Corn yield at the Suffolk 2014 site year comparing poultry litter co-product fertilizers to industry standard fertilizers

Source	Suffolk 2014
	--kg ha^{-1}---
ASH3	6476b
PL	7891a
TSP	6871b
Control	5566c
$LSD_{0.10}$	834†

† A different letter within the column designates significance at the 0.10 level.

Table 4.4: Average corn grain test weight and grain P concentration across 3 site locations comparing PL co-products, fresh PL, and standard fertilizers.

Source	Test Weight	Grain P Concentration
	--------------------------kg m^{-3}------------------------	-----------------------------------g kg^{-1}-------------------------------------
ASH3	686.1a	2.16c
PL	688.3a	2.26b
TSP	690.9a	2.32a
Control	688.9a	2.16c
$LSD_{0.10}$	8.5	0.06

†A different letter within the column designates significance at the 0.10 level.

Table 4.5: Double crop soybean yield response to K source for WWA site location comparing PL co-products, fresh PL, and standard fertilizers.

Source	Yield
	----------------------------------kg ha^{-1}--------------------------------
ASH3	2397a
PL	2414a
KCl	2195ab
Control	2222ab
$LSD_{0.10}$	321

†A different letter within the column designates significance at the 0.10 level.

Table 4.6: Double crop soybean moisture, test weight, and grain K concentration by source over 3 site locations comparing PL co-products, fresh PL, and standard fertilizers.

Source	Grain Moisture	Test Weight	Grain K Concentration
	-------------------%----------------	----------------kg m^{-3}-------------	-----------------g kg^{-1}-------------
ASH3	12.9cd	714.7cd	17.3d
PL	13.1a	718.1abc	18.0b
KCl	13.0a	721.4a	18.4a
Control	13.0a	713.8d	17.9bc
$LSD_{0.10}$	0.1	3.9	0.4

†A different letter within the column designates significance at the 0.10 level.

Table 4.7: Wheat yield, grain moisture, and tissue K concentration response to K source across 3 site locations comparing ash co-product, fresh PL, and standard fertilizers.

Source	Yield	Grain Moisture	Tissue K Concentration
	----------------kg ha^{-1}-------------	------------------%---------------- -	---------------g kg^{-1}-------------- -
ASH3	3214b	14.0b	14.1b
PL	3744a	13.8c	16.2a
KCl	3319b	14.0b	14.2b
Control	3397b	14.3a	12.8c
$LSD_{0.10}$	222	0.1	0.7

†A different letter within the column designates significance at the 0.10 level.

Table 4.8: Soil K Concentration by fertilizer source for the Painter 2014 corn site location.

Source	Painter 2014
	---------------K---------------
	---------------mg kg^{-1}---------------
ASH3	77.0b
PL	74.9bc
TSP	69.4bc
Control	74.4bc
$LSD_{0.10}$	10.0

†A different letter within the column designates significance at the 0.10 level.

4.5 Figures

Figure 4.1: Corn yield by P rate for 2 corn site locations.

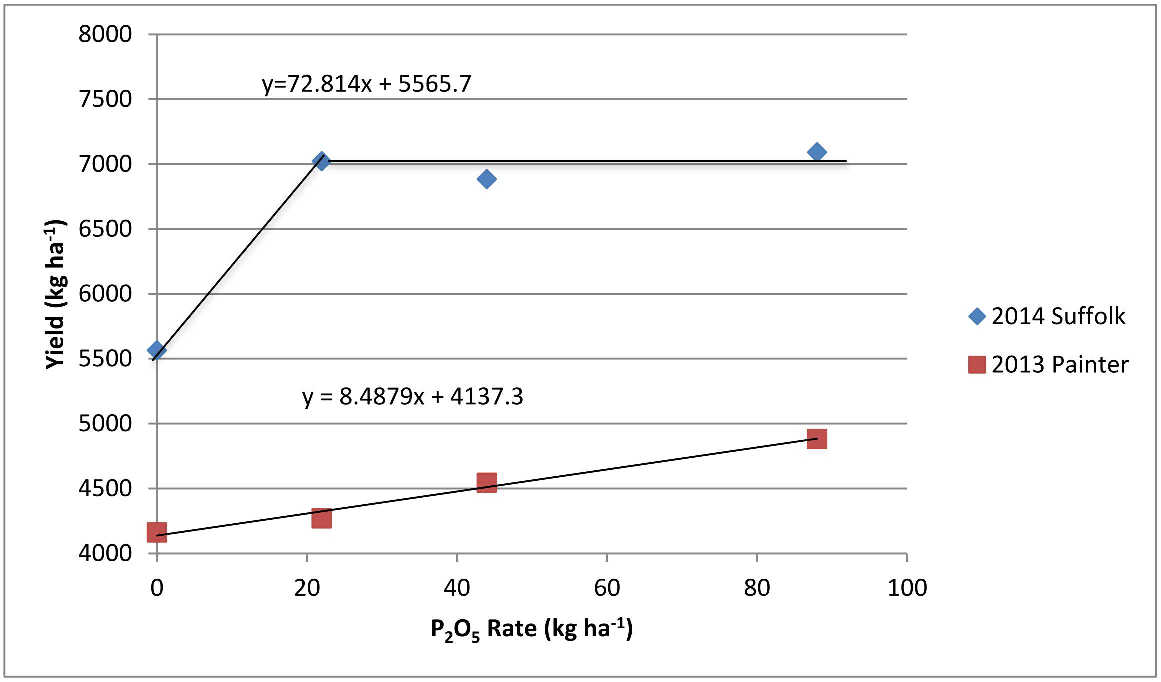


Figure 4.2: Wheat K tissue K concentration response to rate of K across 3 site locations.

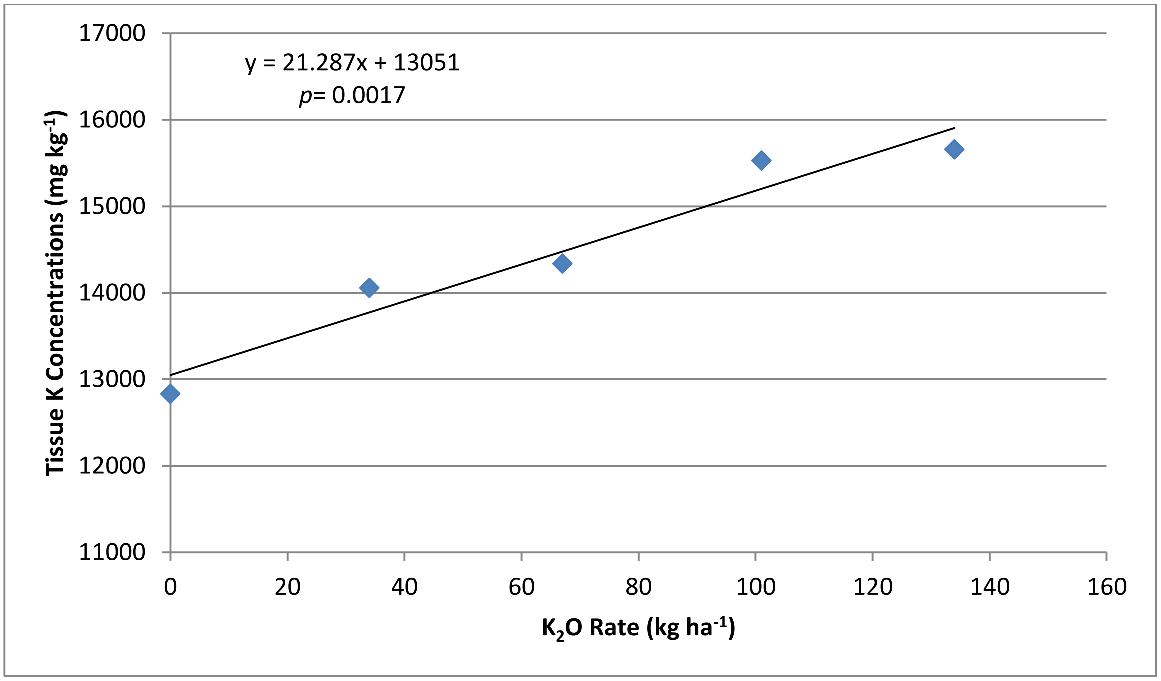


Figure 4.3: Soil P concentration by treatment rate for the Painter 2014 site location.

