Phase I Financial and Scientific Report
Power Auger Modification to Empty Cess Pits
North Carolina State University

Section 1: Phase I Award Financial and Scientific Report

1.0 Activities

The overall objective of the Phase I project was to modify and test a portable, gasoline powered earth auger that can be used to more efficiently and hygienically empty septic tanks, cesspits and latrines.

Fig 1. Initial prototype being tested on mixture of bentonite and horse manure.

Phase I – Initial Prototype Development and Testing

Phase I involved development of an initial prototype and experimental facilities to evaluate the system. Our initial design was a simple modification of a standard earth auger with a machined coupling, PVC pipe and Tee. Fig 1 shows testing of an early design on a mixture of bentonite and horse manure. For our initial experiments, use of actual fecal material would have been cumbersome. As an alternative, a synthetic waste was developed using varying concentrations of bentonite clay. Laboratory testing (Tate Rogers Thesis, 2013) demonstrated bentonite and human stool had similar thixotropic properties, and that bentonite slurries could be prepared with a similar viscosity to fecal sludge in wet pits.

In the first prototype, we used a 4 inch diameter by 2 ft. long steel auger with a 2 ft. extension enclosed in a 4 inch dia. PVC pipe. Initial tests showed the auger was not able to pump bentonite due to the low head produced. To improve performance, the 2 ft. long auger was replaced by a 4 ft. long continuous flight steel auger. Further testing showed: 1) a continuous auger could pump sludge to the top of the auger; and 2) additional head produced was low. In other words, to pump sludge up 3 m, you will need a 3 m long auger. Use of a steel auger this long would greatly increase weight making the machine difficult for one person to operate. To reduce weight, the steel auger was replaced with continuous polyethylene plastic flights used in grain augers. This greatly reduced weight while slightly improving performance due to the reduced friction between the auger flights and the PVC pipe.

Once a functional prototype was developed, the auger was tested to evaluate the effect of auger rotating speed (rpm), auger length, and waste viscosity on pumping rate and discharge head (pressure). The minimum speed to effectively pump the 5 and 6% bentonite simulant waste was 300 rpm, which is the maximum rotational speed of many earth augers. Based on this result, an alternative power drive was developed to generate higher rpm and increased flow.

Phase II – Reinvent The Toilet Fair and Fecal Sludge Management II Conference

In summer and fall of 2012, we had the opportunity to attend the “Reinvent The Toilet Fair” (RTTF) and the Fecal Sludge Management II (FSM2) conference. During both events, we were able to speak with a variety of individuals and groups to gain important insights into the challenges of emptying pits in different parts of the world.

1. Access to the pits is a major concern. Many pits are located down narrow alleys and pathways that cannot be accessed by large equipment. Even equipment such as the Dung Beetle and Vacutug have difficulty in reaching pits. Hand portable equipment is strongly preferred. In some cases, the only access to the pits is within the latrine superstructure and bringing long equipment like the Gulper into the building is a challenge.
2. The basic approach of transferring the waste from the pits into smaller containers that can be transported by hand to a larger collection vehicle is commonly used in many areas. Motorized trikes and rickshaws are used in some areas, but are not able to access all pits.
3. In many larger urban and peri-urban areas, pit emptying is performed by larger organizations (government agencies or private firms) with the resources to empty a large number of pits, transport the pit contents to a central location, treat the waste, and dispose of the treated material in an acceptable manner. For these organizations, much of the cost is associated with off-site transport, treatment and disposal, and the capital cost for equipment to empty the pit is not the primary concern. The primary focus of these groups is on obtaining equipment that is durable, easy to use and repair, and can empty a large number of pits quickly.
4. Accumulation of trash and other non-fecal material in dry pits is a major concern. There are no effective methods of emptying dry pits containing trash other than manual excavation.
5. Trash accumulation in wet pits appears to be less of a concern. Where pour-flush toilets are used, the physical dimensions of the drainpipe prevent entry of most trash that could clog an extraction auger. However, some trash may still enter the pit.
6. In some areas, the waste at the bottom of the pit can become highly compacted. As a result, only the liquid and semi-solid material in the upper portion of the pit can be removed with typical vacuum pumping equipment. Over several emptying cycles, the pit gradually fills with hard, compacted material reducing storage capacity.

Phase III – Equipment Modification to Improve Performance

Based on the insights gained during RTTF and FSM2 conferences, we identified several modifications to improve the versatility and performance of our design. In fall 2012 and early winter 2013, these improvements were incorporated into our prototype and tested in the laboratory and in a simulated pit constructed on the NCSU farms. The improvements included:

1. The upper portion of the extraction auger was modified by replacing the ‘Tee’ fitting with a ‘Wye’ fitting and including a section of reversed flighting at the top of the auger. Together, these changes improved discharge of non-fecal material into the collection container.
2. Several different auger tips were developed to improve performance for a variety of site conditions including tips to reduce trash entry, reduce damage to concrete pit bottoms and break up compacted solids. .
3. The auger body was modified allowing the auger to be shortened or extended depending on site conditions. When entering a building, the auger can be taken apart to negotiate tight

areas, and then assembled to empty the pit. When dry solids are present, the outer pipe can also be shortened, exposing more auger to solids in the pit.

