THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**SOLIDS SEPARATOR**	
APPLICATION:	**SEPARATION OF MANURE SOLIDS FROM FLUSHED SWINE WASTE**	
TECHNOLOGY NAME:	**SOLID BOWL CENTRIFUGE MODEL TS-5000**	
COMPANY:	**TRITON SYSTEMS, LLC**	
ADDRESS:	**5355 ROYAL VALE LANE** **DEARBORN, MI 48126**	**PHONE: (313) 336-4154** **FAX: (313) 963-1707**

NSF International (NSF), in cooperation with the U.S. Environmental Protection Agency (EPA), operates the Water Quality Protection Center under EPA's Environmental Technology Verification (ETV) Program. As part of the Water Quality Protection Center's activities in verifying the performance of source water protection technologies, the ETV Program evaluated the performance of a solid bowl centrifuge for separating solids from flushed swine waste. This verification statement summarizes the test results for the Triton Systems, LLC, Solid Bowl Centrifuge, Model TS-5000. The verification testing was conducted by North Carolina State University's Biological and Agricultural Engineering Department in Raleigh, North Carolina.

EPA created the ETV Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with testing organizations and stakeholder advisory groups consisting of buyers, vendor organizations, and permitters, and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

Technology Description

The following description of the Triton Systems, LLC Solid Bowl Centrifuge Model TS-5000 (TS-5000) was provided by the vendor and does not represent verified information.

The TS-5000 is designed to remove solids from swine wastewater-wash systems. The TS-5000 returns an effluent with less organic content, reduces subsequent wastewater treatment capacity requirements, and provides a solid material that can be used as fertilizer/soil amendment. The separation process relies on an imperforate bowl basket centrifuge operating at up to a maximum of 1,300 times the force of gravity. The high "G" force provides rapid separation of suspended solids from the wastewater. The TS-5000 can process between 25 and 75 gpm, depending on solids loadings and required separation performance.

The centrifuge is designed to operate continuously under automatic control, although manual operation is possible. The centrifuge operation consists of several sequences. Wastewater is pumped to the unit once it is operating at a preset feed speed. Solids begin to accumulate along the wall of the centrifuge during the feeding operation. When the accumulated solids contact a sensor, feed is discontinued and the skimming operation begins. Skimming, the process of removing thin, watery material accumulated along the inside of the bowl, is performed at the same bowl speed as the feeding operation. Skimming is accomplished by moving the end of a rigid tube into the watery layer after it builds up along the inside of the centrifuge bowl. The tube mechanism is attached to translucent tubing so the operator can visually determine when the solids content of the skimmed material increases. The skimmed material contains significant solid material but is still classified as liquid. Returning the skimmed material to the feed tank during normal operation is intended to optimize the removal of solids and further reduces the moisture content in the accumulated solids. When skimming is complete, the centrifuge slows to a preset plow speed. During the plowing operation, a plow blade removes the solids from the unit by scraping them away from the centrifuge wall and allowing them to fall out the bottom of the unit. A preset limit switch prevents the plow blade from contacting the centrifuge wall. Once plowing is complete, the bowl speed increases back to the preset feed speed, feed water flow resumes, and the process is repeated.

Verification Testing Description

Test Site

Verification testing was conducted at the North Carolina State University (NCSU) Lake Wheeler Road Field Laboratory Swine Educational Unit. This farm is designed and operated as a research and teaching facility. The farm capacity is 250 sows for farrow to wean (birth to wean). The farm can finish (grow to a market weight of 250 lb) approximately half of the pigs weaned each year. Under normal operating conditions, waste at the site is removed by flushing under-slat pits with treated wastewater from the onsite lagoon. Flushed waste then flows back to the anaerobic lagoon for treatment. During the verification test, the flushed waste was diverted to a 2,500 gal glass-lined influent mixing tank of 12-ft diameter and 10-ft depth. To minimize aeration and physical changes to the wastewater, the influent mixing tank was equipped with a 5-hp mixer with a 2-ft diameter impeller, designed to keep solids suspended with minimum turbulence.

