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:	**DRAG SCREEN AND CLARIFIER**	
COMPANY:	**HOFFLAND ENVIRONMENTAL INC.**	
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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 drag screen and clarifier system for separating solids from flushed swine waste. This verification statement summarizes the test results for the Hoffland Environmental Inc. drag screen and clarifier, hereinafter referred to as the Hoffland Separator. 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 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 Hoffland Separator was provided by the vendor and does not represent verified information.

The Hoffland Separator consists of an inclined perforated metal screen with a motorized drag conveyor to which incoming wastewater flows, an integral wastewater collection tank that collects and recycles the liquid that passes through the screen, and a solids concentrator (clarifier) that receives input from the wastewater collection tank. The inclined screen removes large solids from the wastewater. Liquid and fine solids that pass through the screen are collected in the wastewater collection tank. Wastewater is pumped from the bottom of the wastewater collection tank to the solids concentrator through a two-inch diameter PVC pipe, entering the concentrator in a central stilling well 30 inches below the effluent weir. Inside the concentrator, the momentum of the liquid is reduced and flow becomes non-turbulent. Thickened solids are moved to the center of the solids concentrator by a sludge rake and flow by gravity from the bottom of the solids concentrator through a six-inch PVC pipe to the screen tank so they are added to the influent stream and are processed by the drag screen. A rubber skimmer that rotates with the sludge rake moves floating solids and scum in the concentrator into a collection box at the top of the unit and out through a four inch pipe connected to the underflow pipe. All liquid effluent leaves the treatment system through the overflow weir at the top of the clarifier. Floating solids are prevented from getting to the effluent weir by a baffle approximately two inches inside the effluent weir. Containers for recovered solids and clarified liquid were used when evaluating the system. The electrical configuration for the Hoffland Separator can be adapted to what is needed in a particular installation. The system was installed at the test site utilizing 240V single-phase power.

The following is a summary of the characteristics of the Hoffland Separator:

Type	Inclined drag screen; bottom feed; and a gravity clarifier
Screen Size	32 in. x 120 in
Screen Perforation	0.09 in
Clarifier Diameter	120 in
Clarifier Depth	191 in
Average Capacity	40 gallons per minute

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 on-site anaerobic lagoon. Flushed waste then flows back to the 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. The influent mixing tank was equipped with a 5-hp mixer with a 2-ft diameter impeller, designed to keep solids suspended while minimizing aeration and physical changes to the wastewater.

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 then pumped from the influent mixing tank to the test system. Liquid discharged from the test system was collected in the effluent tank, and the separated solids were collected in a 300-gallon open poly tank.

Methods and Procedures

Verification testing began on Friday, September 26, 2003 and ended on November 5, 2003. Technology evaluation and sampling procedures were carried out three days per week (Monday, Wednesday, and Friday) for a total of twelve testing events.

At the beginning of each test day, the Hoffland Separator was started and the unit was visually inspected to verify that the conveyor was working correctly. To achieve a balance between the required batch process at the test site and the designed continuous flow process of the Hoffland system, the sludge rake and skimming arm were turned on while wastewater was being collected from the farm.

Wastewater from the swine unit was collected and mixed in the influent mixing tank to equally distribute suspended solids throughout the tank. Wastewater was typically held in the influent mixing tank for less than five minutes, but never more than thirty minutes before being pumped to the Hoffland Separator at a nominal flow rate of 35 gallons per minute. The pump in the wastewater collection tank was operated continuously to transfer wastewater to the clarifier. Wastewater entering the clarifier caused the contained wastewater to overflow the weir and flow through the collection box to the effluent tank. The underflow valve was opened automatically for 10-15 seconds every 5 minutes. At the conclusion of each day's testing, the underflow valve was opened manually for 10-15 seconds every 1.5 minutes for 15 minutes. After the first week of operation, the testing organization and vendor together determined the rake and skimmer should be operated continuously just as they would be in a full-scale, continuous installation.

Measurements made each test day included volume of wastewater entering the system, volume of the effluent stream, weight of solids discharged, and concentrations of quality parameters in each of the sampled components (influent, effluent, and recovered solids). The influent and effluent 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 weights 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 concentrations were multiplied by the appropriate volume or mass measured to obtain the mass in each component. The mass balance of each parameter was calculated based on the values obtained over the entire test period. Samples were also collected once per week and analyzed for *E. coli* and total coliform. The difference in concentrations of the various parameters before and after testing was taken into account in the mass balance. The contents of the clarifier were sampled at the end of the set up period after opening the underflow control valve until the consistency of the material exiting the clarifier changed from sludge to wastewater. At the conclusion of testing, the contents of the clarifier were transferred to the influent mixing tank in several batches where the volume could be measured and the material sampled for analysis.

Performance Verification

System Performance

The mass balance approach allowed for the determination of how the suspended solids and nutrients partitioned through the Hoffland Separator. For each parameter, the total mass recovered in each phase (effluent, solids, and clarifier liquid) is shown in Table 1 as the percent of the mass in the influent. The calculated recoveries from the mass balance are ideally ±10 percent for this type of work, although recoveries outside of this range are common due to the complex nature of both the wastewater and separated solids. The data quality indicators, such as accuracy and precision measurements of laboratory analyses, were all within established limits over the course of the verification test. Because of this, nothing can or should be inferred from mass balance recoveries not equal to 100 percent.

