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August 2010

Environmental Technology Verification Report

Evaluation of Wastewater Treatment Technology for Septage and High Strength Wastewater

Big Fish Environmental, LLC
Big Fish Environmental Septage and High Strength Wastewater Processing System

Prepared for

NSF International

Under a Cooperative Agreement with
U.S. Environmental Protection Agency

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**WASTEWATER TREATMENT – CHEMICAL ADDITION, FILTRATION AND BIOLOGICAL TREATMENT**
APPLICATION:	**TREATMENT OF SEPTAGE AND HIGH STRENGTH WASTEWATER**
TECHNOLOGY NAME:	**BIG FISH ENVIRONMENTAL SEPTAGE AND HIGH STRENGTH WASTEWATER PROCESSING SYSTEM**
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The U.S. Environmental Protection Agency (EPA) created the Environmental Technology Verification (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 recognized standards and testing organizations; stakeholder groups consisting of buyers, vendor organizations, and permitters; and 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 verifiable quality are generated, and that the results are defensible.

NSF International (NSF) operates the ETV Program's Water Quality Protection Center (WQPC) under a cooperative agreement with EPA. The WQPC evaluated the performance of the Big Fish Environmental Septage and High Strength Wastewater Processing System (System) over a period of more than a year. The Big Fish System consists of lime treatment followed by solids separation in a heated screw press,

with filtrate subsequently processed in an aerobic biological treatment system. Effluent from the System is discharged to a municipal wastewater treatment plant. Biosolids are also produced which may be used as fertilizer or soil amendment. This verification statement provides a summary of the test results for the Big Fish System.

TECHNOLOGY DESCRIPTION

The following technology description is provided by the vendor and does not represent verified information.

The Big Fish System (System) combines solids treatment with aerobic wastewater treatment, processing high strength wastes to produce Exceptional Quality (EQ) Class A Biosolids (refer to Federal Rule for Class A Biosolids (40 CFR Part 503)[1] and the EPA document – *A Plain English Guide to the EPA Part 503 Biosolids Rule*[1]) and treated filtrate meeting pretreatment standards for discharge to most secondary wastewater treatment plants (typically 250-300 mg/L BOD_5; 300-350 mg/L TSS; 50-70 mg/L NH_3; and locally determined restrictions for total phosphorus). The system uses a combination of elevated pH for vector (rodents, insects, birds, etc.) control and elevated temperature (time-temperature combination) for pathogen control to meet the Federal Rule for Class A Biosolids. There is no actual testing for vector control addressed in the Rule, only the specified treatment. The first requirement is to treat the waste material with lime to raise the pH to a minimum of 12 for 2 hours, and then maintain a minimum pH of 11.5 after 24 hours without further lime addition. Treatment for pathogen control requires heating the biosolids to a temperature of 72°C for a period of at least 20 minutes. The term EQ Biosolids is identified in the Federal Rule to characterize Class A Biosolids that also meet low-pollutant metals concentrations (see Table 3). If the Class A Biosolids treatment requirements are met and the metal pollutant levels are not exceeded, they are considered EQ Class A Biosolids and can generally be applied as freely as any other fertilizer or soil amendment to any type of land.

Truck-delivered wastes pass through an in-line JWC Muffin Monster 0.25 in. screen to remove any large inorganic particles or debris. A flow meter records the waste volume and an in-line pH meter monitors the waste to confirm the pH is between 4.0 and 9.0. The screened waste passes through a de-grit chamber, into an 11,000-gallon aerated receiving/equalization tank, which is directly connected to a second aerated 15,000-gallon equalization tank.

When 15,000 to 20,000 gallons of waste are accumulated, the waste is pumped to one of the two 20,000-gallon lime treatment tanks. Lime is added to the waste mixture during the transfer to achieve pH 12 for a minimum of 2 hours; the mixture is then held at minimum pH of 11.5 for at least 22 hours. After lime treatment is complete, the wastewater and solids are pumped from the lime treatment tank to a flocculation tank, where polymer is added, and then to a rotary screen thickener prior to entering the screw press. Filtrate extracted by the thickener is discharged to a blending tank for pH adjustment to approximately pH 7.5 – 8.0. The thickened sludge is processed in a heated screw press that raises the solids temperature to a minimum of 72° C for at least 20 minutes which increases the solids content to 40-50%. The combination of the lime treatment and the elevated temperature in the screw press conforms to the treatment requirements established in 40 CFR Part 503 for producing Class A Biosolids. Solids are collected in a hopper and the transferred to an outside covered storage area, while the screw press filtrate is discharged to the blending tank for pH adjustment and subsequent biological treatment.

The aerobic treatment system consists of a series of aerated tanks, followed by a 2,000-gallon quiescent settling tank, a 2,000-gallon re-aeration tank, and two 2,000-gallon discharge tanks. The combined volume of the aerobic treatment tanks is 27,000 gallons. The suspended growth aerated tanks have one or more White Knight™ microbial generators suspended in the tanks to provide a source of supplemental microorganisms to the naturally occurring microorganisms. A hatchery at the facility is also maintained as an additional source of microorganisms if needed. The large capacity of the aeration tanks is designed to provide time for biological treatment to reduce the very high organic loadings that normally remain in

septage type wastes after solids removal. Liquid discharged to the aerated tanks from the screw press and thickener causes water to flow through the system tanks. A float switch in the discharge tank triggers an effluent discharge by pump from the treatment system to the City of Charlevoix, MI municipal sewer system. Solids that accumulate in the settling tank are periodically pumped to the receiving tank for processing through the treatment system. All treatment processes, including truck unloading, occur inside a building equipped with a biofilter to reduce odors.

VERIFICATION TESTING DESCRIPTION

Test Site

The verification test was performed at the Big Fish facility in Charlevoix, Michigan, a full-scale System operating under a permit issued by the Michigan Department of Natural Resources and Environment (MDNRE), and in accordance with the requirements of the City of Charlevoix. Scherger Associates was the lead for the Testing Organization (TO) for this verification and provided technical oversight during the test. The facility has been in operation for over three years, with effluent discharge to the City of Charlevoix municipal WWTP. The System receives septage waste from several septic tank cleanout companies, secondary sludge from the City of Charlevoix WWTP, commercial grease interceptor waste containing fats, oils and grease (FOG) from local businesses, portable toilet waste and fruit processing waste.

Methods and Procedures

Testing was completed in accordance with the approved test plan[(2)] for the System. The verification test was conducted from September 2008 through October 2009 and included thirteen sampling and analysis events over the 14-month test. Monthly sampling events included a 5-day period with two batches of waste being processed, except in March 2009 when only one batch was processed and April 2009 when there was no sampling. Sampling locations included the untreated waste material and the treated effluent. Untreated waste samples were grab samples from the aerated equalization tank. Effluent samples were both composite and grab samples collected during discharge periods. Grab samples were collected each sample day for pH, FOG, temperature, and dissolved oxygen. The composite discharge samples and untreated waste grab samples were collected each sampling day and analyzed for total suspended solids (TSS), five-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), and alkalinity. Weekly composite samples were made of the untreated waste grab samples and the composite discharge samples. This was done by combining aliquots of several individual daily samples to form batch composite samples, which were analyzed for total Kjeldahl nitrogen (TKN), ammonia, nitrite plus nitrate, and total phosphorus (TP). Samples of the biosolids material were collected twice during the verification test and analyzed for percent solids and regulated (40 CFR Part 503) metals (As, Ba, Cd, Cr, Hg, Pb, Ni, Zn). The pH of the lime treated waste material was measured and recorded in the System operating record; the temperature of the biosolids in the screw press was recorded continuously.

The approved test plan included monitoring system performance during startup. From January 2 to January 4, 2009, Big Fish personnel emptied and cleaned the System tanks and restarted the System. The tanks were filled with processed wastewater from the screw process and microorganisms were seeded to the aerated tanks by adding 1,500 gallons of material from the hatchery tank. The White Knight™ microbial generators were hung in place in accordance with standard operating practice. The normal January 2009 verification sampling was performed three weeks after startup and showed the System was producing an effluent comparable to the four months (September 2008 through December 2008) prior to the cleaning and startup demonstration.

All analyses were completed in accordance with USEPA approved methods or *Standard Methods for the Examination of Water and Wastewater*, 20th Edition. An established quality assurance/quality control (QA/QC) program was used to monitor sampling and laboratory procedures. Details on all analytical methods and QA/QC procedures are provided in the full verification report.

PERFORMANCE VERIFICATION

Verification Test Results and Discussion

There were three sampling events during the verification testing that are not included in the data summaries presented in Tables 1 and 2, but are discussed in detail in the Verification Report. In March 2009, the reported effluent BOD_5 data was not consistent with the other reported data for the sampling event (particularly the effluent COD) so none of the day's data were included in the averages for the verification. The other two events occurred in May 2009 when the System received highly concentrated wastes, believed to be fruit waste, increasing the influent holding tank BOD_5 and COD concentrations to 21,000 mg/L and 31,000 mg/L, respectively (the BOD_5 being seven (7) times the mean influent concentrations over the course of the verification). The effluent BOD_5 and COD concentrations increased in the two treated batches following receipt of the waste to a BOD_5 of 5,500 mg/L and 5,700 mg/L, and a COD of 11,000 mg/L and 8,600 mg/L, respectively. The data for these two sampling events were determined to have resulted from System upset (defined in the *Protocol for the Verification of Wastewater Treatment Technologies,* April 2001[(3)]), so the data were not included in the averages for the verification testing indicated in Table 1.

Following the upset, the System was operated in normal aeration recycle mode, without additional waste loading or effluent discharge. After 10 days operation in this mode, a batch of wastes from the holding tank was processed. The effluent BOD_5 (810 mg/L – facility-generated data) indicated the System was recovering, but not yet back to typical discharge concentrations. The System continued to operate with the aeration tanks in normal recycling mode for another ten days, when another batch of waste material was processed and the effluent BOD_5 concentration was found to be 110 mg/L. A subsequent batch of waste was processed and it was confirmed that the system had returned to normal operating conditions (effluent BOD_5 of 96 mg/L). The ETV verification testing for June was performed the week of June 22 and the data showed the System had recovered.