An all-in/all-out closed loop process was developed to eliminate problems and errors associated with flow measurement and sampling. All of the waste generated over a two-day period was left in the under-slat pits until it was flushed and collected in the influent mixing tank. This wastewater was pumped from the influent mixing tank to the test unit. Liquids discharged from the test unit were collected in effluent and skimming tanks, and the separated solids were collected on the adjacent concrete pad.

Methods and Procedures

Verification testing began on Monday, May 20, 2002. Technology evaluation and sampling procedures were carried out three days per week (Monday, Wednesday, and Friday) for four weeks, for a total of 12 testing events.

After the safety status of the unit was assured, the centrifuge was started. As the bowl began to spin, some of the solid material that had remained in the unit from previous tests dropped out of the unit. In an effort to quantify this material for the mass balance, an initial plow sequence, that was not part of the normal operating procedures as defined in the operations manual, was performed on each test day. The mass of material removed during this pre-plow operation was recorded in addition to the material that had fallen out since the last test day. After the material was removed from below the unit, wastewater flow was started.

Wastewater from the swine unit was collected and mixed in the influent mixing tank to equally distribute solids throughout the tank. Wastewater was typically held in the mixing tank for less than five minutes, but never more than thirty minutes. Wastewater was then pumped to the centrifuge at a nominal flow rate of 35 gallons per minute while the centrifuge unit was operating at the preset feed speed (1,200 rpm).

Under normal operating conditions, the TS-5000 is run continuously, and skimming and plowing operations are initiated automatically based on the depth of accumulated solids in the bowl. Batch processing is specified by the *ETV Test Plan for the Verification of Technologies for Separation of Manure Solids from Flushed Swine Waste* for all solids separation technologies undergoing verification testing to ensure that sufficient wastewater is provided to the technology on test dates. It also allows accurate calculation of mass in and mass out of the technology being verified and ensures consistency between verification tests. The batch processing approach required that automatic operation be suspended and that skimming and plowing operations be activated manually during this verification test. To compensate for the longer time the unit would spin in a field installation, the feed pump was turned off and the unit maintained the same feed speed for one hour prior to skimming. Skimming was performed at the same bowl speed as the feeding operation and was initiated manually by actuating the skimmer advance switch on the control panel. Under normal operating conditions, the skimmed liquid would be returned to the wastewater storage unit or the feed tank to be sent through the separator again. Under the batch processing used in this verification test, this skimming liquid was collected in a tank separate from the effluent, was quantified and analyzed separately, and was ultimately disposed in the lagoon. The skimming operation continued until solids were observed leaving the system with the skimming liquid. Following skimming, a manual switch was turned that slowed the centrifuge bowl to the preset plow speed. A control panel light indicated when this speed was reached, and the plowing was then initiated manually. The plow blade moved through its normal range of motion and automatically retracted. The plow procedure was then repeated. Solids removed during the plowing process dropped out of the bottom of the unit. Once all effluent and solids were removed from the discharge points, the unit was shut down.

Measurements made each test day included volume of wastewater entering the unit, volume of the skimming stream, volume of the effluent stream, weight of solids removed (plowed) from the unit, and concentrations of quality parameters in each of the sampled components (influent, effluent, solids, and skimming liquid). The influent, effluent, and skimming liquid volumes were determined based on the waste depths and dimensions of each tank. The weight of the solids was determined as the difference in the weight of large containers with and without the solids. Weights were measured at the testing location using appropriate scales. Concentrations of the quality parameters were determined by laboratory analysis of grab samples collected in triplicate. The analyses performed included solids (total, suspended, and volatile), total organic carbon (TOC), nutrients, metals, pH, conductivity, and bulk density. The

mean daily values were summed over the test period and converted to mass in order to complete the mass balance.

At the end of the test period, the centrifuge was accelerated to 100 rpm and eight plow cuts were performed to remove built up solids and obtain full plow blade travel. Any solid residue that did not fall out of the centrifuge during this final plowing process was removed manually after the system was completely powered down. The mass of this material was recorded for inclusion in the mass balance.