Table 1. Partitioning and Recovery of Parameters from Influent

Parameter	Percent Found In: Recovered Solids	Liquid Effluent	Clarifier Liquid	Total (Solids, Effluent, Clarifier)
Total Solids	9.7	46	24	79
Dry Solids	12			
Suspended Solids		29	26	67
Total Nitrogen	5.2	67	22	94
Total Phosphorus	5.6	62	23	90
Potassium	0.37	85	12	97
Copper	4.5	37	38	80
Zinc	6.0	44	45	95
Chloride	0.69	87	8	95

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

The characteristics of the liquid effluent and the recovered solids are shown in Tables 2 and 3, respectively. All values presented in the table reflect means calculated over the test period. Over the entire test period, the effluent stream from the Hoffland Separator had an average suspended solids concentration of 2,650 mg/L, which, when converted to mass based on the volume of the effluent, represents 29% of the mass of suspended solids in the influent. Solids recovered by the Hoffland Separator contained 13.4 percent dry matter (86.6 percent moisture). The Hoffland Separator recovered 273 lb of dry solids, representing 12 percent of the 2,310 lb of suspended solids in the influent. Suspended solids remaining in the clarifier at the end of the test accounted for 26 percent of the influent suspended solids, leaving 33 percent of the suspended solids for which the mass balance analysis could not account.

Table 2. Influent / Effluent Characteristics

Parameter	Units	Influent	Effluent
Total solids	mg/L	10,600	5,100
Volatile solids	mg/L	7,490	3,030
Suspended solids	mg/L	8,690	2,650
Total organic carbon	mg/L	1,590	1,250
Total Kjeldahl nitrogen	mg/L	799	561
Ammonia nitrogen	mg/L	347	388
Total phosphorus	mg/L	297	192
Ortho phosphorus	mg/L	140	142
Potassium	mg/L	383	341
Chloride	mg/L	240	219
Copper	mg/L	5.23	2.02
Zinc	mg/L	7.58	3.47
N:P:K ratio		2.7:1:1.3	2.9:1:1.8
pH		7.49	7.04
Conductivity	µmhos/cm	4,061	4,072
Total coliform	MPN/100mL	8.8×10^7	1.3×10^7
E. coli	MPN/100mL	5.9×10^7	1.0×10^7

Note: The data in Table 2 are based on twelve samples.

Table 3. Recovered Solids Characteristics

Parameter	Units	Concentration
Dry matter	percent by weight	13.4
Volatile solids	percent by weight	11.5
Total carbon	percent by weight	1.68
Total nitrogen	percent by weight	0.54
Total phosphorus	µg/g	2,180
Potassium	µg/g	185
Chloride	µg/g	216
Copper	µg/g	30.7
Zinc	µg/g	59.3
Bulk density	g/mL	0.997
Total coliform	MPN/g	5.3×10^7
E. coli	MPN/g	3.9×10^7
N:P:K ratio		2.5:1:0.1

Note: The data in Table 3 are based on twelve samples.

Operation and Maintenance Results

Operational Observations

On October 6th, a pipe supplying flush water to the swine barns broke, postponing the verification test on that day. Investigation into the cause of that break found additional plumbing problems that caused the flush system to shut down from October 10th to October 13th. Regular verification testing resumed on October 15th after the swine houses were cleaned and waste was collected for two days, as stated in the test plan. Another pipe break on October 22nd caused the system to shut down until October 27th. Testing resumed two days later without further problems, after cleaning the swine houses and collecting the waste.

Maintenance Observations

The only operational problem with the Hoffland Separator resulted from floating solids that may have occurred, in part, because of delays due to the plumbing problems described above. After the first two weeks of operation, floating solid flocs began to appear at the effluent weir and soon began to block effluent flow from individual weir outlets. The weir was cleaned by hosing and scraping away the solids. Because access was limited to about 20 degrees on either side of a ladder mounted on the outside wall of the clarifier, clearing all of the individual weir outlets was difficult and less than completely effective. The situation recurred after another 3-4 days of operation and the cleaning procedures were repeated. All material removed during the cleaning process was recovered in the effluent tank and included in the mass balance. Floating solids were also observed in the central stilling well of the clarifier.

A permanent installation would be expected to require some maintenance over time, such as lubricating bearings and washing the screen. The drip pan under the upper portion of the screen that extends beyond the sump must also be cleaned periodically. The manufacturer's operations manual did not include a routine maintenance schedule.

Electrical Requirements

The Hoffland Separator required 240 V, single-phase electrical power to operate the two electric motors (totaling five hp). Units for installation with three-phase power and voltages up to 575 V are available. The Hoffland Separator's two motors were wired to the main connection box. Electrical installation consisted of supplying power to the unit and making the appropriate connections at the unit's control panel.

A data logger measured current and voltage and calculated values of kilowatts, which were recorded every ten seconds. Peak power consumption usually occurs when motors are first started, either at the beginning of the test or after a pause in motor operation as indicated by a drop in power consumption. The mean peak power consumption during the verification test was 1.41 kW. The overall mean power consumption during operation was 0.96 kW. During the entire verification test, the Hoffland Separator used approximately 0.51 kW-h of energy per 1,000 gallons of wastewater treated.

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 NSF International's QA Management Program.

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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.