4. The standard mechanical drive was replaced with a hydraulic drive. This increased the pumping rate and allowed the auger to be easily reversed to discharge fecal material and/or trash that had entered the auger. Hydraulic power is provided to the auger from a separate gasoline powered hydraulic pump. The hydraulic fluid travels through rubber hoses to the hydraulic motor that drives the auger. When the pit is located within 100 ft. of a vehicle, the hydraulic pump could remain on the vehicle and the hydraulic hoses would run from the vehicle to the pit. The hydraulic pump is also fitted with rubber tires allowing transport to more remote locations.

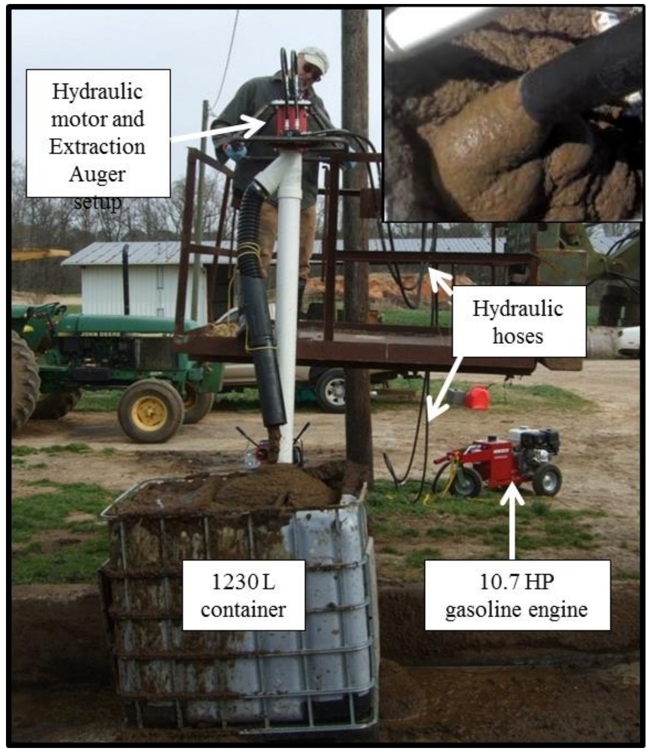

Fig 2. Hydraulic powered auger being tested on a simulated pit containing cattle manure.

In January 2013, our modified designs were tested on a simulated pit containing a slurry of cow manure, sand and wood shavings (see Fig 2). During the initial testing, the wood shavings would jam between the auger flights and pipe, eventually causing the auger to bind. While jams could be easily ejected by reversing the auger, this did reduce productivity. This problem was resolved by increasing the gap between the auger flights and pipe. This greatly improved performance allowing the machine to pump up to 94 lpm of manure at a 2 m lift height.

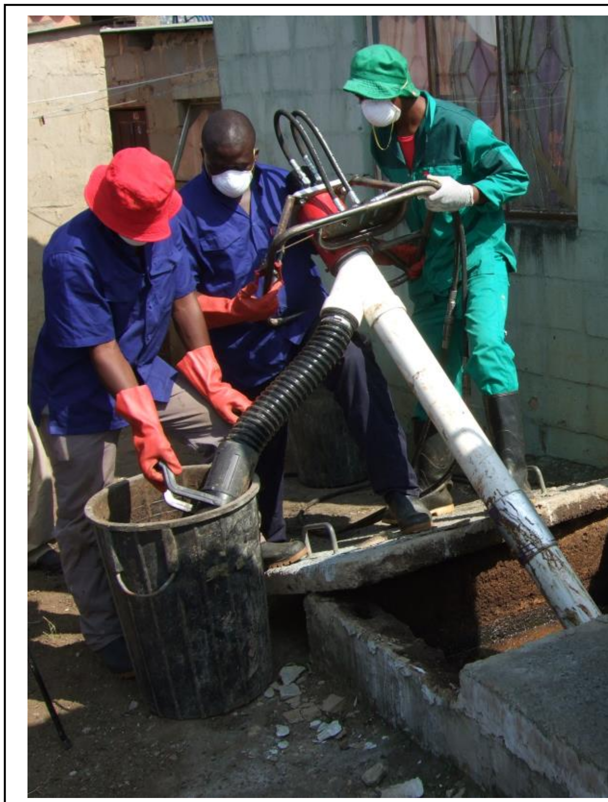

Fig. 3. Extraction auger in use in Durban, SA.

Phase IV – Field Testing in South Africa

In March 2013, our modified design was tested on a range of wet and dry pits in South Africa. Field testing of the extraction auger generated the following conclusions.