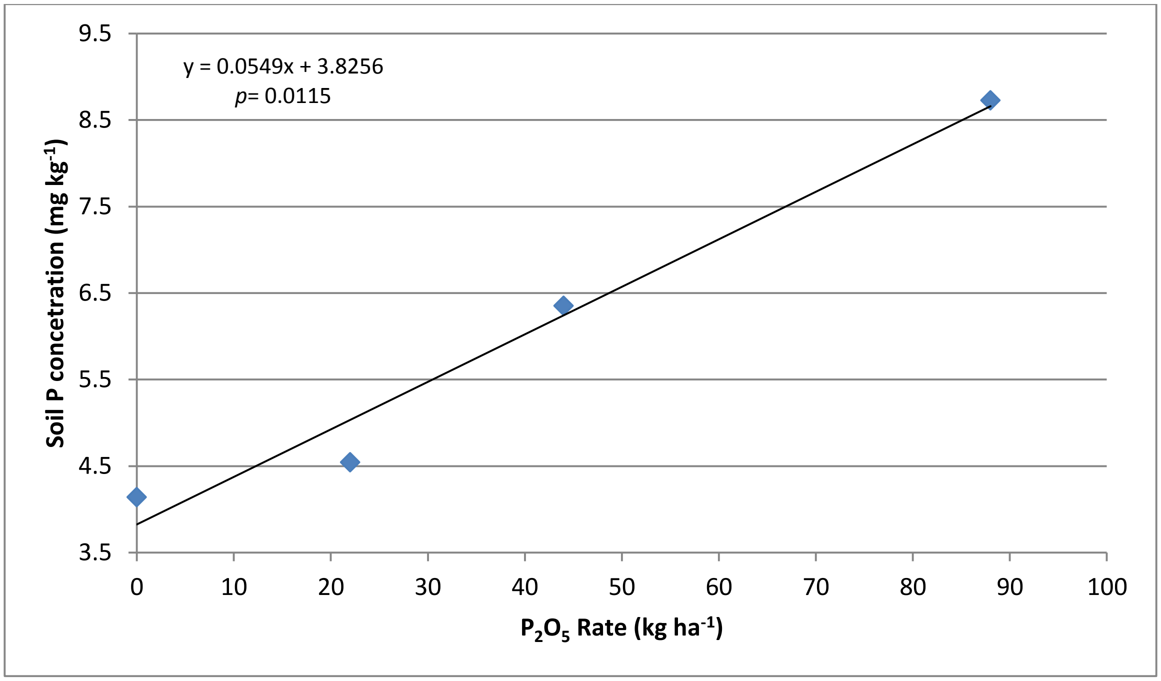
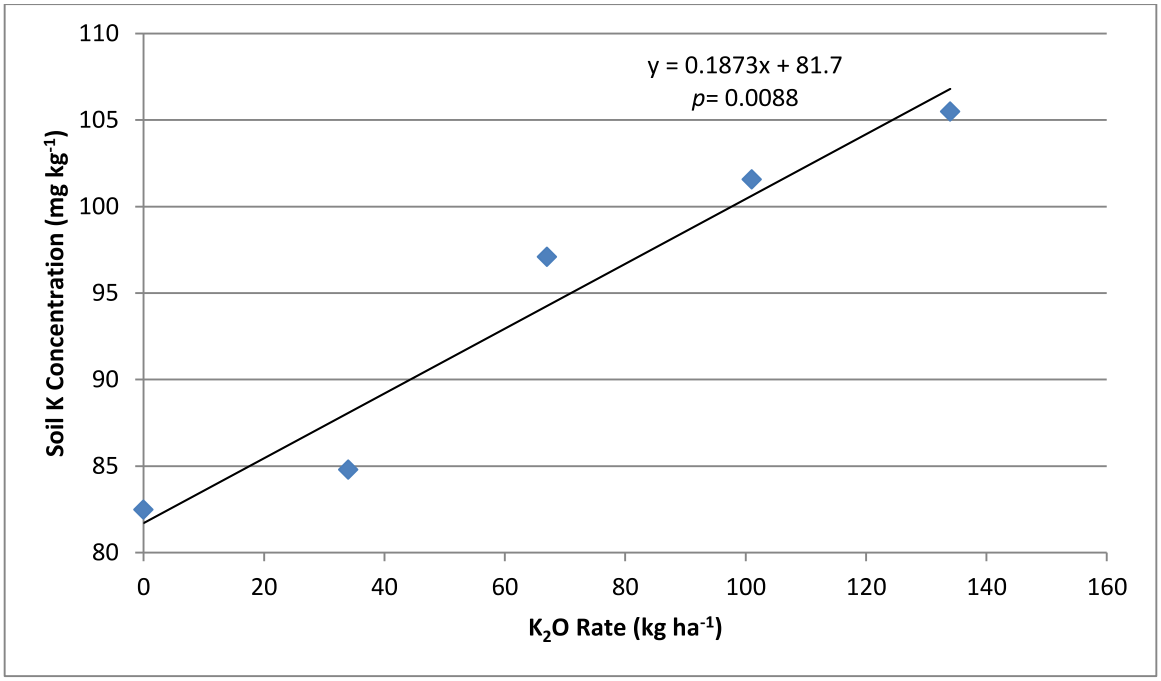


Figure 4.4: Soil K concentration by treatment rate for Wheat K site locations.



5. Granulation of ash co-products.

5.1. Materials and Methods

We demonstrated the ability of ash co-products to be granulated into spheres similar to inorganic fertilizer sources using commercial granulation equipment. Granulation binder additives were necessary to introduce the liquid needed for the granule formation using centrifugal force. Binders included water, urea-ammonium nitrate solution, and lignosulfonate. Urea was added to several treatments to introduce inorganic N back into the fertilizer formulation. The ASH3, from combustion

5.2. Results and Discussion

In all cases, suitable spheres were formed, regardless of binder. It did take several tries for the proper ratio of binder and ash to be mixed, but after trial and error a suitable product was developed. All ash granules had suitable hardness, size, and shape as commercial fertilizer sources. As each binder and/or additive was changed, a new ratio of ash and binder was needed for optimal performance.

5.3 Conclusion

Ash co-products can be granulated into commercial fertilizer sources that look similar to those fertilizers already used by commercial farmers. Ash each ash product and fertilizer formulation comes into production, that particular fertilizer product will need to be researched to ensure overall fertilizer characteristics are maintained.

6. Summary and Conclusions

Several factors impact the overall nutrient concentrations of PL ash co-products and their resulting availability. The thermo-combustion system is one variable; which includes the temperature of combustion, the fuel to oxygen ratio for combustion, the residence time of the PL feedstock, and if the system has an exhaust scrubbing system to catch fly ash co-products. Another major factor is the PL from which the co-product is formed; the initial concentration of nutrients, the bedding material, and the moisture content of the PL impact the end co-product. Our study found that nutrient densification varied between P concentrations of 4-10 times concentrated, K concentration ranged 2.5-5 times concentrated, and S ranged 2-3 times concentrated. Our comparisons between total nutrient digestions and water soluble extractions found that the ash products were significantly less plant available than the standard fertilizers (TSP and KCl). A greater amount of the co-products will have to be applied to meet the same nutrient availability of the standards. Overall, if all ideal combustion criteria are met, then PL co-products are feasible to use a fertilizer sources, but will need to be individually analyzed for nutrient content before making application recommendations. More research into balance comparisons are needed to be able to identify stronger relationships within the nutrients.