Table 1 presents the results for BOD_5, COD and TSS. The influent concentrations are typical of a septage/high strength wastewater mixture. The treated effluent had a mean reduction of 97.7% (median 97.3%) for BOD_5. The mean and median COD removal was 98.4% and the mean and median TSS removal was 99.6%. The mean influent FOG concentration was 370 mg /L (median 140 mg/L). The effluent mean FOG concentrations was 5.1 mg/L (median 3.0 mg/L), resulting in a mean removal of 98.6% (median 97.5%). Fourteen of the 22 effluent samples showed an FOG concentration of <3 mg/L.

Table 2 presents the results for TKN, NH_3-N, NO_2+NO_3, and TP. Total nitrogen (TN) was determined by adding the concentrations of the TKN (organic plus ammonia nitrogen), and NO_2 plus NO_3 in the effluent. The overall system removal efficiency for TN was 80% (mean and median). Mean TP removal was 95.3% (median 97.3%).

Table 1. BOD_5, COD and TSS Data Summary

	BOD_5 (mg/L)		COD (mg/L)		TSS (mg/L)	
	Influent	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
Mean	3,300	75	17,500	270	13,700	55
Maximum	15,000	190	31,000	400	28,000	170
Minimum	27	7	3,700	25	3,700	10
Std. Dev.	2,900	44	8,000	96	6,500	42

Note: Data in Table 1 are based on 22 samples of influent and 22 samples of effluent and do not include the results for the upset period that occurred in May 2009. During the upset, BOD_5 removal was reduced to 43 – 74% and COD to 57 – 64%; TSS removal remained at 90 – 99% during the upset.

Table 2. Nitrogen and Phosphorus Data Summary [1,2]

	TKN (mg/L)		Ammonia (mg/L)		Nitrite/Nitrate (mg/L)	
	Influent	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
Mean	440	83	93	60	3.2	3.8
Maximum	550	170	160	120	15	13
Minimum	170	42	8	14	<0.05	<0.05
Std. Dev.	100	35	48	30	5.3	3.7

	Total Nitrogen (mg/L)		Total Phosphorus (mg/L)	
	Influent	**Effluent**	**Influent**	**Effluent**
Mean	440	85	128	3.3
Maximum	550	170	280	7.1
Minimum	170	49	2.6	<0.05
Std. Dev.	100	34	90	1.8

[1] Data in Table 2 are based on 12 samples of influent and 12 samples of effluent and do not include the results for the upset period that occurred in May 2009.

[2] Nitrogen data reported in mg/L as N; phosphorus data reported as mg/L as P.

The nitrogen data indicate that a large percentage of the total nitrogen was organic nitrogen. A comparison of the mean influent TKN (440 mg/L) with the mean influent ammonia concentration (93 mg/L) shows that organic nitrogen represented approximately 79% of the nitrogen in the wastes received at the facility (nitrite-nitrate was low at 3.2 mg/L). Based on review of the ammonia and nitrite-nitrate data, it appears that the biosolids produced by the screw press contained a large amount of the organic nitrogen removed by the System. If appreciable organic nitrogen reduction were occurring in the biological system aeration tanks, the ammonia and/or nitrite-nitrate concentrations in the effluent would increase significantly (which they did not). The reduction in ammonia could be attributed to association with the biosolids or possibly volatilization from aeration in the System.

The pH ranged from 12.1 to 12.9 during the initial 2-hour period after lime addition to the treatment tanks and after 24 hours the pH ranged from 11.6 to 12.8. The programmable logic controller records show that the proper screw press rate (38% motor speed) was maintained at all times ensuring the minimum contact time in the screw press at elevated temperature was achieved. The screw-press temperature ranged from 90°C to 100° C, well above the minimum requirement of 72°C for a 20 minute contact time. Samples of the biosolids were collected and analyzed for regulated metals as part of this verification. These data are shown in Table 3. Based on the data collected during the verification test, all batches of biosolids produced met the requirements to be classified as EQ Class A Biosolids.

Operation and Maintenance Results

Lime, used to raise the pH to meet the requirements for vector reduction in the biosolids and to aid in the dewatering processes, can also enhance phosphorus removal. The mean quantity of lime used was 11 lbs of lime per 1000 treated gallons. Polymer was added to the lime treated waste material as it was pumped from the holding tank to the thickener. A cationic polymer, Aquaben HF 748E, was used from September 2008 through July 2009 at mean addition rate of 0.63 gallons of concentrated polymer (as purchased) per 1000 treated gallons. A different cationic polymer, ERC Associates ERC840HX was used from August through October 2009 at a mean addition rate of 1.15 gallons of concentrated polymer (as purchased) per 1000 treated gallons. The concentrated polymer is diluted in the injection system used to feed the polymer. Muriatic acid was used to neutralize the filtrate extracted in the rotary screen thickener, which is discharged to a blending tank ahead of the aerobic processing tanks. The acid was fed from the containers

Table 3. Biosolids Metals Concentration

Analyte	Units	3/13/2009	6/18/2009	Pollutant Concentration Limits for EQ Class A Biosolids
Arsenic	mg/kg	3.5	4.4	41
Cadmium	mg/kg	2.4	2.2	39
Chromium	mg/kg	18	19	1,200
Copper	mg/kg	430	260	No standard
Lead	mg/kg	21	23	300
Mercury	mg/kg	0.33	0.22	17
Nickel	mg/kg	12	12	420
Selenium	mg/kg	5.9	2.6	36
Zinc	mg/kg	1,300	990	7,500
Total Solids	%	50	60	NA

received from the supplier without intermediate dilution. The mean muriatic acid use was 0.55 gallons per 1000 treated gallons.

The electric power and natural gas use during the verification test was monitored using the facility electric and gas meters. These meters measured total use for the facility. Electrical use averaged 671 kWh per day based on 5-day operating periods treating two batches per week. Steam for heating the biosolids in the screw press was generated on-site with a gas fired boiler. Natural gas use averaged 25 cubic feet per day based on the 5-day operating periods treating two batches per week during the verification test.

There were no major mechanical component failures or major downtime periods during the verification test. Operation and maintenance of the System was observed by the testing organization representatives who were on- site for several days each month to collect samples and review operating records. These observations provided information on System operability, complexity, and degree of maintenance required. The Big Fish System was found to be easily operated, requiring only routine maintenance, and was reliable during the verification period.

Quality Assurance/Quality Control

Prior to the start of the verification test, NSF completed a QA/QC audit of the RTI Laboratories (RTI). These audits included: (a) a technical systems audit to assure the testing was in compliance with the test plan, (b) a performance evaluation audit to assure that the measurement systems employed at the test site and by RTI were adequate to produce reliable data, and (c) a data quality audit of at least 10 % of the test data to assure that the reported data represented the data generated during the testing. During testing, NSF conducted a QA/QC audit of the Big Fish Environmental test site. EPA QA personnel also conducted a quality systems audit of NSF's QA Management Program.

Original signed by
Sally Gutierrez *October 26, 2010*
Sally Gutierrez Date
Director
National Risk Management Research Laboratory
Office of Research and Development
United States Environmental Protection Agency

Original signed by
Robert Ferguson *November 2, 2010*
Robert Ferguson Date
Vice President
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NOTICE: Verifications are based on an evaluation of technology performance under specific, predetermined criteria and the appropriate quality assurance procedures. EPA and NSF make no expressed or implied warranties as to the performance of the technology and do not certify that a technology will always operate as verified. The end user is solely responsible for complying with any and all applicable federal, state, and local requirements. Mention of corporate names, trade names, or commercial products does not constitute endorsement or recommendation for use of specific products. This report in no way constitutes an NSF Certification of the specific product mentioned herein.

Supporting Documents

Referenced Documents:40 CFR Part 503, *Standards for the Use or Disposal of Sewage Sludge*, Subchapter O, http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title40/40cfr503_main_02.tpl

1) *A Plain English Guide to the EPA Part 503 Biosolids Rule*, http://www.epa.gov/OW-OWM.html/mtb/biosolids/503pe/index.htm
2) *Test Plan for Big Fish Environmental, LLC Big Fish Environmental Septage Processing System,* dated July 2008; http://www.epa.gov/etv/pubs/04_vp_wastewater.pdf
3) *The Protocol for Verification of Wastewater Treatment Technologies,* dated April 2001 (see below for availability).

EPA's Office of Wastewater Management has published a number of documents relevant to this verification, including:

Handbook for Management of Onsite and Clustered Decentralized Wastewater Treatment Systems, http://www.epa.gov/owm/onsite
Onsite Wastewater Treatment Systems Manual, http://www.epa/gov/owm/mtb/decent/toolbox.htm

Source of Verification Information:

Copies of, *Test Plan for Big Fish Environmental, LLC Big Fish Environmental Septage Processing System,* dated July 2008, the Verification Statement, and the Verification Report are available from: ETV Water Quality Protection Center Manager (order hard copy), NSF International, P.O. Box 130140, Ann Arbor, Michigan 48113-0140 (http://www.nsf.org/etv (electronic copy); or http://www.epa.gov/etv (electronic copy)). Appendices are not included in the Verification Report, but are available from NSF upon request.

Environmental Technology Verification Report

Wastewater Treatment Technology for Septage and High Strength Wastewater

Big Fish Environmental, LLC
Big Fish Environmental Septage and High Strength Wastewater Processing System

Prepared for

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Ann Arbor, MI 48105

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Under a Cooperative Agreement with the U.S. Environmental Protection Agency

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Notice

The U.S. Environmental Protection Agency (EPA), through its Office of Research and Development, has financially supported and collaborated with NSF International (NSF) under a Cooperative Agreement. The Water Quality Protection Center (WQPC), operating under the Environmental Technology Verification (ETV) Program, supported this verification effort. This document has been peer reviewed and reviewed by NSF and EPA and recommended for public release.