1. The hydraulic powered extraction auger was easily carried to all of the pits

investigated. While it was not possible to drive a vehicle close to many latrines, access with the equipment was not a problem. Fig 3 shows use of the extraction auger down a narrow alley.

2. Clogging with trash and other debris was not a problem. Reversing the auger ejected most debris. While elastic bands (presumably from disposable diapers) did occasionally get wrapped around the auger, they did not result in jamming of the equipment. When trash was caught in the auger, the machine could be easily reversed, ejecting most of the trash and other debris.
3. The machine was very effective at pumping medium viscosity wastes containing a mixture of liquid and solid material. Fig 4 shows five containers pumped out of a pit in Durban, SA after about 20 minutes operation.
4. The equipment was not very effective in removing watery, low viscosity waste. This characteristic was identified early in the laboratory testing. However in this field, it is not a significant drawback since other available technologies (Gulper, Vacutug or a simple trash pump) are effective in removing this type of waste.
5. The equipment was not effective in removing solid waste in dry pits without some liquid material. The auger was able to drill into the solid waste. However, this just formed a ‘posthole’ in the non-flowing solid waste. Additional work is needed to develop an effective method to empty ‘dry’ pits. This could include mixing the solid waste with liquid, followed by augering or use of other equipment.
6. There is an incredible variation in the composition of waste in these pits. One pit may contain semi-solid material that is easily removed with the extraction auger, while another pit 30 m away contains very hard, floating material that is difficult to penetrate. No single technology will be appropriate for this wide range of conditions. To be effective, operators need a range of tools to manage the broad range of conditions encountered.

Fig 4. Waste extracted from pit in Durban, SA.

7. It is difficult to determine the amount and character of waste through the toilet, prior to breaking the pit seal. Assessment methods are needed to determine when pits need to be emptied and to identify the best approach for removing the waste. This evaluation needs to be performed through the toilet, without excavating the actual pit and breaking the seal.
8. Better methods are needed to reduce spread of waste and fecal borne pathogens during pit empyting including training for pit emptiers on health risks, standardized sanitation protocols, and technologies to disinfect waste as it is being removed from the pit.

2.0 Challenges

The biggest challenge in this project was the incredible diversity of conditions in pits that can influence the use and performance of pit emptying equipment. Based on our own experience in South Africa and conversations with others, there is no single technology appropriate for all pits, even within a small geographic area. A design that works well for pour flush systems could be a complete failure with dry pits. To be successful, pit emptiers will need a variety of different tools and training on how to use these tools in a safe, sanitary and effective manner.

The design developed in Phase I of this project was effective in emptying semi-solid waste from difficult to access pits, even when the pits contained trash and other debris. The extraction auger system has met all listed criteria for Technology Readiness Level ITRL) of 7. We have demonstrated the use of a fully functional prototype assembled from commercially available components in an operational environment (wet and dry pits in South Africa).

While the extraction auger was effective in emptying wet pits containing semi-solid sludge, additional work is needed to develop tools and procedures to safely and effectively empty the broad range of pits present in many areas. Needs identified in this project include:

- Modify our current design to improve the performance, durability and sanitary use of this equipment for pits containing semi-solid waste.
- Develop equipment to efficiently mix dense solid waste with liquid to form a semi-solid material that can be more easily extracted.
- Modify the existing auger design to facilitate its use with currently available vacuum technologies to remove both the dense material and free liquid from the pit.
- Develop methods to assess the amount of waste in a pit and its general composition without significant excavation or breaking the seal on the pit.
- Develop methods to disinfect waste as it is being extracted from the pit. One potential approach would be to blend a lime slurry with the waste during pumping.

Great challenges remain in safely and effectively removing wastes from pits. A variety of different tools are needed to safely and effectively empty pits. Currently available vacuum technologies and the extraction auger developed in this project can help. However, additional tools and equipment are needed to expand the range of pits that can be emptied. In addition, guidance documents are needed to train pit emptiers on safe, sanitary methods for emptying pits under a range of conditions. This guidance should include: a) assessing pit contents; b) selection of appropriate tools and equipment for a given site; c) basic equipment maintenance; d) appropriate waste disposal methods; and e) general sanitation during the process.

3.0 Other Sources of Project Support

North Carolina State University has provided major support to this project through use of a wide variety of university facilities and personnel. These services are normally paid for by a general overhead charge. It was not possible to charge the project directly for these services due to university accounting procedures. Support has included: a) use of facilities (offices, labs, library, etc.); b) equipment fabrication by a trained machinist in the departmental machine shop; c) equipment testing in our research laboratories under the direction of a full-time laboratory manager; d) use of the university research farms for pilot testing; and e) waste disposal by NCSU Environmental Health and Safety. Prior gifts to NCSU provided $4,600 to support travel and shipping to Pietermaritzburg, South Africa for field testing of the extraction auger.