The industry inorganic standard fertilizer (TSP) and fresh PL had the greatest initial availability for P and K. Overtime, some of the ash co-products reached similar availabilities comparable to the standards but differed due to the variability in their systems of formation. Further ash research will be needed for each thermo-conversion system and feedstock as the burning process significantly alters the overall nutrient water solubility over time.

Poultry litter co-products vary greatly based on thermo-conversion system and initial feedstock. If all ideal combustion criteria are met (ie. 700-1000ºC; 25% moisture), then PL co-products are feasible to use as fertilizer sources, but will need to be individually analyzed for nutrient content before making application recommendations. A greater amount of the co-products will have to be applied to meet the same nutrient availability of the standards due to their lower availability. Fresh PL tends to be the better fertilizer due to its added N content, which is lost in thermo-conversion systems and would have to be supplemented with the ash co-products. More research using the water soluble availabilities instead of the total concentration nutrients of the co-products are needed to be able to identify stronger relationships with standard fertilizers.

Eastern Shore RC&D
Project Financial Report Form
CIG 69-3A75-11-198

Tax ID Number	02-0534828		
Sub-award	Farm Pilot Project Coordination	Invoice Payable to:	(same)
Contact Person:	Jule Doran	Phone #:	(813) 222-3286
Mailing Address	P.O. Box 3031	Email:	jule.doran@fppcinc.org
	Tampa, FL 33601-3031		
Project Title:	*Glenn Rodes Farm*		
Reporting Period:	January 2015 - August 2015		

Funds (Federal)

	TOTAL Project Budget	Project Budget Begin Q1 2015	2015 Expenditures Expenditures	*Unexpended Project Balance
Personnel	$ 39,043.00	$ (2,052.45)	$ -	$ (2,052.45)
Travel	$ 14,625.00	$ 5,770.78	$ 3,718.33	$ 2,052.45
Equipment	$ -	$ -		$ -
Supplies	$ 2,400.00	$ 956.07	$ 956.07	$ -
Contractual	$ 90,000.00	$ -		$ -
Construction	$ -	$ -		$ -
Other Direct	$ -			$ -
*TOTAL	$ 146,068.00	$ 4,674.40	$ 4,674.40	$ -

Authorized Signature: Jule Doran

Date: 10/6/15

Eastern Shore RC&D
Project Financial Report Form
CIG 69-3A75-11-198

Tax ID Number	02-0534828		
Sub-award	Farm Pilot Project Coordination	Invoice Payable to:	(same)
Contact Person:	Jule Doran	Phone #:	(813) 222-3286
Mailing Address	P.O. Box 3031	Email:	jule.doran@fppcinc.org
	Tampa, FL 33601-3031		
Project Title:	*Marc Marsh Farm*		
Reporting Period:	January 2015 - August 2015		

Funds (Federal)

	TOTAL Project Budget	Project Budget Begin Q1 2015	2015 Expenditures Expenditures	*Unexpended Project Balance
Personnel	$ 85,500.00	$ 2,037.50	$ 2,037.50	$ -
Travel	$ 22,805.00	$ 12,792.64	$ 12,792.64	$ -
Equipment	$ -	$ (35,000.00)	$ (35,000.00)	$ -
Supplies	$ 62,375.00	$ 19,470.05	$ 19,470.05	$ -
Contractual	$ 31,500.00	$ 31,500.00	$ 31,500.00	$ -
Construction	$ -	$ -		$ -
Other Direct	$ 18,031.00	$ 18,031.00	$ 18,031.00	$ -
*TOTAL	$ 220,211.00	$ 48,831.19	$ 48,831.19	$ -

Authorized Signature: Jule Doran

Date: 10/6/15

Eastern Shore RC&D CIG
Match through FPPC

			Actual
Non-Federal Cash Match			
Personnel			
	BGP Manager	$5,600	$5,600
	Farmer - GR	$21,000	$21,000
	Farmer - MM	$21,000	$24,552
Equipment			
	BGP Gasifier	$100,000	$100,000
	Global ReFuel	$75,000	$86,921
Construction			
	Farmer - GR	$15,000	$16,562
In-kind MATCH			
Fringe			
	Farmer - GR	$7,000	$13,000
	Farmer - MM	$7,000	$7,000
Travel			
	Farmer - MM	$9,625	$9,800
Equipment			
	Farmer - MM	$16,000	$18,052

BGP International cost Allocations for FPPC S.C. Project 2012 -Sept. 2015

	Total hours	hourly Rate	Total/Invoice amount	
Webinar	54	$ 50.00	$ 2,700.00	
Marketing Materials			$ 8,000.00	
Office Rental			$ 7,800.00	
Website Design			$ 8,500.00	
Website redesign			$ 4,950.00	
Network Solutions Online			$ 1,220.00	
Callture conference Call lines			$ 320.00	
FPPC Conference Calls	32	$ 50.00	$ 1,600.00	
Travel			$ 7,000.00	
Investor Email for prospecting and Webinar	98	$ 50.00	$ 4,900.00	
Investor Meetings	118	$ 50.00	$ 5,900.00	80 meeting dates at 1.5 hours per meeting
Total Costs			**$ 52,890.00**	

Detailed List of Meetings upon request

Eastern Shore RC&D/FPPC Riverhill Farms

P.O. Box 442, Melfa, VA 23410

2013 Date of Contribution	Description of Contributed Item(s) or Service	Purpose for which Contribution was made	Real or Approx. Value of Contribution	How was Value Determined (i.e. actual, appraisal, fair market value)	Who Made this Value Determination?	Was Contribution Supported by Federal Funds? (If so, indicate source)
11/30/12	Shipping and manure for testing	Testing and programming the system	$2,600	Actual		No
12/3/12 - 3/1/13	manhours to operate at fabrication facility	test fire turkey litter to program PLC	$13,960	Actual		No
02/27/13	manhours, supplies and carrier costs	shipping to Port Republic	$5,500	Actual + fair market		No
03/30/13	HVAC ductwork materials and installation- Landis	Deliver heat to the house	$11,500	Actual		No
3/18/13 - 3/30/13	manhours, travel - Jim Raley	Operate and monitor equipment, training	$7,286	Actual		No
04/25/13	Shipping and manure for testing	Testing to reduce smoke	$2,650	Actual		No
2/27/13 - 3/1/13	manhours, travel	site design coordination & set equipment	$8,773	Actual + fair market		No
02/27/13	Shipping equipment to Port Republic	Shipping equipment	$2,500	Actual		No
3/18/13 - 3/25/13	manhours, travel	site training and testing of equipment	$5,231	Actual + fair market		No
4/22/13 - 4/26/13	manhours, travel, supplies	installation and training	$6,921	Actual + fair market		No
02/27/13	equipment discount	Cost Share	$20,000	Actual		No

Name of Contributing Organization/Agency/Business/Individual:

Phone #: 260-425-9325 **Address: 801 Glasgow Avenue, Fort Wayne, Indiana 46803**

Signature: Tony Tranquill **Date: July 5, 2013**

Global Refuel

Glenn Rodes
5535 Lawyer Road
Port Republic, VA 24471
September 29, 2015

Eastern Shore Resource Conservation and Development Council
P.O. Box 442
Melfa, VA 23410

RE: 2011 CIG Grant Award for *On-farm Demonstration of Energy Generation and Phosphorus Recycling as an Alternative to Land Application of Poultry Litter on the Delmarva*

Dear Eastern Shore Resource Conservation and Development Council,

I own and operate the turkey farm in Port Republic, VA where FPPC has supported the installation of a Global Refuel poultry litter combustion unit to heat one of my turkey houses. I have provided direct support of managing the farm's manure as a feedstock for the equipment and in operating the equipment over the specified performance period. This contribution is estimated at $19,000 for labor, other than construction for the building and $6,500 for fringe over a two-year period. I build a building with a concrete pad to house the system. This cash match including labor was a total of $18,561.82. I have also provided the use of my skid steer to load manure and unload ash for the project. This in-kind match totals approximately $6,500.