Foreword

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

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Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
Big Fish	Big Fish Environmental, LLC
Big Fish System	Big Fish Septage and High Strength Wastewater Processing System
BOD_5	5 –day biochemical oxygen demand
°C	Celsius degrees
COD	Chemical oxygen demand
DO	Dissolved oxygen
DQI	Data quality indicators
ETV	Environmental Technology Verification
°F	Farenheit degrees
FOG	Fats, oil, and grease
ft^2	Square foot (feet)
gal	Gallons
gpd	Gallons per day
gpm	Gallon(s) per minute
GP	Generic protocol
In.	Inch
Kg	Kilogram(s)
L	Liters
lbs	Pounds
MDL	Minimum detection level
MDNRE	Michigan Department of Natural Resources and Environment
NH_3-N	Ammonia nitrogen
NO_2	Nitrite
NO_3	Nitrate
NRMRL	National Risk Management Research Laboratory
µg/L	Microgram(s) per liter (ppb)
mg/L	Milligram(s) per liter
mL	Milliliter(s)
NSF	NSF International
NIST	National Institute of Standards and Technology
O&M	Operations and maintenance
PM	Project Manager for the Testing Organization (TO)
ppb	Parts per billion (µg/L)
QA	Quality assurance
QC	Quality control
RPD	Relative percent difference
SD	Standard deviation
SOP	Standard operating procedure
T	Temperature
TKN	Total Kjeldahl nitrogen

TO	Testing Organization
TP	Total phosphorus
TSS	Total suspended solids
USEPA	U.S. Environmental Protection Agency
VO	Verification Organization (NSF)
VTP	Verification test plan
WWTP	Wastewater treatment plant
WQPC	Water Quality Protection Center

Acknowledgments

The Testing Organization (TO), Scherger Associates, was responsible for managing the testing sequence on site at the Big Fish Environmental facility in Charlevoix, MI, including collection of samples, checking that equipment and instruments were being monitored and maintained, collection of field data, and data management. Mr. Dale Scherger was the Project Manager for the TO. Mr. Randy Holecheck was the field technician responsible for sample collection and system observations.

RTI Laboratories, Inc. conducted the analytical work for this study, with primary contacts being Mr. Brian Hall and Ms. Patricia Jennings. RTI is NELAC accredited to drinking water, wastewater, and hazardous and solid waste in the State of Illinois, and the State of Michigan for drinking water analysis. Mr. John Campbell is the manufacturer and assembler of the equipment and facility

The TO thanks NSF International, especially Mr. Thomas Stevens, Project Manager, for providing guidance and program management. The TO also thanks Mr. Brian Darrah, the Big Fish System supervisor for his efforts in maintaining all the records required by the ETV program and assistance in scheduling the treatment system activities to meet the ETV sampling schedule.

Chapter 1 Introduction

1.1 ETV Purpose and Program Operation

The U.S. EPA created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The ETV Program's goal is to further environmental protection by substantially accelerating the acceptance and use of innovative, 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 recognized standards and testing organizations (TOs); stakeholders groups that consist of buyers, vendor organizations, consulting engineers, and regulators; and 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.

In cooperation with EPA, NSF operates the Water Quality Protection Center (WQPC), one of six centers under ETV. This WQPC focuses on technologies addressing wet weather flows and source water protection (SWP), and includes the verification testing of wastewater treatment systems that provide protection for groundwater and surface water sources. NSF International (NSF) operates the WQPC under the sponsorship of the Urban Watershed Management Branch, Water Supply and Resources Division, National Risk Management Research Laboratory. The role of NSF is to provide technical and administrative leadership in conducting the testing.

The ETV program has developed verification testing protocols that serve as templates for conducting verification tests for various technologies. The *Protocol for the Verification of Wastewater Treatment Technologies*, April 2001[1] was published as the guidance document for test plan development for verification testing of decentralized wastewater treatment systems for all non-residential (commercial and industrial) wastewater and for residential wastewater with flow rates greater than 1,500 gallons per day (gpd). The goal of the verification testing process is to generate high quality data for verification of equipment performance.

It is important to note that verification of the equipment does not mean or imply that the equipment is “certified” or “approved” by NSF or USEPA. Instead, verification testing is a formal mechanism by which the performance of equipment can be determined, resulting in the issuance of a Verification Statement and report by NSF and USEPA.

The WQPC evaluated the performance of the Big Fish Environmental Septage and High Strength Wastewater Processing System (Big Fish System) for the removal of contaminants present in septage and high strength wastewater. These contaminants include total suspended solids (TSS),

biochemical oxygen demand (BOD_5), COD, fats, oil, and grease (FOG), and nutrients, (including phosphorus, total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), and nitrite plus nitrate nitrogen (NO_2+NO_3)). This report provides the verification test results for the Big Fish System in accordance with the GP [(1)], and the technology specific test plan, *Verification Test Plan for Big Fish Environmental Septage Processing System,* July 2008 [(2)] (VTP). The purpose of the VTP is to assure performance of the product in accordance with manufacturer claims.

1.2 Testing Participants and Responsibilities

The ETV testing of the Big Fish System was a cooperative effort between the following participants:

- NSF
- Scherger Associates
- RTI Analytical Laboratories, Inc.
- Big Fish Environmental, LLC
- USEPA

1.2.1 NSF International – Verification Organization (VO)

The WQPC of the ETV is administered through a cooperative agreement between EPA and NSF. NSF is the verification partner organization for the WQPC and the SWP area within the center. NSF administers the Center and contracts with the Testing Organization (TO) to develop and implement the VTP, conduct the verification test, and prepare the verification report.

NSF's responsibilities as the VO included:

- Review and comment on the site specific VTP;
- Coordinate with peer reviewers to review and comment on the VTP;
- Coordinate with the EPA Project Officer and the technology vendor to approve the VTP prior to the initiation of verification testing;
- Review the quality systems of all parties involved with the TO and, subsequently, qualify the companies making up the TO;
- Oversee the technology evaluation and associated laboratory testing;
- Provide quality assurance/quality control (QA/QC) review and support for the TO;
- Carry out an on-site audit of test procedures;
- Oversee the development of a verification report and verification statement;
- Coordinate with EPA to review the verification report and sign the verification statement; and
- Prepare and disseminate the Verification Report and Verification Statement.

The key contact at NSF for the VO is:

Mr. Thomas Stevens, Program Manager
(734) 769-5347 email: stevenst@nsf.org

NSF International
789 N. Dixboro Road
Ann Arbor, MI 48105
(734) 769-8010

1.2.2 U.S. Environmental Protection Agency (EPA)

The EPA Office of Research and Development, through the Urban Watershed Management Branch, Water Supply and Water Resources Division, NRMRL, provides administrative, technical, and QA guidance and oversight on all ETV WQPC activities. EPA reviews and approves each phase of the verification project. EPA's responsibilities with respect to verification testing include:

- Review and approve verification test plan;
- Provide QA and technical review comments for verification report; and
- Review and sign verification statement.

The key EPA contact for this program is:

Mr. Ray Frederick, Project Officer, ETV Water Quality Protection Center
(732)-321-6627 email: frederick.ray@epa.gov

U.S. EPA, NRMRL
Urban Watershed Management Branch (MS-104)
2890 Woodbridge Ave.
Edison, NJ 08837-3679

1.2.3 Testing Organization (TO)

The TO for the verification testing was consortium headed by Scherger Associates. Mr. Dale A. Scherger was the Project Manager (PM) for the TO. An experienced wastewater operator in the Charlevoix, MI area, Mr. Randy Holecheck, collected all samples, prepared and shipped the samples to the laboratory, and monitored the test site during the testing. Scherger Associates developed the test plan, analyzed the data, and prepared the verification report. RTI Laboratories performed all of the analytical work. The laboratory was responsible for laboratory quality assurance for the verification test through its QA group. NSF audited the laboratory prior to the initiation of the test.

The responsibilities of the TO included:

- Prepare the site specific VTP;
- Conduct verification testing, according to the VTP;
- Oversee the operation and maintenance of the system during ETV testing;
- Schedule and coordinate the activities of all verification testing participants, including establishing a communication network and providing logistical and technical support;
- Resolve any quality concerns encountered and report all findings to the VO;
- Manage, evaluate, interpret and report data generated by verification testing;
- Evaluate and report on the performance of the technology; and
- Document changes in plans for testing and analysis, and notify the VO of any and all such changes before changes were executed.

The key personnel and contacts for the TO were:

Scherger Associates:

Mr. Dale Scherger, P.E.
Scherger Associates
3017 Rumsey Drive
Ann Arbor, MI 48105-9723
(734) 213-8150 email: daleres@aol.com

RTI Laboratories, Inc.

Mr. Brian Hall and Ms. Patricia Jennings
RTI Laboratories, Inc.
31628 Glendale Street
Livonia, MI 48150
(734) 422-8000 email: bhall@rtilab.com; pjennings@rtilab.com

1.2.4 Technology Vendor

The wastewater treatment technology evaluated was the Big Fish System designed, assembled, and installed by Big Fish Environmental, LLC. The vendor was responsible for supplying the equipment needed for the VTP, supporting the TO in providing needed information and facilities for on-site work, and ensuring proper operation of the equipment during the verification test period. Specific responsibilities of the vendor were:

- Initiate application for ETV testing;
- Provide input to the verification testing objectives to be incorporated into the VTP;
- Select the test site (Charlevoix site already in place);
- Provide complete ready to operate equipment, and the operations and maintenance (O&M) manual(s) typically provided with the technology (including instructions on installation, start-up, O&M) for verification testing;
- Provide any additional equipment, piping, pumps, valves, flow meters, tanks, etc. needed to setup the test (none required);

- Provide any existing relevant performance data for the technology if it has been tested/operated at other locations;
- Review and approve the site-specific VTP;
- Provide logistical and technical support;
- Operate the technology during the verification testing;
- Arrange for shipments of septage and other wastewaters or residuals to the facility during the verification test;
- Review and comment on the verification report; and
- Provide funding for verification testing.

The key contact for Big Fish Environmental, LLC was:

Mr. John Campbell
Big Fish Environmental, LLC
12640 Taylor Road
P.O. Box 528
Charlevoix, MI 49720
(231) 547-4429 Email: info@bigfishenvironmental.com

1.2.5 ETV Test Site

As described in Section 1.4, the verification test was performed at the Big Fish facility in Charlevoix, MI. Big Fish owns, operates, and maintains the septage processing system at this location. As the owner Big Fish will:

- Provide space and utilities for the verification test; and
- Provide access to the existing equipment, piping, pumps, valves, flow meters, tanks, etc. needed to setup the test.

1.3 Background and Objectives

Verification testing of wastewater treatment systems under the ETV WQPC is designed to verify a technology's contaminant removal performance, and the O&M of the commercial-ready technology, following technically sound protocols and appropriate quality assurance and control. A primary objective of the ETV is to measure the performance of these technologies through a well-defined test plan that includes measurement of contaminants present in residential and non-residential wastewaters, before and after application of the treatment technology.