Performance Verification

System Performance

The mass balance approach allowed for the determination of the proportion and mass of the recovered solids and how the nutrients partitioned between the solid and liquid phases. These results are shown in Table 1. The skimming liquid contained less than 1.4 percent of any of the parameters and is therefore not included as a separate column in Table 1. For each parameter, the total mass recovered from the centrifuge (effluent, skimming liquid, solids) is shown in Table 1 as the percent of the mass in the influent.

Table 1. Partitioning and Recovery of Parameters from Influent

Parameter	Percent In: Recovered Solids	Liquid Effluent	Total (Solids, Effluent, Skimming)
Dry matter / suspended solids	55	29	84
Total nitrogen	20	69	90
Total phosphorus	42	40	82
Potassium	3.2	89	94
Copper	22	51	74
Zinc	30	48	78
Chloride	1.6	93	96

Note: The data in Table 1 are based on twelve samples.

While the recoveries from the mass balance would ideally be within ± 10 percent of 100 for this type of work, lower recoveries are common due to the complex nature of both the wastewater and separated solids. The flushed swine waste entering the treatment unit included colloidal and suspended solids, as well as larger aggregates of organic waste, microbial biomass, and undigested feed. Mixing of the influent, as was done during the verification test, increases the opportunities to obtain consistent samples but cannot overcome the inherent heterogeneity of the wastewater. Sampling anomalies may have occurred, resulting in some of the influent samples, collected in triplicate, containing larger amounts of solids than were consistent with the rest of the influent.

Recovery of some parameters is also influenced by the additional sample preparation required for solid samples and the lower precision of quantifying solids compared to liquids. This is a practical consideration that is inherent in this type of analysis and not an artifact of the laboratory or the equipment being evaluated. The data quality indicators demonstrate that the analytical procedures performed within expected limits.

The characteristics of the liquid effluent and the recovered solids are shown in Tables 2 and 3, respectively. All values presented in the tables reflect means calculated over the test period.

Over the entire test period, 1,750 lb of dry solids were recovered by the TS-5000, representing 55 percent on a mass basis of the 3,200 lb of suspended solids in the influent. The recovered solids contained 26 percent dry matter (74 percent moisture).

Most of the remaining solids were released with the effluent stream (29 percent), which had a suspended solids concentration of 3,680 mg/L. The solids not contained in the recovered material or in the effluent were in the skimming liquid. This material would be returned to the feed tank in normal continuous operation. Centrifuges are generally expected to be less efficient when used for batch processing, due to the lower bowl speeds during the start up and shutdown phases.

Table 2. Influent/Effluent Characteristics

Parameter	Units	Influent	Effluent
Total solids	mg/L	12,900	6,340
Volatile solids	mg/L	9,420	4,030
Suspended solids	mg/L	11,700	3,680
Total Kjeldahl nitrogen	mg/L	1,060	792
Ammonia nitrogen	mg/L	454	420
Total phosphorus	mg/L	423	182
Ortho phosphorus	mg/L	179	88
Potassium	mg/L	534	516
Chloride	mg/L	271	272
Copper	mg/L	9.2	5.0
Zinc	mg/L	15.3	7.9
N:P:K ratio		2.51:1.00:1.26	4.35:1.00:2.84
pH		7.23	7.51
Conductivity	µmhos/cm	4820	4760
Total coliform	MPN/100mL	1.3×10^{10}	2.0×10^{10}
E. coli	MPN/100mL	8.1×10^{9}	1.5×10^{10}

Note: The data in Table 2 are based on 12 samples, with the exception of the *E. coli* data, which are based on eight samples.