Total cash match: $37,561.82

Total in-kind contribution: $13,000

Total match: $50,561.82

Sincerely,
Glenn E Rodes
Glenn Rodes

FPPC **Farm Pilot Project Coordination, Inc.**
Technologies for Nutrient Management

August 1, 2015

Dear RC&D,

Please allow this letter to confirm that Farm Pilot Project Coordination received a total of $100,000, as a cash match from BGP. These funds were used towards the expense related to the gasifier modifications.

Best regards,

Jule M. Doran

101 East Kennedy Boulevard, Suite #3250, Tampa, FL 33602

M Marsh Farms
2434 Brocks Mill Rd
Cheraw, SC 29520
September 18, 2015

Eastern Shore Resource Conservation and Development Council
P.O. Box 442
Melfa, VA 23410

RE: 2011 CIG Grant Award for On-farm Demonstration of Energy Generation and Phosphorus Recycling as an Alternative to Land Application of Poultry Litter on the Delmarva

Dear Eastern Shore Resource Conservation and Development Council,

I own and operate the poultry farm in Cheraw, SC where FPPC partnered with the Eastern Shore Resource Conservation and Development Council on a manure to energy project that produces grid-connected electricity from the energy in poultry litter. I have supported this project on my farm for the original project, and I have continued my cooperation and support to realize additional development and optimization of the project equipment.

I provided direct support to managing the farm's manure as a feedstock for the equipment and in operating the equipment over the specified performance period. This cash contribution is estimated at $21,000 for labor and $7,000 for fringe benefits over a two-year period. I will continue to work with FPPC engineers on the project and provide the use of my farm bungalow for FPPC's field staff on travel. This in kind contribution totaled $9,800. I also provided the use of my skid steer to load manure and unload ash for the project which took the place of using rental equipment. This in-kind match totals $16,000. I also paid for the rental of a lift for the project which totaled $2,052. I provided extra help for the project by paying for a technician's time to help with the project for a week. This totaled $1,500.

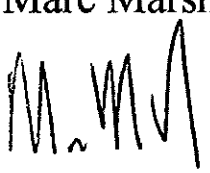
My total cash contribution towards the projects was: $24,552

My total in-kind contribution towards the project was: $32,800

Total: $57,352

The challenges presented by this project are certainly worthwhile and I am happy to be part of this innovative development.

Sincerely,
Marc Marsh



VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY
Blacksburg, VA 24061

INVOICE 7

GRANT CODE 417090

REFERENCE NO. AWARD RECIEVED 2/12/13

DATE: July 1, 2015

Eastern Shore RC&D Council Inc

CTG

Sara Reiter
PO Box 442
Melfa, VA 23410

PAYMENT DUE in 30 DAYS

INVOICE MUST BE INCLUDED WITH PAYMENT
MAKE CHECKS PAYABLE TO TREASURER, VA TECH AND MAIL TO:

Office of Sponsored Programs
North End Center (MC 0170)
300 Turner Street, Suite 4200
Blacksburg, VA 24061

DATE	DESCRIPTION	CREDITS	CHARGES
05/01/15 through 06/30/15 Final	Payment requested for research project entitled: " On-Farm Demonstration of Energy Generation nd Phosphorus Recycling as an Alternative to and Application of Poultry Litter on the Delmarva" PI : Mark Reiter		$1,946.64
	I certify to the best of my knowledge that all expenses reported here are accurate, allowable and allocable to this award. Advances	$0.00	
	PAID #1649 8/25/16	To Be Filed	
	*Both Invoices on Same check.		
	Mubera Cuskovic Post Award Administrator (540)231-9395		

1-30 Days Past Due	31-60 Days Past Due	Over 60 Days Past Due
$2,100.32	$0.00	$0.00

CURRENT AMOUNT DUE	$1,946.64
AMOUNT PAST DUE	$2,100.32
TOTAL AMOUNT DUE	$4,046.96

NET DUE 30 DAYS

NO CASH DISCOUNT

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Blacksburg, VA 24061

INVOICE
7

GRANT CODE
417090

REFERENCE NO.
AWARD RECIEVED 2/12/13

SUBMISSION DATE: July 1, 2015

AGENCY: Eastern Shore RC&D Council Inc

PERIOD: 05/01/15 through 06/30/15

Major Cost Elements	Current Expenditures	Cumulative Expenditures
Salaries and Wages	$1,535.59	$15,731.11
Fringe Benefits	$119.01	$1,263.42
Contractual Services	$0.00	$0.00
Computing Services	$0.00	$0.00
Travel	$0.00	$0.00
Materials and Supplies	$0.00	$0.00
Awards	$0.00	$0.00
Other	$0.00	$0.00
uipment	$0.00	$0.00
Subcontractors	$0.00	$0.00
Total Direct Cost	$1,654.60	$16,994.53
Indirect Costs	$292.04	$2,999.53
Total	$1,946.64	$19,994.06
Advances	$0.00	
Net Bill	$1,946.64	
Retainage	$0.00	$0.00

Submitted By:

Mubera Cuskovic

Mubera Cuskovic
Post Award Administrator
(540)231-9395

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Blacksburg, VA 24061

INVOICE 6

GRANT CODE 417090

REFERENCE NO. AWARD RECIEVED 2/12/13

CIG

PAYMENT DUE in 30 DAYS

TE: May 4, 2015

Eastern Shore RC&D Council Inc

Sara Reiter
PO Box 442
Melfa, VA 23410

INVOICE MUST BE INCLUDED WITH PAYMENT
MAKE CHECKS PAYABLE TO TREASURER, VA TECH AND MAIL TO:

Office of Sponsored Programs
North End Center (MC 0170)
300 Turner Street, Suite 4200
Blacksburg, VA 24061

DATE	DESCRIPTION	CREDITS	CHARGES
04/01/15 through 04/30/15 Partial	Payment requested for research project entitled: " On-Farm Demonstration of Energy Generation nd Phosphorus Recycling as an Alternative to and Application of Poultry Litter on the Delmarva" PI : Mark Reiter I certify to the best of my knowledge that all expenses reported here are accurate, allowable and allocable to this award. **Advances**	$0.00	$4,675.02
	To Be Filed #1649 PAID 8/25/15 Mubera Cuskovic Post Award Administrator (540)231-9395		

1-30 Days Past Due	31-60 Days Past Due	Over 60 Days Past Due
$0.00	$0.00	$0.00

CURRENT AMOUNT DUE	$4,675.02
AMOUNT PAST DUE	$0.00
TOTAL AMOUNT DUE	$4,675.02

NET DUE 30 DAYS

NO CASH DISCOUNT

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Blacksburg, VA 24061

INVOICE
6

GRANT CODE
417090

REFERENCE NO.
AWARD RECIEVED 2/12/13

SUBMISSION DATE: May 4, 2015

AGENCY: Eastern Shore RC&D Council Inc

PERIOD: 04/01/15 through 04/30/15

Major Cost Elements	Current Expenditures	Cumulative Expenditures
Salaries and Wages	$3,687.86	$14,195.52
Fringe Benefits	$285.81	$1,144.41
Contractual Services	$0.00	$0.00
Computing Services	$0.00	$0.00
Travel	$0.00	$0.00
Materials and Supplies	$0.00	$0.00
Awards	$0.00	$0.00
Other	$0.00	$0.00
uipment	$0.00	$0.00
Subcontractors	$0.00	$0.00
Total Direct Cost	$3,973.67	$15,339.93
Indirect Costs	$701.35	$2,707.49
Total	$4,675.02	$18,047.42
Advances	$0.00	
Net Bill	$4,675.02	
Retainage	$0.00	$0.00