The Big Fish Systems are designed to treat septage, portable toilet waste, fruit processing waste, wastewater treatment plant biosolids, waste containing FOG and other high organic strength wastewaters to meet the regulatory requirements for discharge of treated effluent to a municipal wastewater treatment system, while producing an Exceptional Quality (EQ) Class A Biosolids, which can be used for agricultural or home garden use. Actual numerical standards for discharge

to municipal treatment systems will vary by location. The Big Fish System is designed to meet pretreatment standards for discharge to most secondary wastewater treatment systems (typically 250-300 mg/L BOD_5; 300-350 mg/L TSS; 50-70 mg/L NH_3; and locally determined restrictions for TP). The system that was tested in this verification is a full scale, commercially available unit installed and operated by Big Fish in Charlevoix, MI. The effluent from the system discharges to the City of Charlevoix Wastewater Treatment Plant (WWTP).

The objective of this Verification Test Plan (VTP) was to determine the performance attained by the Big Fish System when used to treat a mixture of wastewaters. These wastes contain organic, solids, and nutrient constituents that can impact groundwater and surface water if discharged or disposed of untreated. Reductions in contaminant loads were evaluated to determine the effectiveness of the system to remove suspended solids, BOD, FOG, and nutrients (phosphorus and nitrogen). The production of biosolids meeting one of the six treatment options for Class A pathogen reduction and vector attraction reduction, as defined in 40 CFR 503.32 and 503.33, and the EQ designation in accordance with Tables 2-1 and 2-2 of the EPA Plain English Guide to the EPA Part 503 Biosolids Rule, EPA/832/R-93/003, September 1994 was also verified during the test. The objective was achieved by implementing testing and monitoring procedures presented in the VTP.

During the verification, the treatment system received septage from residential and commercial septic tanks, portable toilet waste, fruit processing waste, municipal WWTP secondary sludge, and commercial wastes with FOG, containing solids, organics, nutrients, and other constituents typically present in residential and commercial septage and related wastes. During this evaluation, the term "wastewater" received at the test site is a combination of all of these waste sources, in varying amounts. The treatment system was challenged under a variety of hydraulic loading conditions and contaminant loads during the 13 month test period. Waste generation and demand for treatment varied seasonally, so the one-year test period covered high and low demand periods. The influent and effluent to/from the system were sampled and the samples were analyzed for various contaminants or contaminant indicators, including BOD_5; COD; TSS; nitrogen compounds (TKN, NH_3, NO_2+NO_3), TP and FOG. The results were used to calculate removal efficiencies and to determine the system treatment effectiveness. These parameters and other operating parameters (flow, pH, alkalinity, temperature, dissolved oxygen, per cent solids, biosolids production) were monitored to meet the ETV objective of providing an overall assessment of the technology that can be used by permit writers, buyers, and users of the technology.

The treatment system was also observed for O&M characteristics, including the performance and reliability of the equipment, the amount of personnel time required to operate the process, the level of operator skill required, the maintenance required to maintain process operation and overall power and natural gas consumption. Data were also collected on the generation of residues.

1.4 Test Site Description

The verification test was performed at the Big Fish facility in Charlevoix, Michigan, as shown in Figure 1-1.

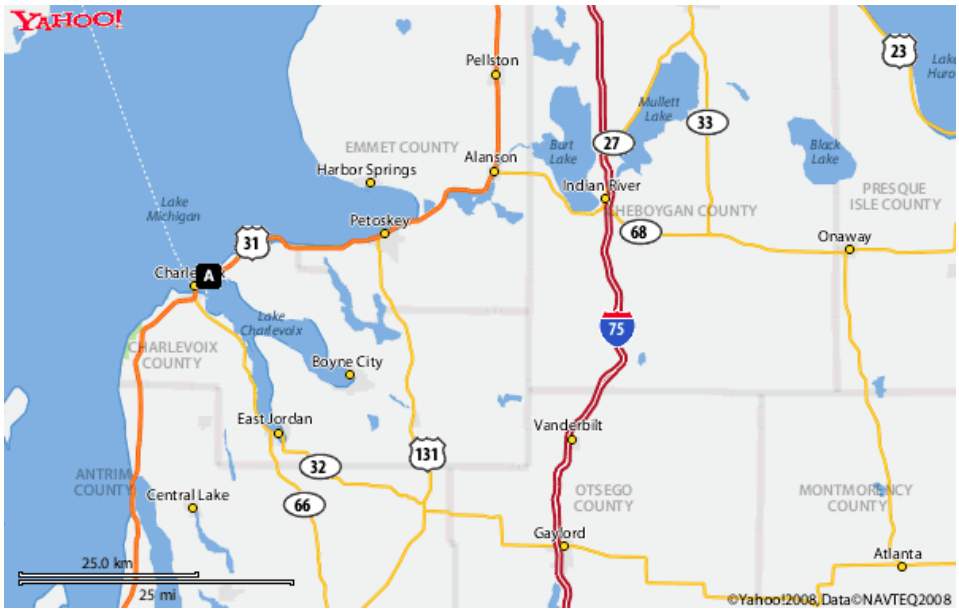


Figure 1-1. Verification test site location map.

Big Fish has built a full-scale treatment system in Charlevoix to serve the surrounding area. Big Fish owns, operates, and maintains the system as a private business under a permit issued by the Michigan Department of Natural Resources and Environment (MDNRE) and in accordance with the requirements of the City of Charlevoix set forth in a letter of determination. The system receives septage waste from several septic tank cleanout companies, secondary sludge from the City of Charlevoix WWTP, commercial grease interceptor waste containing FOG from local businesses, portable toilet waste and fruit processing waste. The current treatment system has been in operation for over three years. Treated effluent is discharged to the City of Charlevoix municipal WWTP. The MDNRE permit and the City of Charlevoix require that monthly operating reports be submitted to document system performance. Table 1-1 shows the permit limits set for the Big Fish facility.

Table 1-1. Discharge Permit Limits for the Big Fish Facility

Parameter	Sample Frequency	Sample Type	Permit Limit
Flow	Every discharge period	Meter	Report
pH	Every discharge period	grab	pH 6 to 9
BOD_5	Every discharge period	Composite	300 mg/L maximum.
TSS	Every discharge period	Composite	350 mg/L maximum
Ammonia	Every discharge period	Composite	65 mg/L (as N) maximum
TP	Every discharge period	Composite	3.0 lbs/day

1.5 Historical Flow and Effluent Quality

The volume of wastewater received and treated at the facility has been collected as part of normal facility operation and for reporting to the MDNRE. The system operates in a batch/semi continuous mode. Under normal operation, when the aerated equalization/receiving tanks are full, wastewater is transferred to the completely mixed lime reaction/holding tank, where lime is added to the wastewater to bring the tank contents to a pH of 12. The contents are mixed for 24 hours to meet the pH holding time for Class A Biosolids vector attraction reduction, and are then processed through the screw press over a 16-20 hour period (typical process time) to meet the temperature requirement for Class A pathogen reduction. The filtrate from the screw press is discharged to the aerobic treatment tanks, while the dewatered solids are collected in a bin for subsequent transport of the biosolids to a storage area. The filtrate displaces treated water in the aerobic system and settling tanks that had been in a recycle mode following the previous treatment period. The number of discharges per month can vary from two or three, up to 10-15 during busy months. A summary of the average monthly flow rates and reported water quality data for the period January 2007 through January 2008 (before the verification testing) is shown in Table 1-2.

Table 1-2. Summary Flow Rate and Water Quality Data for Test Site (January 2007 through January 2008)

	Average Monthly Effluent (gal)	BOD_5 (mg/L)		TSS (mg/L)		NH_3 (mg/L as N)		TP (mg/L as P)		
		Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Eff. (lbs/day)
Average	74,587	3,300	105	10,900	123	111	23	310	10	1.6
Maximum	177,720	4,380	210	14,060	266	407	53	652	25	2.8
Minimum	12,985	1,980	27	6,930	15	26	1.0	32	1.3	0.04

Calculated based on actual daily volume discharged and the effluent concentration associated with the discharge volume; effluent TP are in lbs/day.

Note: Influent and effluent water quality data was available from the monthly reports prepared for the MDNRE. These data show no violations of the MDNRE limits.

Chapter 2 Technology Description and Operating Processes

2.1 Technology Overview

The treatment of concentrated wastewaters, such as septage, presents a challenge to municipal wastewater treatment systems due to the intermittent and highly variable volume of wastewater being delivered. The Big Fish Environmental System has combined processes to treat these high strength wastes, producing EQ Class A Biosolids and municipal strength wastewater, which can be discharged for final treatment at a municipal wastewater treatment system. The system combines solids treatment and handling with aerobic wastewater treatment to achieve the process objectives. An overview of the process steps is shown in Figure 2-1, Figure 2-2 provides a process flow diagram for the entire process and Figure 2-3 shows the biosolids-processing diagram. Each of the processes is discussed in detail in the following sections.