Operation and Maintenance Results

Operational Observations

Several types of operational problems were seen with the TS-5000. First, the bowl speed during the plow or pre-plow sequence did not maintain the 100 rpm design speed, but varied between 30 and 140 rpm throughout the verification test. Although the vendor explained this as normal operation while the drive motor and centrifuge bowl match speeds, the situation caused the system to be shut down on three occasions due to either an out-of-balance condition or operator-perceived instability of the structure. Second, on three occasions, the bowl speed began to increase after the plow sequence rather than to shut down. The manual "Cycle Stop" control did not interrupt this sequence and the operator had to use the "Control Power" switch to disconnect power at the control panel. Finally, the nature of the centrifuge operation introduced a significant amount of air into the liquid effluent, as evidenced by foaming that occurred whenever the centrifuge was operated. Generally this foam dissipated within 24 to 48 h of shutting off the unit. Additional operational observations are described in the verification report.

Table 3. Recovered Solids Characteristics

Parameter	Units	Concentration
Dry matter	percent by weight	26.2
Volatile solids	percent by weight	22.3
Total nitrogen	percent by weight	0.86
Total phosphorus	µg/g	7,280
Potassium	µg/g	714
Chloride	µg/g	179
Copper	µg/g	83.0
Zinc	µg/g	185
Bulk density	g/mL	0.736
Total coliform	MPN/g	6.1×10^{10}
E. coli	MPN/g	3.5×10^{10}
N:P:K ratio		1.18:1.00:0.098

Note: The data in Table 3 are based on 12 samples, with the exception of the *E. coli* data, which are based on eight samples.

Maintenance Observations

The skimming volume was low on test days seven, eight, and nine (approximately 15 gal compared to typical values of 50 gal). The system also chattered harshly during the plow sequence of test nine. Because of these observations, the NCSU staff opened the access hatch of the TS-5000 and inspected the bowl at the end of test nine. Hair and debris had accumulated on the leading edge of the plow blade. After consultation with the vendor, the unit was cleaned, as this type of maintenance would be expected in a commercial application. The hair and solids were removed from the blade with a shovel (an effort of about 15 min).

Electrical Requirements

The standard electrical installation of the TS-5000 is three-phase, but the system can be installed on 240 V single-phase power, as it was for the verification test. Current and voltage were measured during every test day, allowing the calculation of total, peak, and mean power. The peak power usually occurred at the start of the feed cycle and was never maintained for more than one ten-second reading. The manual operation procedures described previously included an hour of operation at full feed speed without any wastewater entering the system. This operation consumed power at a lower rate than during the feeding operation. The mean power consumed during the feeding operation, more representative of continuous operation, was generally less than 20 kW with a mean peak of 30 kW.

Quality Assurance/Quality Control (QA/QC)

During testing, NSF International completed QA audits of the NCSU Biological and Agricultural Engineering Department's Environmental Analysis Laboratory and Swine Educational Unit, Lake Wheeler Road Field Laboratory. NSF personnel completed: (1) a technical systems audit to assure the testing was in compliance with the test plan, (2) a performance evaluation audit to assure that the measurement systems employed by the laboratory and the field technicians were adequate to produce reliable data, and (3) a data quality audit of at least ten percent of the test data to assure that the reported data represented the data generated during the testing. In addition to the quality assurance audits performed by NSF International, EPA QA personnel conducted a quality systems audit of the NSF QA Management Program and accompanied NSF during audits of the NCSU facilities.

Original signed by		*Original signed by*	
Lee A. Mulkey	*09/30/03*	*Gordon E. Bellen*	*10/02/03*
Lee A. Mulkey	Date	Gordon E. Bellen	Date
Acting Director		Vice President	
National Risk Management Research Laboratory		Research	
Office of Research and Development		NSF International	
United States Environmental Protection Agency			

Availability of Supporting Documents

Copies of the *ETV Test Plan for the Verification of Technologies for Separation of Manure Solids from Flushed Swine Waste*, dated April 2002, the Verification Statement, and the Verification Report are available from the following sources:

ETV Water Quality Protection Center Manager (order hard copy)
NSF International
P.O. Box 130140
Ann Arbor, Michigan 48113-0140
(734) 769-8010
NSF web site: http://www.nsf.org/etv (electronic copy)
EPA web site: http://www.epa.gov/etv(electronic copy)

NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.