Submitted By:

Mubera Cuskovic

Mubera Cuskovic
Post Award Administrator
(540)231-9395

Employee Time Sheet Tracking Form (Excel)

Organization: ES RC&D

Tracking Form Page #:

Employee Name: Josephine Mooney

PAY PERIOD: Q3 2014 Plus Q1-3 2015

DATE	DESCRIPTION OF ACTIVITY: General summary of work performed by subject area	Hours attributed to funding source			Total Number of Hours
		Funding Source 1:	Total amount includes fringe	Funding Source 3:	
	Grant Adminstration, Financial Reporting and Management	CIG Grant			
Q3 2014	Total 54 hours in Q3 at $26 hr plus .065 fringe =$27.69		1507.1		54
Q1 thru Q3 2015	Total 125 hours at $26 hr plus .065 fringe =$27.69		3461.62		124
	WAGE EMPLOYEES. TOTAL $ Amount plus HOURS ----> *Use this figure for wage employees. Multiply hours by employee hourly pay to calculate charges for each funding source.*	0	4969	0	178
	SALARY EMPLOYEES. $ TIME SPENT ----> *This percent is used for salaried employees. Total must be 100%.*				

Signature of Employee : Josephine Mooney

Signature of Supervisor: Edwin R. Long

Note: $1507.10 was reported on the 2014 Q3 report but the total was not carried over in the final amount requested nor in the payment check

Therefore on the close out for 2015 the $1507.10 was added to the amount accumulated in Q's 1 thru 3 in 2015

(DCR199-174) (09/2011)

REQUEST FOR ADVANCE OR REIMBURSEMENT (See instructions on back)	OMB APPROVAL NO. 0348-0004		PAGE 1 OF 2 PAGES
	1. TYPE OF PAYMENT REQUESTED	a. "X" one or both boxes: ☐ ADVANCE ☒ REIMBURSEMENT; b. "X" the applicable box: ☐ FINAL ☒ PARTIAL	2. BASIS OF REQUEST: ☒ CASH ☐ ACCRUAL
3. FEDERAL SPONSORING AGENCY AND ORGANIZATIONAL ELEMENT TO WHICH THIS REPORT IS SUBMITTED: USDA - NRCS	4. FEDERAL GRANT OR OTHER IDENTIFYING NUMBER ASSIGNED BY FEDERAL AGENCY: 69-3A75-11-198		5. PARTIAL PAYMENT REQUEST NUMBER FOR THIS REQUEST: 361-8
6. EMPLOYER IDENTIFICATION NUMBER: 54-1422494	7. RECIPIENT'S ACCOUNT NUMBER OR IDENTIFYING NUMBER	8. PERIOD COVERED BY THIS REQUEST — FROM (month, day, year): 07 01 14	TO (month, day, year): 09 30 14

9. RECIPIENT ORGANIZATION	10. PAYEE (Where check is to be sent if different than item 9)
Name: Eastern Shore RC&D	Name
Number and Street: P.O. Box 442	Number and Street
City, State and ZIP Code: Melfa, VA 23410	City, State and ZIP Code

11. COMPUTATION OF AMOUNT OF REIMBURSEMENTS/ADVANCES REQUESTED

PROGRAMS/FUNCTIONS/ACTIVITIES ►		(a) RC&D	(b) FPPC Subaward A	(c) FPPC Subaward B	TOTAL
a. Total program outlays to date	(As of date)	$ 10,590.09	$ 246,814.60	$ 245,317.82	$ 502,722.51
b. Less: Cumulative program income					0.00
c. Net program outlays (Line a minus line b)		10,590.09	246,814.60	245,317.82	502,722.51
d. Estimated net cash outlays for advance period					0.00
e. Total (Sum of lines c & d)		10,590.09	246,814.60	245,317.82	502,722.51
f. Non-Federal share of amount on line e		0.00	105,421.00	113,758.00	219,179.00
g. Federal share of amount on line e		10,590.09	141,393.60	131,559.82	283,543.51
h. Federal payments previously requested		9,082.9	138,387.32	85,052.27	[illegible]
i. Federal share now requested (Line g minus line h)		1,507.10	3,006.28	46,507.55	49,513.83
j. Advances required by month, when requested by Federal grantor agency for use in making prescheduled advances	1st month				0.00
	2nd month				0.00
	3rd month				0.00

12. ALTERNATE COMPUTATION FOR ADVANCES ONLY

a. Estimated Federal cash outlays that will be made during period covered by the advance	$
b. Less: Estimated balance of Federal cash on hand as of beginning of advance period	
c. Amount requested (Line a minus line b)	$ 0.00

AUTHORIZED FOR LOCAL REPRODUCTION (Continued on Reverse) STANDARD FORM 270 (Rev. 7-97) Prescribed by OMB Circulars A-102 and A-110

Please note. In Q3 2014 we requested $1507.10 reimbursement but it dropped out of the total column and therefore was never paid.

So we have added that amount to the amount claimed for

Q's 1 thru 3 2015 on the close out SF 230 .

Also attached below is the reimbursement payment we received for Q3 showing we received the lower amount of

$49, 513.83 instead of what we should have received if I hadn't made the mistake.

$49,513.83 Plus $1507.10 should have totaled $51,020.93.

I apologize for the error and any confusion this has caused.

Shore Bank

June 2015

C1G

STATE AND MUNICIPAL CHECKING - XXXXXX0397

Account Summary

Date	Description	
05/30/2015	Beginning Balance	$15,989.80
06/30/2015	Ending Balance	$107,221.14

Other Credits

Date	Description	Amount
	MISC PAY USDA TREAS	
	MISC PAY USDA TREAS	

Daily Balances

Date	Amount

Overdraft and Returned Item Fees

	Total for this period	Total year-to-date
Total Overdraft Fees		
Total Returned Item Fees		

Rec'd 8.1.13

Eastern Shore RC&D/FPPC Riverhill Farms

P.O. Box 442, Melfa, VA 23410

2013 Date of Contribution	Description of Contributed Item(s) or Service	Purpose for which Contribution was made	Real or Approx. Value of Contribution	How was Value Determined (i.e. actual, appraisal, fair market value)	Who Made this Value Determination?	Was Contribution Supported by Federal Funds? (If so, indicate source)
11/30/12	Shipping and manure for testing	Testing and programming the system	$2,600	Actual		No
12/3/12 - 3/1/13	manhours to operate at fabrication facility	test fire turkey litter to program PLC	$13,960	Actual		No
02/27/13	manhours, supplies and carrier costs	shipping to Port Republic	$5,500	Actual + fair market		No
03/30/13	HVAC ductwork materials and installation- Landis	Deliver heat to the house	$11,500	Actual		No
3/18/13 - 3/30/13	manhours, travel - Jim Raley	Operate and monitor equipment, training	$7,286	Actual		No
04/25/13	Shipping and manure for testing	Testing to reduce smoke	$2,650	Actual		No
Q1 2/27/13 - 3/1/13	manhours, travel	site design coordination & set equipment	$8,773	Actual + fair market		No
02/27/13	Shipping equipment to Port Republic	Shipping equipment	$2,500	Actual		No
Q2 3/18/13 - 3/25/13	manhours, travel	site training and testing of equipment	$5,231	Actual + fair market		No
4/22/13 - 4/26/13	manhours, travel, supplies	installation and training	$6,921	Actual + fair market		No
Q1 02/27/13	equipment discount	Cost Share	$20,000	Actual		No