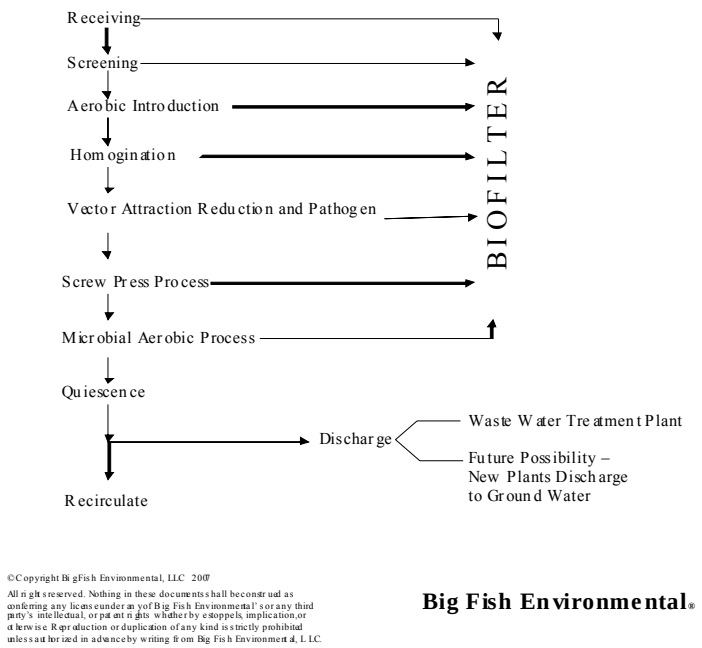
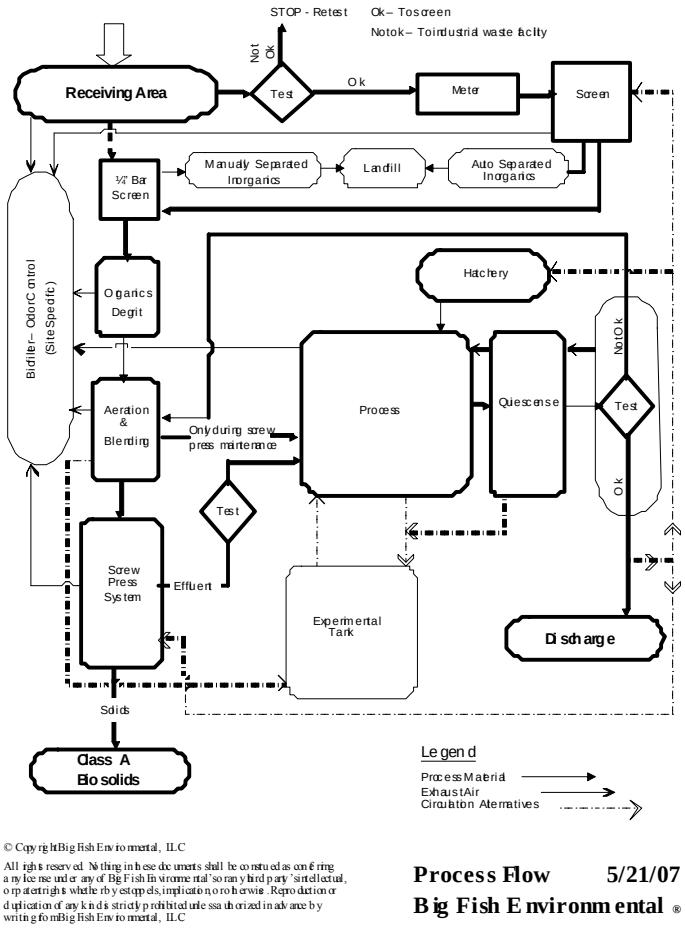


Figure 2-1. Big Fish System overview of processing steps.

2.1.1 Truck Unloading, Screens, and Equalization

The Big Fish truck unloading is inside the main building adjacent to the aerobic treatment tanks and other processing equipment. Trucks enter the unloading area and close the large roll-up door

to control odors. The Big Fish site was designed with a biofilter for control of odors, but it was not part of this verification. Trucks are unloaded by pressurizing the truck tank. A JWC Muffin Monster ¼-in. (6 mm) screen is in line to remove any large inorganic particles or debris. A flow meter records the amount of wastewater unloaded from the truck, and an in-line pH meter monitors the wastewater to confirm the pH is greater than 4.0 and less than 9.0. The screened wastewater then passes through a de-grit chamber and flows into the first 11,000 gal receiving/equalization tank. This tank is aerated, which provides mixing of the various wastewater received and provides oxygen to maintain dissolved oxygen levels so that the stored wastewater remains aerobic. The first receiving/equalization tank is connected to a second aerated 15,000 gal equalization tank. Large volume equalization is used to mix the variety of wastewater being received and to provide sufficient volume for the batch treatment in the vector attraction and pathogen reduction treatment step (lime treatment and subsequent screw press operation for solids separation).



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Process Flow 5/21/07
Big Fish Environmental ®

Figure 2-2. Big Fish System process flow diagram.

Once 20,000 gal or more of wastewater is accumulated in the equalization system, the wastewater is ready for transfer to the lime treatment system. A pump in the second equalization tank is activated to transfer the wastewater to one of the lime treatment tanks.

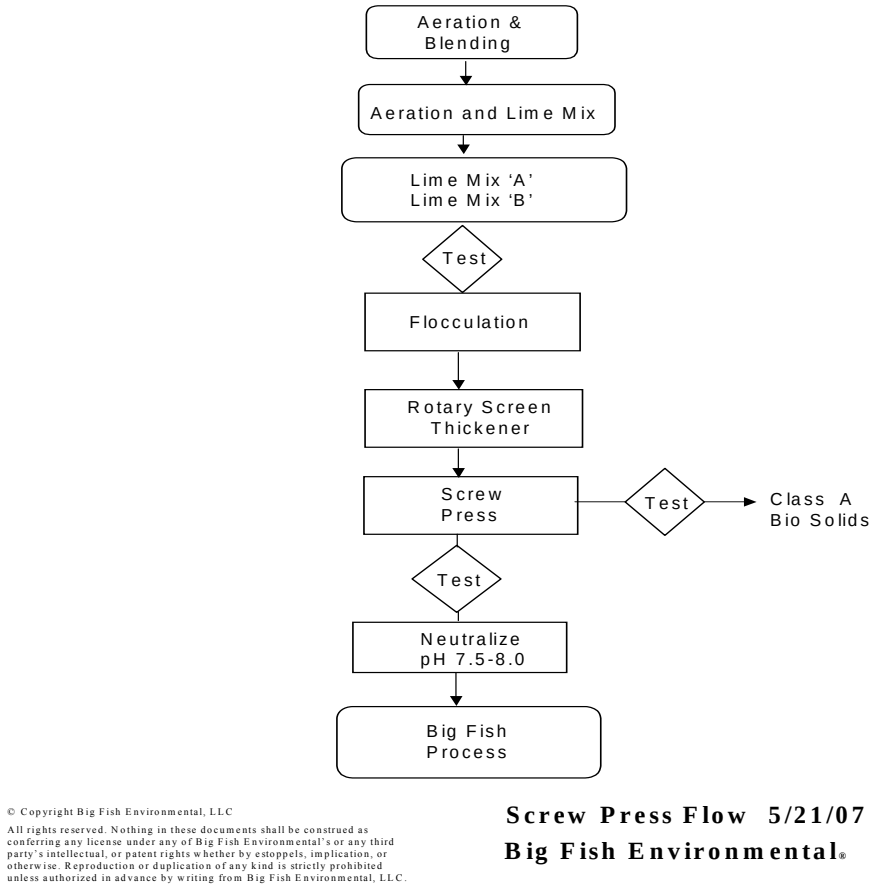

Figure 2-3. Big Fish System biosolids process description.

2.1.2 Lime Treatment and Solids Separation – Biosolids Production

Figure 2-3 shows a process flow description of the biosolids treatment part of the Big Fish System. When a batch of wastewater is ready for treatment, the lime feed system is activated and the equalization tank pump is started. Lime is added directly to the flowing wastewater as it is transferred to a lime treatment tank. The lime feed system uses a standard lime feeder to introduce hydrated lime directly into the flowing wastewater. The lime dosage can be adjusted by changing the lime feed rate and dosing time.

There are two 20,000 gal lime treatment tanks. Each tank mixes the material to ensure that all of the wastewater and solids are brought to the elevated pH. Lime is added to the influent waste mixture (septage, FOG, secondary biosolids, etc) to achieve pH 12 for a minimum of 2 hours, and then is held at minimum pH of 11.5 for a minimum of 22 hours. pH is monitored and recorded in the operation log to document that a pH of 12 or greater is maintained for at least two hours. Once these first pH criteria are met, the wastewater continues to be treated in the lime tank for a minimum of 22 additional hours. During this period, pH is monitored and recorded to document that a pH >11.5 is maintained for the entire period.

After lime treatment is complete, the wastewater/solids are pumped from the lime treatment tank through a flocculation tank and a rotary screen thickener to build solids particle size and thicken the solids prior to entering the screw press. Polymer is added to the material entering the flocculation tank. Typically, the solids content after flocculation and thickening is 17-18%. Filtrate extracted in the rotary screen thickener is discharged to a blending tank. The pH is adjusted with muriatic acid to approximately pH 7.5 – 8.0.

The thickened sludge is processed in a screw press that also heats the solids to a minimum of 72° C (162° F) for a minimum of 20 minutes. The screw press is a hollow core design that has proven very effective in increasing the solids content to 40-50%. The combination of the lime treatment and the elevated temperature in the screw press meets the treatment requirements of the EPA Biosolids Rule to produce EQ Class A Biosolids. A boiler supplies steam that is circulated through the screw press to provide the heat to raise the solids temperature. The temperature of the solids exiting the screw press is measured and recorded to document the operating conditions. Solids are collected in a hopper and the transferred to an outside covered storage area. The filtrate from the screw press is discharged to the first aerobic treatment tank for subsequent biological treatment.

2.1.3 Aerobic Treatment, Settling and Discharge

The aerobic treatment system consists of a series of aerated tanks followed by a quiescent settling tank, a re-aeration tank, and two discharge tanks. The aerobic treatment tanks have a combined volume of 27,000 gal. There is one 15,000-gal tank and eight (8) 2,000 gal tanks. Each tank is aerated and has one or more White Knight^{TM} microbial generators, in-the-tank breeding columns that introduce, cultivate and release select groups of microorganisms, installed in the tank. These White Knight^{TM} generators are suspended in the aerated and well-mixed treatment tanks to provide a source of microorganisms in addition to the naturally occurring microorganisms in the suspended growth aerobic system.

A hatchery is used as part of the Big Fish system to supplement the quantity of microorganisms. The hatchery is a 250 gal tank that holds "seed" material from the main aeration system. The microbial population is kept alive by periodic feeding with molasses or other organic food. This simple system maintains an acclimated culture that can be used when the system is upset or to start the system after cleaning. The large capacity of the aeration tanks provides time for biological treatment to reduce the very high organic loadings that are normally still present in septage type wastes, even after solids removal.

Treated water from the aerobic system enters a 2,000 gal settling tank. This is a standard tank, with no special settling enhancements such as weirs or sludge collecting rakes. The quiescent settling tank provides sufficient time for the solids to separate. The clarified wastewater then enters the 2,000 gal re-aeration tank where the dissolved oxygen is increased prior to discharge. The aerated water then flows into two 2,000 gal discharge tanks. Solids that accumulate in the settling tank are periodically removed and placed back into the receiving tank for processing through the lime treatment and screw press processes.

When liquid is discharged from the screw press and thickener, the water balance within the system demands that water (effluent) be discharged from the system. The discharge pump is activated to pump the effluent to the municipal sewer system. The effluent passes through a flow meter to record the volume of the discharge and a sampler on the discharge line collects a composite sample over the period of discharge.

As shown in the summary flow data (Table 1-2), the volume of wastewater delivered/treated can vary from 13,000 to 178,000 gal per month. This means that the system operation can vary from as few as one batch in a month to as many as 10-15 batches (2-30 operating days). Big Fish has stabilized the operation of the aerobic system by using a combination of internal recycle, organism augmentation, and food addition during periods of low demand and between actual production/discharge days. When material is not being processed through the thickener and screw press, the discharge pump is not used and the liquid within the biological treatment system is recycled back to the first aerobic treatment tank. Thus, liquid is always moving through the aerobic, settling, re-aeration, and discharge tanks in the treatment system. Big Fish monitors the system on a periodic basis to determine if additional organisms or food need to be added to the system. The White Knight™ microbial generators are the primary approach to maintaining healthy microorganism populations during extended recycle periods. In addition, an on-site hatchery (aerated tank with organism from the main system) is maintained and fed with molasses or other food sources to grow and maintain an adapted culture of mixed organisms. These microorganisms can be added to the treatment system if prolonged recycling periods are encountered or if upset conditions occur. This also reduces the time needed to reestablish operating conditions after a tank clean-out has been done and restarting is necessary. Further, if the organic content of the main aerobic treatment system gets very low due to lack of septage/wastewater to be processed, supplemental food sources can be added to the system to maintain a healthy population of microorganisms. These additions of organisms and food generally are only needed in the winter months when incoming wastewater volumes are very low.

2.1.4 Operation and Maintenance

The Big Fish System is typically operated by one person in an eight hour day. During months when demand is high and three or more batches per week are being processed, additional personnel are used to support the operation.

Incoming truckloads of septage are unloaded by truck drivers using an automated system that tracks the flow of material being unloaded and the pH of the incoming material. If the pH is out

of range (<4.0 or >9.0), the system automatically stops the unloading process. Material flows into the screen and grit removal systems and enters an aerated, mixed, holding tank. This process can occur anytime without an onsite operator being present.

While some parts of the system are automated (discharge pump from the effluent tank, temperature monitoring of the screw press, etc.), the operator initiates all transfers from the holding tank to the lime treatment tanks, starts the lime addition, and collects samples for pH measurements, etc. After lime treatment is complete and pH is confirmed, the operator manually transfers treated wastewater to the thickener, starts the polymer and acid pumps, and starts the screw press. Once started, the process operates with only minimal oversight, while the operator performs other support duties such as on-site laboratory tests (pH, TSS, BOD_5, ammonia, temperature, dissolved oxygen, etc.). The effluent discharge pump starts automatically when the water level increases in the discharge tank, and the automatic sampler starts collecting the effluent composite sample.

The operator maintains a set of logs that are used to track all pertinent operating data. These data included discharge flow volume, tank levels, biosolids production volume, electrical usage, various temperature readings, pH, dissolved oxygen, etc. The programmable logic controller on the screw press monitors and records the biosolids temperature and screw press speed. These records document the operating conditions that are used to evaluate system performance and provide data for the monthly reports to regulatory agencies.

Major maintenance activities are recorded in a maintenance logbook. Routine maintenance activities such as cleaning, lubrication, clearing lines, etc. are not specifically documented.

2.2 Big Fish Environmental Claims

Big Fish claims their treatment system can treat septage, portable toilet waste, fruit processing waste, municipal secondary sludge, and FOG wastes to produce EQ Class A Biosolids and a wastewater that meets criteria for discharge to municipal wastewater treatment systems as shown in Table 2-1.

Table 2-1. Big Fish System Wastewater Treatment Claims

Parameter	Effluent Characteristics after Treatment
BOD_5	< 300 mg/L
TSS	< 350 mg/L
NH_3-N	< 65 mg/L (as N)
TP	5 – 15 mg/L (as P)

Chapter 3 Methods and Test Procedures

3.1 Verification Test Plan and Procedures

This section summarizes each of the testing elements performed during verification, including sample collection methods, analytical protocols, equipment startup, and equipment operation. QA/QC procedures and data management approach are discussed in detail in the VTP.

The VTP, *Verification Test Plan for Big Fish Environmental, LLC,* July 2008 [(2)], is included in Appendix B. The VTP details the procedures and analytical methods used to perform the verification test, including the various tasks designed to verify the performance of the Big Fish System and to obtain information on O&M requirements. The VTP covered two distinct phases of fieldwork: evaluation of the startup of the unit and a 13 month verification test that included a monthly sampling program. The verification test was completed between September 2008 and October 2009.

Given the nature of the wastes received at this facility and its location in northern Michigan, it was expected that a significant seasonal variation in wastewater volumes would occur. Septic tank pumping, portable toilet use and the generation of fruit processing waste typically only occurs from April through October/November due to the cold temperatures in the winter and the presence of seasonal dwellings in the service area. Based on these factors, the initial test program sampling requirement (composite samples over four days, once per month) was modified for winter months to allow for two batches of material to be processed on different weeks rather than in one week. Under this approach, the number of BOD_5, COD, TSS, FOG, and alkalinity samples (samples that are not composited over several days) remained at two per month, and the nutrient samples were actually increased from one composite per month to two samples per month of both influent and effluent. Sufficient wastewater was available during the verification test such that the "normal" two batch weekly composite approach was achieved during twelve of the 13 sampling periods. One month, March 2009, included only a single sampling event, i.e. one batch of wastewater was processed and sampled.

3.2 Installation and Startup Procedures

The Big Fish System was installed and operating at the test site for over two years prior to the verification test. The System had been treating various wastewaters and meeting the State of Michigan discharge permit limits. The existing system was in use on a regular basis to treat customer wastes. Therefore, the test plan did not include or require observation of the actual installation of the tanks and equipment.

In the planning process, Big Fish agreed to demonstrate startup of the system during a low demand month in either January or February. Therefore, the system cleaning and restart procedure described below were developed to allow observation of system startup, which should be representative of a new system startup or a restart of an existing system that has experienced

an upset condition. Big Fish emptied the aerobic treatment tanks, the settling tanks, and the discharge tank. These tanks were cleaned, visually inspected, and placed back into service. Once the System was clean, it was restarted using normal startup procedures.

The tank cleaning procedure included pumping all of the wastewater out of the aerobic treatment tanks, the settling tank, re-aeration tank, and final discharge tank. This wastewater was sent to the municipal treatment system. This work was accomplished in one day. The tanks were then rinsed and cleaned to remove solids buildup in the tanks. Once the tanks were clean, they were filled with a combination of processed wastewater from the screw press process. Microorganisms were seeded to the aerated tanks by adding 1500 gal of material from the hatchery tank. The White Knight™ microbial generators were hung in place in accordance with standard operating practice.

The startup period was completed in less than thirty days, so no special sampling under the ETV plan was required. The normal January 2009 verification sampling was performed three weeks after startup. The Big Fish operators performed daily field tests (pH, dissolved oxygen and temperature) and settleable solids were monitored three times per week during the startup. Table 3-1 shows the startup monitoring data and observations recommended by Big Fish. All field test data collected during startup were recorded in the logbook. Visual observations and any changes made to the system were recorded in the logbook to track the startup process.

Big Fish management and the on-site operator determined that the startup was complete after approximately three weeks and, after consultation with Scherger Associates and NSF, the verification testing was resumed. This decision was based on reviewing the operating conditions and the effluent quality, which indicated the system was stable and operating in accordance with the Big Fish specifications.

3.3 Verification Testing

3.3.1 Introduction

The Big Fish System was designed to treat septage and similar wastewater to meet typical discharge standards to municipal treatment systems, as established by state and local governments. This verification test was designed to determine the effluent quality achieved by the Big Fish treatment system. This was achieved for liquid effluent by collecting and analyzing samples of the treated water discharged from the aerobic treatment system. Biosolids quality was determined by monitoring and evaluation of operating parameters according to the published Federal Rule to demonstrate that EQ Class A Biosolids criteria were met for all dewatered biosolids produced.

Table 3-1. Startup Monitoring – Typical Big Fish System Recommended Schedule

Sample Schedule Parameter	Frequency	Sample Type	Recordkeeping
Flow rate (gpd)	Daily	Meter	Recorded by time and date
pH	Daily	Grab	Recorded by time and date
Temperature	Daily	Grab	Recorded by time and date
Settleable solids	3/week	Grab	Recorded by date
Dissolved oxygen	Daily	Grab	Recorded daily during startup

3.3.2 Objectives

The objectives for the experimental design for this verification test were:

- Determine the level of treatment performance of the Big Fish System in removing key target constituents, including TSS, BOD_5, COD, FOG, TKN, NH_3, and TP;
- Determine if the biosolids meet EQ Class A requirements;
- Document the basic operation and maintenance requirements during the test;
- Document the solids residuals produced by the system; and
- Document the chemical use and power consumption of the system.

3.3.3 Verification Test Period

The test period began in September 2008 and continued for 13 months. No more than 36 days of upset conditions or downtime was allowed by the protocol during the verification test period. Sampling was suspended from mid-March through April 2009 due to reduced incoming wastewater volume, thought to be the result of the economic downturn. Sampling resumed in May 2009. A system upset occurred in May due to a very high organic content waste entering the system, which was reflected in the May samples. The system was back to normal operation within a couple of weeks and the June sampling showed that the system had recovered from the upset. The test included a full range of flow conditions and influent characteristics. Historical data and general information available about the test site indicated that with reasonable spacing of sampling, all types of conditions were monitored over the 13 month period.

3.3.4 Flow Monitoring

The volume and type of waste from each truckload received at the site was recorded for characterization. When the system was ready for treatment of a batch of wastewater, the volume of liquid placed in the lime treatment tank was recorded, based on the time the pump was operated and the wastewater level in the lime treatment tank after the transfer was complete.

The effluent discharged to the municipal collection system from the Big Fish System was monitored by a Seametrics electromagnetic flow meter on the discharge line to the municipal

system. The discharge volume was recorded and provided the flow record for the verification test.

3.3.5 Sampling Locations and Procedures

Sampling locations included the untreated wastewater influent (mixed wastewater in the equalization tank) and the final treated effluent discharged to the municipal treatment system. The untreated wastewater was collected as grab samples from the equalization tank prior to the transfer of a batch of wastewater to the lime treatment tank. This mixed wastewater represented the entire mixture of wastewater being treated for that batch, and was matched with the discharged wastewater that occurred when the lime treated wastewater was processed through the screw press and the resultant liquid processed through the aerobic treatment system. The treated effluent was collected using the existing composite sampler located on the discharge line just prior to the effluent entering the municipal wastewater collection system. This location is the official sampling location for the facility operating permit. Composite samples were collected for the duration of the discharge, which was typically 12-16 hours, but could extend longer depending on batch size and discharge rate. The composite sampler collected equal aliquots on a time basis, which was equivalent to a flow weighted composite sample as the discharge was pumped to the municipal system at a constant flow rate.