TOTAL #86921

Name of Contributing Organization/Agency/Business/Individual:

Phone #: 260-425-9325 Address: 801 Glasgow Avenue, Fort Wayne, Indiana 46803

Signature: Tony Tranquill Date: July 5, 2013

in 2013 Q2 Report

Match Documentation
- Tony Tranquill
- Global Refuel

Eastern Shore of Virginia
Resource Conservation and Development Council

Accomack County
Sandra Hart-Mears
Barney Selph
Dave Vaughn
Ex-officio
Grayson Chesser

Northampton County
Butch Nottingham
Joseph Mysko
Sally Richardson

Accomack/ Northampton Planning District Commission
Ray Rosenberger
Dr. Arthur Schwarzschild

Eastern Shore Soil and Water Conservation District
Ruth Boettcher
Edwin R. Long
Keith Privett
Daniel Chuquin

USDA-NRCS
Acquisitions Division
PO Box 2890, Room 5224-S
Washington, DC 20013

November 24, 2015

RE: $8,000 ES RC&D Contribution to Cost Share/MATCH
CIG Grant: *"On-Farm Demonstration of Energy Generation and Phosphorus Recycling as an Alternative to Land Application of Poultry Litter on the Delmarva"*
Original Award Number: 68-3A75-11-198/ **Revised Award:** 69/3A75-11-198
Award Period: 9/15/2011 - 9/15/2014 with a no-cost extension through 9/15/2015

The ES RC&D Council, along with grant partners, is pleased to close out the final details of this research project.

During the course of the project, then Projects Director Sara Reiter worked closely with Virginia Tech and FPPC staff in various capacities. In addition to Sara's time that was reimbursed by the grant, Sara invested additional hours of approximately 3-5 hours per month for over two years, paid by the ES RC&D but not reimbursed by the grant.

Those accumulated hours represent more than $8,000 cost-share contribution by the Council to the CIG research project.

If you have any additional questions, please feel free to contact me at 757-710-7523 or by email at EdwinLong@verizon.net

Yours truly,

Edwin R. Long

Edwin R. Long
Chairman, Eastern Shore RC&D

FILE COPY

Molly Joseph Ward
Secretary of Natural Resources

Clyde E. Cristman
Director

COMMONWEALTH of VIRGINIA

DEPARTMENT OF CONSERVATION AND RECREATION

600 East Main Street, 24th Floor
Richmond, Virginia 23219
(804) 786-6124

November 6, 2015

Josephine A. Mooney
Projects Director
Eastern Shore Resource Conservation & Development Council (ESRCDC)
P.O. Box 442
Melfa, VA 23410

Dear Ms. Mooney:

This letter is to confirm your request that the Department of Conservation and Recreation's Agricultural Best Management Practices Cost-share Program (VACS) designate $150,000 of fiscal year 2015 cost-share funds as in kind match for the "On-farm demonstration of energy generation and phosphorus recycling as an alternative to land application of poultry litter on the Delmarva".

This grant proposal may claim these in-kind match funds from the VACS that were allocated to the Eastern Shore SWCD for use in Accomack and Northampton County during the 2015 fiscal year. Based upon historic data this area typically implements numerous best management practices focused on the reduction of nitrogen and phosphorous contaminates from surface waters.

I trust this letter will be sufficient documentation for confirmation of match. Should you need additional information in the future please contact Gary Moore at the letterhead address or via telephone at (804) 692-0070.

Sincerely,

Darryl Glover
Director, Division of Soil and Water Conservation

CC: Faye Campbell, DCR Finance Office
Gary Moore, DCR Ag. Incentives Program Manager
Jane Corson-Lassiter, USDA NRCS

Match Documentation
Glenn Rodes
Rec'd 8.1.13

Q1 2013 Match Documentation
Cost Info on Litter Burner Project –
Glenn Rodes Costs for Building Construction/Unit Installation (supplied by farmer)

2013 in Q2 Report

	Pad work	2000.00
Building permit	25.00	
	Trusses	1371.00
	Wall forms	50.00
Concrete 35 yds.	3430.22	
	Lumber	1539.48
	Wire and plumbing	619.57
	Roof and side metal	2162.72
	Air permit fee	50.00
	Computer and labor	1543.83
	Humidity sensor	250.00
	Port-o-potty 3 months @ 60.00	180.00
total 13221.82 – CONSTRUCTION		
	125hrs farmer labor @ 35.00	4375.00
	Labor to install roof	440.00
total4815.00 – LABOR		

TOTAL = 18,036.82

Virginia Tech Subcontract to NRCS RC&D Council

Title: "On-farm Demonstration of Energy Generation and Phosphorus Recycling as an Alternative to Land Application of Poultry Litter on the Delmarva."

Date: October 1, 2011 to September 30, 2014

Amount:
Requested: **$20,000**
Cost-Shared: **$5,000** match

Source: **Virginia Tech Eastern Shore Agricultural Research and Extension Center**
Type: In-kind
Status: Pledged
Source Type: Non-Federal
Description: Direct and Indirect

Contact: Dr. Mark Reiter, VA Tech Eastern Shore AREC, 33446 Research Drive, Painter, VA 23424, (757)414-0724, mreiter@vt.edu

Requested Budget:

Item	Fiscal Year 2011-2012	Fiscal Year 2012-2013	Fiscal Year 2013-2014	Total
	$	$	$	$
Personnel – Field technician to assist with ash collection, analysis, and field research.	5,010	3,630	3,702	**12,342**
Fringe – Currently 37.75% of salary.	1,890	1,370	1,398	**4,658**
Equipment	0	0	0	0
Supplies	0	0	0	0
Travel	0	0	0	0
Indirect – 15% of total costs.	1,218	882	900	**3,000**
Total	**8,118**	**5,882**	**6,000**	**20,000**

Cost Share Match:

Item	Fiscal Year 2011-2012	Fiscal Year 2012-2013	Fiscal Year 2013-2014	Total
	$	$	$	$
Personnel – Project PI time and effort for data collection, research and information dissemination.	1,061	1,111	1,155	**3,327**
Fringe – Currently 27.75% of salary.	294	308	321	**923**
Equipment	0	0	0	**0**
Supplies	0	0	0	**0**
Travel	0	0	0	**0**
Indirect – 15% of total costs.	240	250	260	**750**
Total	**1,595**	**1,669**	**1,736**	**5,000**

VIRGINIA DEPARTMENT OF AGRICULTURE
AND CONSUMER SERVICES
Division of Marketing
P.O. Box 686, Melfa, VA 23410
Phone (757) 787-5876 Fax (757) 787-0958

Dear Josephine and Council Members:

Stephen Versen and I are proud of the work that we accomplished on the Eastern Shore RC&D CIG grant on manure to energy that utilized chicken manure to generate energy, fertilizer, and supplement heat in poultry houses. It was an ambitious project that yielded a significant amount of data that will assist future researchers in this endeavor. Based on feedback from USDA, they were well pleased with the results and plan to continue this important work.

As stipulated in the proposal, VDACS in cooperation with Virginia Tech Extension organized and facilitated meetings, arranged for visits and tours by scientists and farmers, and provided exposure at the 2014 Virginia Ag Expo attended by over 3000 farmers and agribusinesses. We worked with Farm Bureau and the Virginia Potato and Vegetable Growers to highlight the ongoing work, and made it possible for RC&D to exhibit free of charge at the Easter Shore Ag Conference for three years, where over 200 attendees daily over six days had the chance to interact with staff and learn about the project. We have also participated with the Waste Solutions Forum in the Shenandoah Valley of Virginia, hosting presentations and assisting with on-site visits at the Glenn Rodes farm in Port Republic. We have worked with numerous stakeholders in small and large groups in formal and informal settings to raise awareness about the potential and real benefits and hurdles facing farmer- owned and operated manure to energy projects. We are confident that this work has laid the foundation for future research. We are pleased that the work conducted under this CIG was collaborative with a CIG administered by the National Fish and Wildlife Foundation with additional funding from EPA and the Bay Funders Network.