In addition to the influent and effluent sampling locations, the individual truckloads of wastewater were monitored for volume and pH, as previously described, and were available along with a description of the type wastewater being received. Samples were collected for pH from the lime treatment tank to document the pH and time of treatment of the tank contents to confirm the requirements for Class A Biosolids were met. After lime treatment, the wastewater pH was adjusted to 7.5 - 8.0 using muriatic acid, and the adjusted pH was recorded. Temperature was monitored at the screw press to document that the biosolids were heated to the required greater than 72° C for a minimum of 20 minutes.

Both grab and composite samples were collected during all sampling events. The type of sample depended on the requirements and the holding time for each analysis. Grab samples at both the influent and effluent sample locations were collected each sample day for pH, temperature, dissolved oxygen, and FOG. Grab samples of the influent mixed wastewater were also collected for TSS, BOD_5, COD, alkalinity, TKN, NH_3-N, NO_2+NO_3, and TP. Composite samples of the discharge were collected each sampling day for TSS, BOD_5, COD, Alkalinity, TKN, NH_3-N, NO_2+NO_3, TP, chloride and sodium. A refrigerated automatic composite sampler was used to the collect the effluent composite samples. For all monthly sample periods except March 2009, where two consecutive days of discharge and sampling occurred, an aliquot of the daily composite sample was taken each day to create a two-day composite sample for TKN, NH_3-N, NO_2+NO_3, TP, chloride and sodium. Table 3-2 shows a summary of the sample collection and analysis program.

Table 3-2. Summary of Sampling Collection and Analysis

Parameter	Sample Type Influent	Sample Type Effluent	Frequency	Number of Events	Estimated Number of Samples (2)
pH	Grab	Grab	Daily(1)	25	50
T	Grab	Grab	Daily(1)	25	50
FOG	Grab	Grab	Daily(1)	25	50
TSS	Grab	24-hour composite	Daily(1)	25	50
BOD_5	Grab	24-hour composite	Daily(1)	25	50
COD	Grab	24-hour composite	Daily(1)	25	50
Alkalinity	Grab	24-hour composite	Daily(1)	25	50
TKN	Grab	96-hour composite(3)	One per event(1)	13	26
NH_3-N	Grab	96-hour composite(3)	One per event(1)	13	26
NO_2 +NO_3	Grab	96-hour composite(3)	One per event(1)	13	26
TP	Grab	96-hour composite(3)	One per event(1)	13	26
Sodium	Grab	96-hour composite(3)	One per event(1)	13	26
Chloride	Grab	96-hour composite(3)	One per event(1)	13	26

(1) Influent grab samples were collected when the process was started by filling the batch lime tanks, normally twice per week on Monday and Wednesday. The two influent grab samples were then composited for parameters listed as one per event. Effluent samples were composited when a discharge occurred usually form Tuesday afternoon to Wednesday morning, and from Thursday afternoon to Friday morning. Effluent composite samples from the two discharges were composited into a single composite for those parameters listed as one per event.

(2) Number of samples is based on two (2) sampling locations, untreated influent and the final treated effluent.

(3) A composite was made by taking the 24 hour daily composite, preserving it, and combining the preserved daily composite samples over a five-day period to form a single, event composite covering the treatment of two batches.

Dewatered biosolids were produced from the screw press. Treatment conditions were designed to produce Class A Biosolids, according to EPA requirements (40 CFR Part 503) which are based on treatment conditions and include pathogen reduction and vector attraction reduction. While this designation is not based on detailed analysis of the biosolids, Class A designation does require testing for fecal coliform with the frequency based biosolids production. Fecal coliform were monitored by Big Fish, using the same laboratory that was performing the verification analysis, and were reported to the State of Michigan in their annual report. These data are in Appendix A. While routine analyses were not required of the biosolids, the verification test included analysis for heavy metals and moisture/solids content. Grab samples of the biosolids were collected twice during the verification and were analyzed for percent solids and metals (As,

Cd, Cr, Cu, Hg, Pb, Ni, Se, Zn). The heavy metals data were to verify that the EQ requirements were achieved, as they are based on heavy metals concentration. The volume of biosolids produced by the screw press was recorded for each sampling event.

3.3.6 Sampling Schedule

The verification test consisted of twenty-five (25) sampling days over the 13-month test period. In the original test plan design, sampling varied during high and low flow months. During high flow months (six months during the test), the two days of sampling for the month were designed to occur on consecutive processing days with batch sizes of a minimum of 5,000 gal treated and discharged per day. During the remaining six months (lower flow demand periods), due to the anticipated lack of wastewater volume, the two sampling days were allowed anytime the system was treating wastewater and discharge occurred, even if they were not consecutive days. As stated in the VTP, it was expected that the schedule may require adjustment based on actual incoming waste loads to the faculty.

Wastewater volumes and planning of incoming loads allowed for the normal two consecutive batch processing approach to be performed during all of the months except March and April 2009. In March only one batch of processed wastewater could be sampled, and sampling was suspended for the month of April 2009 because of low influent volume. Once waste delivery and sampling resumed in May 2009, there was sufficient wastewater volume to use the normal processing approach contained in the ETV protocol, i.e. processing and sampling of two consecutive batches. Influent samples were taken on the first and third days of the week, and effluent samples (composite over the discharge time) were started on day two and four, generally being completed by the morning of the next day (days three and five).

Test Schedule:
September 22-26, 2008
October 13-17, 2008
November 10-14, 2008
December 8-12, 2008
January 26-30, 2009
January 26-30, 2009
February 16-20, 2009
March 9-11, 2009
May 18-22, 2009
June 22-26, 2009
July 20-24, 2009
August 17-21, 2009
September 21-25, 2009
October 19-23, 2009

3.3.7 Sample Preservation and Storage

The sample bottles required for the various analyses were provided by RTI, the subcontracted laboratory for this work. Table 3-3 shows the bottle types, sample size, and preservation required for each parameter. The bottles were provided with preservative, as needed, and were labeled by analysis type. The samples were logged, placed in coolers with ice to maintain temperature, and shipped to the laboratory by overnight express shipment.

Table 3-3. Preservation, Bottle Type, and Sample Size by Analysis

Sample Matrix	Analyses	Bottle Type/Size	Preservation/Holding Time
Wastewater	pH	Plastic 250 mL	None, analyze immediately
	T	Plastic 250 mL	None, analyze immediately
	FOG	Glass 1 L	Cool to 4º C, pH < 2 H_2SO_4, 28 days
	TSS	Plastic, 200 mL	Cool to 4º C, 7 days
	Alkalinity	Plastic, 250 mL	Cool to 4º C, 7 days
	BOD_5	Plastic, 500 mL	Cool to 4º C, 24 hours
	COD	Plastic, 100 mL	Cool to 4º C, pH < 2 H_2SO_4, 28 days
	TP	Plastic, 500 mL	Cool to 4º C, pH < 2 H_2SO_4, 28 days
	TKN	Plastic, 500 mL	Cool to 4º C, pH < 2 H_2SO_4, 28 days
	NH_3-N	Plastic, 500 mL	Cool to 4º C, pH < 2 H_2SO_4, 28 days
	$NO_2 + NO_3$	Plastic, 500 mL	Cool to 4º C, pH < 2 H_2SO_4, 28 days
	Sodium	Plastic 100 mL	pH<2 HNO3, 180 days
	Chloride	Plastic 100 mL	Cool to 4º C, 28 days
Solids	Metals	Plastic or glass, 250 mL or larger	Cool to 4º C, 6 months
	Percent solids	Plastic or glass, 500 mL	Cool to 4º C, 7 days

3.3.8 Chain of Custody

Chain of Custody was maintained for all samples collected during the verification test and sent to the outside laboratory. The TO operators filled out a chain of custody form for each set of samples. The form was signed and dated for each set of samples delivered to RTI. The receiving technician acknowledged receipt of the samples by signing the chain of custody form. All copies of the chain of custody records were maintained by the TO and by the chemical laboratory for all samples. Copies of the completed chain of custody forms were included with all laboratory reports transmitting final analytical results.

3.4 Analytical Methods

All analytical methods used during the verification test were USEPA approved methods[3,4] or methods from *Standard Methods for the Examination of Water and Wastewater*, 20th Edition[5]. All were in the Test Plan and QAPP approved by USEPA. Table 3-4 shows the analytical methods used for the verification test and the typical detection limits that were achieved by these methods.

Table 3-4. Analytical Methods

Sample Matrix	Analyses	Reference Methods	Reporting Detection Limit for Matrix
Liquid	pH	SM 4500-H B	N/A
	T	SM 2550 B	N/A
	DO	SM 4500-O G	0.5 mg/L
	FOG	EPA 1664A	3.0
	Alkalinity	SM 2320 B	10 mg/L
	TSS	SM 2540 D	3 mg/L
	BOD_5	SM 5210 B	3 mg/L
	COD	EPA 410.4	20 mg/L
	TP	SM 4500 P F	0.05 mg/L
	TKN	EPA 351.2	0.1 mg/L
	NH_3-N	SM 4500 NH3 D	0.04 mg/L
	$NO_2 + NO_3$	SM 4500 NO3 H	0.02 mg/L
	Chloride	EPA 300.0	1.0 mg/L
	Sodium	EPA 200.8	0.5 mg/L
Solid	Metals	EPA 200.8/245.1	Varies by metal and solids content
	Total solids	SM 2540 B	10 mg/kg

Three parameters were measured in the field - pH, dissolved oxygen, and temperature. RTI conducted all other analyses. All work was performed in accordance with QA/QC protocol as described in the Quality Assurance Project Plan developed for the verification test.

3.5 Operation and Maintenance

The Big Fish System was operated during the verification test by Big Fish personnel in accordance with the Operating Manual. The TO monitored the system during the test, including review of operating conditions, maintenance performed and operating records.

The Operating Manual, which provided detailed information for each unit operation, was available for review before the verification test began. The detailed instructions included descriptions of the operating data (pH, times, temperature, flows, etc.) that are recorded in the facility operating log. A field logbook was maintained by the TO to provide written notes for each visit to the site.

Any major maintenance activity performed by Big Fish personnel was logged in an on-site maintenance log and was reviewed by the TO.