Over the course of the project VDACS staff contributed approximately 600 hours ($26,760.00) of staff time in steering committee, field days, outreach and promotion activities. We are confident that in a few years converting manure to energy and to a rich phosphrous substance that can be more easily transported will be an available alternative for poultry growers. . We recognize the importance of this work to balance the use of nutrients generated from animal agriculture in areas where excess contributes to water quality concerns.

Thank you for allowing Kevin and me to work with you on this important project and wish each of you the best in your future endeavors.

Sincerely,

Butch Nottingham

REQUEST FOR ADVANCE OR REIMBURSEMENT

(See instructions on back)

OMB APPROVAL NO. 0348-0004

PAGE 1 OF 2 PAGES

1. TYPE OF PAYMENT REQUESTED
a. "X" one or both boxes: ☐ ADVANCE ☑ REIMBURSE-MENT
b. "X" the applicable box: ☑ FINAL ☐ PARTIAL

2. BASIS OF REQUEST: ☑ CASH ☐ ACCRUAL

3. FEDERAL SPONSORING AGENCY AND ORGANIZATIONAL ELEMENT TO WHICH THIS REPORT IS SUBMITTED: USDA/NRCS

4. FEDERAL GRANT OR OTHER IDENTIFYING NUMBER ASSIGNED BY FEDERAL AGENCY: 69-3A7511-198

5. PARTIAL PAYMENT REQUEST NUMBER FOR THIS REQUEST: 361-9

6. EMPLOYER IDENTIFICATION NUMBER: 54-1422494

7. RECIPIENT'S ACCOUNT NUMBER OR IDENTIFYING NUMBER:

8. PERIOD COVERED BY THIS REQUEST
FROM (month, day, year): 01/01/2015
TO (month, day, year): 08/15/2015

9. RECIPIENT ORGANIZATION
Name: Eastern Shore RC&D
Number and Street: P.O. Box 442
City, State and ZIP Code: Melfa, VA 23410

10. PAYEE (Where check is to be sent if different than item 9)
Name:
Number and Street:
City, State and ZIP Code:

11. COMPUTATION OF AMOUNT OF REIMBURSEMENTS/ADVANCES REQUESTED

PROGRAMS/FUNCTIONS/ACTIVITIES ►		(a) VATech Subaward C	(b)	(c)	TOTAL
a. Total program outlays to date (As of date)		$ 22,812.08	$	$	$ 22,812.08
b. *Less:* Cumulative program income					0.00
c. Net program outlays (*Line a minus line b*)		22,812.08	0.00	0.00	22,812.08
d. Estimated net cash outlays for advance period					0.00
e. Total (*Sum of lines c & d*)		22,812.08	0.00	0.00	22,812.08
f. Non-Federal share of amount on line e		2,818.02			2,818.02
g. Federal share of amount on line e		19,994.06			19,994.06
h. Federal payments previously requested		11,272.08			11,272.08
i. Federal share now requested (*Line g minus line h*)		8,721.98	0.00	0.00	8,721.98
j. Advances required by month, when requested by Federal grantor agency for use in making prescheduled advances	1st month				0.00
	2nd month				0.00
	3rd month				0.00

12. ALTERNATE COMPUTATION FOR ADVANCES ONLY

a. Estimated Federal cash outlays that will be made during period covered by the advance	$
b. *Less:* Estimated balance of Federal cash on hand as of beginning of advance period	
c. Amount requested (*Line a minus line b*)	$ 0.00

AUTHORIZED FOR LOCAL REPRODUCTION

(Continued on Reverse)

13.	CERTIFICATION	
I certify that to the best of my knowledge and belief the data on the reverse are correct and that all outlays were made in accordance with the grant conditions or other agreement and that payment is due and has not been previously requested.	SIGNATURE OR AUTHORIZED CERTIFYING OFFICIAL Edwin R. Long TYPED OR PRINTED NAME AND TITLE Edwin Long, Chairman	DATE REQUEST SUBMITTED January 7, 2016 TELEPHONE (AREA CODE, NUMBER, EXTENSION) 757-442-9126

This space for agency use

Public reporting burden for this collection of information is estimated to average 60 minutes per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding the burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the Office of Management and Budget, Paperwork Reduction Project (0348-0004), Washington, DC 20503.

PLEASE DO NOT RETURN YOUR COMPLETED FORM TO THE OFFICE OF MANAGEMENT AND BUDGET. SEND IT TO THE ADDRESS PROVIDED BY THE SPONSORING AGENCY.

INSTRUCTIONS

Please type or print legibly. Items 1, 3, 5, 9, 10, 11e, 11f, 11g, 11i, 12 and 13 are self-explanatory; specific instructions for other items are as follows:

Item	*Entry*
2	Indicate whether request is prepared on cash or accrued expenditure basis. All requests for advances shall be prepared on a cash basis.
4	Enter the Federal grant number, or other identifying number assigned by the Federal sponsoring agency. If the advance or reimbursement is for more than one grant or other agreement, insert N/A; then, show the aggregate amounts. On a separate sheet, list each grant or agreement number and the Federal share of outlays made against the grant or agreement.
6	Enter the employer identification number assigned by the U.S. Internal Revenue Service, or the FICE (institution) code if requested by the Federal agency.
7	This space is reserved for an account number or other identifying number that may be assigned by the recipient.
8	Enter the month, day, and year for the beginning and ending of the period covered in this request. If the request is for an advance or for both an advance and reimbursement, show the period that the advance will cover. If the request is for reimbursement, show the period for which the reimbursement is requested.
Note:	The Federal sponsoring agencies have the option of requiring recipients to complete items 11 or 12, but not both. Item 12 should be used when only a minimum amount of information is needed to make an advance and outlay information contained in item 11 can be obtained in a timely manner from other reports.
11	The purpose of the vertical columns (a), (b), and (c) is to provide space for separate cost breakdowns when a project has been planned and budgeted by program, function, or activity. If additional columns are needed, use as many additional forms as needed and indicate page number in space provided in upper right; however, the summary totals of all programs, functions, or activities should be shown in the "total" column on the first page.
11a	Enter in "as of date," the month, day, and year of the ending of the accounting period to which this amount applies. Enter program outlays to date (net of refunds, rebates, and discounts), in the appropriate columns. For requests prepared on a cash basis, outlays are the sum of actual cash disbursements for goods and services, the amount of indirect expenses charged, the value of in-kind contributions applied, and the amount of cash advances and payments made to subcontractors and subrecipients. For requests prepared on an accrued expenditure basis, outlays are the sum of the actual cash disbursements, the amount of indirect expenses incurred, and the net increase (or decrease) in the amounts owed by the recipient for goods and other property received and for services performed by employees, contracts, subgrantees and other payees.
11b	Enter the cumulative cash income received to date, if requests are prepared on a cash basis. For requests prepared on an accrued expenditure basis, enter the cumulative income earned to date. Under either basis, enter only the amount applicable to program income that was required to be used for the project or program by the terms of the grant or other agreement.
11d	Only when making requests for advance payments, enter the total estimated amount of cash outlays that will be made during the period covered by the advance.
13	Complete the certification before submitting this request.

REQUEST FOR ADVANCE OR REIMBURSEMENT

(See instructions on back)

OMB APPROVAL NO. 0348-0004

1. TYPE OF PAYMENT REQUESTED
a. "X" one or both boxes: ☐ ADVANCE ☑ REIMBURSEMENT
b. "X" the applicable box: ☑ FINAL ☐ PARTIAL

2. BASIS OF REQUEST: ☑ CASH ☐ ACCRUAL

3. FEDERAL SPONSORING AGENCY AND ORGANIZATIONAL ELEMENT TO WHICH THIS REPORT IS SUBMITTED: USDA/NRCS

4. FEDERAL GRANT OR OTHER IDENTIFYING NUMBER ASSIGNED BY FEDERAL AGENCY: 69-3A7511-198

5. PARTIAL PAYMENT REQUEST NUMBER FOR THIS REQUEST: 361-10

6. EMPLOYER IDENTIFICATION NUMBER: 54-1422494

7. RECIPIENT'S ACCOUNT NUMBER OR IDENTIFYING NUMBER:

8. PERIOD COVERED BY THIS REQUEST
FROM (month, day, year): 01/01/2015
TO (month, day, year): 08/15/2015

9. RECIPIENT ORGANIZATION
Name: Eastern Shore RC&D
Number and Street: P.O. Box 442
City, State and ZIP Code: Melfa, VA 23410

10. PAYEE (Where check is to be sent if different than item 9)
Name:
Number and Street:
City, State and ZIP Code:

11. COMPUTATION OF AMOUNT OF REIMBURSEMENTS/ADVANCES REQUESTED

PROGRAMS/FUNCTIONS/ACTIVITIES ►		(a) RC&D	(b) FPPC Subaward A	(c) FPPC Subaward B	TOTAL
a. Total program outlays to date (As of date)		$ 15,949.23	$ 251,489.00	$ 369,425.00	$ 636,863.23
b. *Less:* Cumulative program income					0.00
c. Net program outlays (*Line a minus line b*)		15,949.23	251,489.00	369,425.00	636,863.23
d. Estimated net cash outlays for advance period					0.00
e. Total (*Sum of lines c & d*)		15,949.23	251,489.00	369,425.00	636,863.23
f. Non-Federal share of amount on line e			105,421.00	149,214.00	254,635.00
g. Federal share of amount on line e		15,949.23	146,068.00	220,211.00	382,228.23
h. Federal payments previously requested		10,980.51	141,393.60	171,379.81	323,753.92
i. Federal share now requested (*Line g minus line h*)		4,968.72	4,674.40	48,831.19	58,474.31
j. Advances required by month, when requested by Federal grantor agency for use in making prescheduled advances	1st month				0.00
	2nd month				0.00
	3rd month				0.00

12. ALTERNATE COMPUTATION FOR ADVANCES ONLY

a. Estimated Federal cash outlays that will be made during period covered by the advance	$
b. *Less:* Estimated balance of Federal cash on hand as of beginning of advance period	
c. Amount requested (*Line a minus line b*)	$ 0.00

13.	CERTIFICATION	
I certify that to the best of my knowledge and belief the data on the reverse are correct and that all outlays were made in accordance with the grant conditions or other agreement and that payment is due and has not been previously requested.	SIGNATURE OR AUTHORIZED CERTIFYING OFFICIAL Edwin R. Long	DATE REQUEST SUBMITTED January 7, 2016
	TYPED OR PRINTED NAME AND TITLE Edwin Long, Chairman	TELEPHONE (AREA CODE, NUMBER, EXTENSION) 757-442-9126

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4	Enter the Federal grant number, or other identifying number assigned by the Federal sponsoring agency. If the advance or reimbursement is for more than one grant or other agreement, insert N/A; then, show the aggregate amounts. On a separate sheet, list each grant or agreement number and the Federal share of outlays made against the grant or agreement.
6	Enter the employer identification number assigned by the U.S. Internal Revenue Service, or the FICE (institution) code if requested by the Federal agency.
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11	The purpose of the vertical columns (a), (b), and (c) is to provide space for separate cost breakdowns when a project has been planned and budgeted by program, function, or activity. If additional columns are needed, use as many additional forms as needed and indicate page number in space provided in upper right; however, the summary totals of all programs, functions, or activities should be shown in the "total" column on the first page.
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11b	Enter the cumulative cash income received to date, if requests are prepared on a cash basis. For requests prepared on an accrued expenditure basis, enter the cumulative income earned to date. Under either basis, enter only the amount applicable to program income that was required to be used for the project or program by the terms of the grant or other agreement.
11d	Only when making requests for advance payments, enter the total estimated amount of cash outlays that will be made during the period covered by the advance.
13	Complete the certification before submitting this request.

FEDERAL FINANCIAL REPORT

(Follow form instructions)

1. Federal Agency and Organizational Element to Which Report is Submitted USDA/NRCS	2. Federal Grant or Other Identifying Number Assigned by Federal Agency (To report multiple grants, use FFR Attachment) 69-3A7511-198	Page 1	of 1 pages

3. Recipient Organization (Name and complete address including Zip code)
Eastern Shore RC&D
P.O. Box 442, Melfa, VA 23410

4a. DUNS Number 198117251	4b. EIN 54-1422494	5. Recipient Account Number or Identifying Number (To report multiple grants, use FFR Attachment)	6. Report Type ☐ Quarterly ☐ Semi-Annual ☐ Annual ☒ Final	7. Basis of Accounting ☒ Cash ☐ Accrual

8. Project/Grant Period From: (Month, Day, Year) January 01, 2015	To: (Month, Day, Year) August 15, 2015	9. Reporting Period End Date (Month, Day, Year) Final: August 15, 2015

10. **Transactions**	Cumulative
(Use lines a-c for single or multiple grant reporting)	
Federal Cash (To report multiple grants, also use FFR Attachment):	
a. Cash Receipts	659,675.31
b. Cash Disbursements	659,675.31
c. Cash on Hand (line a minus b)	0.00
(Use lines d-o for single grant reporting)	
Federal Expenditures and Unobligated Balance:	
d. Total Federal funds authorized	421,650.00
e. Federal share of expenditures	402,222.29
f. Federal share of unliquidated obligations	0.00
g. Total Federal share (sum of lines e and f)	402,222.29
h. Unobligated balance of Federal funds (line d minus g)	19,427.71
Recipient Share:	
i. Total recipient share required	482,728.00
j. Recipient share of expenditures	482,728.00
k. Remaining recipient share to be provided (line i minus j)	0.00
Program Income:	
l. Total Federal program income earned	0.00
m. Program income expended in accordance with the deduction alternative	
n. Program income expended in accordance with the addition alternative	
o. Unexpended program income (line l minus line m or line n)	

11. Indirect Expense	a. Type	b. Rate	c. Period From	Period To	d. Base	e. Amount Charged	f. Federal Share
				g. Totals:			

12. *Remarks: Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing legislation:*

13. **Certification: By signing this report, I certify to the best of my knowledge and belief that the report is true, complete, and accurate, and the expenditures, disbursements and cash receipts are for the purposes and intent set forth in the award documents. I am aware that any false, fictitious, or fraudulent information may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 18, Section 1001)**

a. Typed or Printed Name and Title of Authorized Certifying Official Edwin R. Long Chair	c. Telephone (Area code, number and extension) 757-710-7523
	d. Email address edwinlong@verizon.net
b. Signature of Authorized Certifying Official Edwin R. Long Chair	e. Date Report Submitted (Month, Day, Year) 01/07/2016
	14. Agency use only:

Standard Form 425 - Revised 6/28/2010
OMB Approval Number: 0348-0061
Expiration Date: 10/31/2011

Paperwork Burden Statement
According to the Paperwork Reduction Act, as amended, no persons are required to respond to a collection of information unless it displays a valid OMB Control Number. The valid OMB control number for this information collection is 0348-0061. Public reporting burden for this collection of information is estimated to average 1.5 hours per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding the burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the Office of Management and Budget, Paperwork Reduction Project (0348-0061), Washington, DC 20503.