The Big Fish operators recorded the level in each chemical solution tank (acid and polymer) at the end of each treatment period and recorded when a new tank of solution was prepared or placed into use. The quantity of lime used was determined by recording the length of time the lime feeder was operating and calculating total pounds fed to the batch of material being treated. These records were reviewed by the TO on a monthly basis. Chemical use during the verification test was determined form these records.

Power consumption was monitored on a daily basis. A standard electrical power meter was already installed at the site. Meter readings were taken daily throughout the test and recorded in the operating logbook. The electrical meter included the power by all the equipment and also included power for lighting, heater fans, and other general power used in the building dedicated to the System. The natural gas used to heat the boiler that feeds the screw press was also monitored from the gas meter at the site, and the readings were recorded in the logbook.

Any other observations on the operating condition of the unit, or the test system as a whole, were recorded in the logbook.

Odor, if any, was observed on each TO visit to the site (minimum of three to four days per month while processing). Also, any citizen complaints are part of the operating record and are included in the verification test record.

The plant operating and maintenance logbooks provided the information to validate the flow and operating conditions during the test periods. They served as the basis for making qualitative performance determinations regarding the unit's operability and the level/degree of maintenance required. These plant O&M logs were maintained by Big Fish personnel and reviewed by the TO throughout the verification test.

Chapter 4 Results and Discussion

4.1 Introduction

This chapter presents the verification test results for the Big Fish System, including the laboratory results for influent and effluent samples, operating data for the facility during the test, and observations on the O&M of the system during startup and normal operation. Supporting laboratory reports, spreadsheets and logs are available in Appendices E, and F.

4.2 Verification Test

The verification test officially started in September 2008, with initial characterization data collection performed in August 2008. All results for the remainder of the test period were considered part of the verification test. The startup evaluation described in Sec. 3.2 was performed in the middle of the verification test four months after the verification started and conducted during a low demand period to minimize the down time encountered during the verification testing process.

4.2.1 Verification Test - Flow Conditions

The Big Fish System operates as a batch type process with waste material from the waste receiving (holding) tanks being pumped to the lime treatment tank on a batch by batch basis. Once the lime treatment is complete and the proper pH conditions are confirmed, the lime treated waste is pumped to the thickener after neutralization by acid and polymer addition. The clarified liquid from the thickener flows to the aeration system and the thickened solids are pumped through the heated screw press. The liquid from the screw press (liquids from solids dewatering) also flows to the aeration system and the biosolids are discharged into a storage hopper.

The facility has a flow meter that measures all water discharged from the facility to the municipal sewer system. The total flow from the facility includes not only the liquid from the thickener and screw press operation, which is the actual liquid from the solids removal processes, but also all other water used in the process and in the facility. Water used for wash-down and equipment cleaning goes through the meter as well as the water from the treatment process. In order to obtain a more direct measurement of the flow of liquid from the treatment of incoming waste material, the actual volume of lime treated material pumped from the lime tank to the thickener and screw press was recorded. Also, the volume of material transferred from the holding tank to the lime treatment tank was recorded so that lime use could be matched to actual waste volume treated in the lime system. There was no "dilution" effect on the effluent samples collected and analyzed as the effluent samples included only wastewater that was discharged from the treatment tanks.

Table 4-1 shows the volumes of lime treated material processed for each batch processed through the thickener and screw press. These batches represent the time periods when verification sampling and analysis were performed and are typical of the batches the facility processed prior

to the verification test. The actual total discharge to the municipal system is also shown in Table 4-1. Observation of the facility operation indicates that these are reasonable batch sizes to process in this size facility. The smallest batch size was 6,886 gal, which was larger than the minimum of 5,000 gal specified in the test plan. The volume of the waste material transferred from the holding tank to the lime treatment system is shown in Table 4-13 with the lime use data.

Table 4-1. Batch Treatment Volume and Discharge

Date		Lime Tank Transfer to dewatering and liquid treatment (gal)	Flow Meter Discharge to City (gal)
Influent	**Effluent**		
09/22/08	09/24/08	12,240	15,240
09/24/08	09/26/08	14,998	19,671
10/13/08	10/15/08	15,484	14,860
10/15/08	10/17/08	10,301	10,769
11/10/08	11/12/08	11,420	17,523
11/12/08	11/14/08	15,523	19,684
12/08/09	12/10/09	6,886	10,826
12/10/09	12/12/09	10,993	13,646
01/26/09	01/28/09	10,627	11,943
01/28/09	01/30/09	16,035	16,767
02/16/09	02/18/09	12,304	14,340
02/18/09	02/20/09	13,940	18,507
03/09/09	03/11/09	16,190	16,196
05/18/09	05/20/09	11,442	15,436
05/20/09	05/22/09	13,930	21,068
06/22/09	06/24/09	12,581	22,957
06/24/09	06/26/09	11,767	16,145
07/20/09	07/22/09	12,209	23,053
7/22/090	07/24/09	13,187	19,838
08/17/09	08/19/09	12,117	16,992
08/19/09	08/21/09	13,078	20,095
09/21/09	09/23/09	12,301	20,456
09/23/09	09/25/09	10,249	17,589
10/19/09	10/21/09	10,593	17,942
10/21/09	10/23/09	17,185	19,357
Number of batches		25	25
Mean		12,703	17,236
Median		12,301	17,523
Maximum		17,185	23,053
Minimum		6,886	10,769
Std. Dev.		2,330	3,372

4.2.2 BOD_5/COD, TSS, and FOG Results and Discussion

Tables 4-2 and 4-3 present the influent and effluent BOD_5, COD, TSS and FOG concentrations measured during the verification test. Over the course of the verification, the influent waste material had a mean BOD_5 of 3,300 mg/L and median concentration of 2,700 mg/L with a range of 48 to 15,000 mg/L. The mean influent COD was 17,500 mg/L and the median was 20,000 mg/L with a range of 3,700 to 31,000 mg/L. Influent TSS ranged from 3,700 to 28,000 mg/L with a mean value of 13,700 mg/L and a median of 14,000 mg/L. The influent FOG ranged from 34 to 2,200 mg/L with a mean of 370 mg/L and a median of 140 mg/L. These concentrations showed that the septage material and other wastes (holding tank waste, fruit waste, municipal sludges) were highly concentrated waste materials, as expected. The concentrations were in the typical concentration ranges expected in septage type materials.

As shown in Table 4-2, the BOD_5 concentration in the final treated effluent had a mean value of 75 mg/L and a median concentration of 72 mg/L with a range of 7 to 190 mg/L. The Big Fish System achieved a mean BOD_5 removal of 97%. The treated effluent had a mean COD concentration of 270 mg/L, a median concentration of 280 mg/L with a range of 25 to 400 mg/L. The mean COD removal was 98.4%.

The effluent TSS mean concentration was 55 mg/L with a median concentration of 43 mg/L and a range of 10 to 170 mg/L. TSS removal was very high during the verification with a mean removal of 99.6%, a median removal of 99.6%, and a range of 98.3% to 99.9% removal.

The system removed most of the FOG present in the waste material to below the detection limit of 3 mg/L. Effluent concentration was below 3 mg/L on 18 of the 25 samples collected and analyzed. The mean FOG concentration was calculated to be 5.1 mg/L, based on setting concentrations below the detection limit to the reporting limit of 3 mg/L. The median concentration was <3 mg/L. The highest concentration in the discharge was 28 mg/L.

All of the data collected for the 13 months when verification test sampling occurred are included in Tables 4-2 and 4-3. However, data from the months of March and May 2009 are excluded from the summary statistics. The ETV protocol calls for removing upset periods from the summary statistics, but all data is to be reported. As discussed below, an upset occurred in May 2009 and the BOD_5 results for the March effluent sample appeared suspect. Therefore, these data are not included in the summary statistics. There was no sampling in April 2009 due to business conditions at that time. Suspension of sampling for the month of April was approved by NSF and EPA.

There was an upset period in May 2009 when BOD_5 removal was reduced to between 43% and 74% with effluent concentrations of 5,500 mg/l and 5,700 mg/L in the two batches treated. COD concentrations in the effluent also increased to 11,000 mg/L and 8,600 mg/L, as would be expected. It is believed the cause of this upset was due to the addition of highly concentrated fruit waste to the untreated material in the holding tank. This increased the influent BOD_5 concentration to 21,000 mg/L and the COD to 31,000 mg/L. This very high organic loading was

a seven-fold increase over the mean influent BOD_5 concentration measured during the verification test. Following the upset, the system was operated in the normal aeration recycle mode without additional new material being processed or effluent discharged until June 1, a ten-day period. A batch of material was then processed from the holding tank and discharge occurred. This effluent showed a BOD_5 of 810 mg/L (facility generated data), which indicated the system was recovering, but not yet back to the more typical discharge concentrations of 50 to 100 mg/L BOD_5. The system continued to operate with the aeration tanks in the normal recycling mode. Ten days later, on June 10, another batch of waste material was processed and the effluent BOD_5 concentration dropped to 110 mg/L. A subsequent batch of material processed on June 12 confirmed that the system had returned to normal operating conditions with the effluent having a BOD_5 concentration of 96 mg/L. The ETV verification testing for June was performed the week of June 22 and the data, presented in Table 4-2, shows that the system had recovered from the shock to the system due to the high organic loading the week of May 18th.

The March 2009 ETV data for the batch material treated from March 9 to 11, 2009 indicated that there may be a problem with BOD_5 removal. The reported BOD_5 concentration in the effluent was 930 mg/L. However, the COD concentration was reported to be 400 mg/L, less than the BOD_5 concentration and in the normal range of previous measurements. The TSS concentration in the effluent was also in the normal range. Two subsequent batches processed on March 25th and 27th showed effluent BOD_5 of 60 and 59 mg/L (facility generated data). It would appear that the effluent BOD_5 results for the verification test batch in March were an anomalous value and most likely no upset had occurred. Give the uncertainty of this value, these data are not included in the summary statistics presented in Table 4-2.

Table 4-2. BOD_5 and COD Results

Sample Date		BOD_5 (mg/L)			COD (mg/L)		
Influent	Effluent	Influent	Effluent	Removal (%)	Influent	Effluent	Removal (%)
09/22/2008	09/24/2008	1,300	51 (1)	96.1	22,000	25	99.9
09/24/2008	09/26/2008	2,600	110	95.8	22,000	380	98.3
10/13/2008	10/15/2008	5,200	29	99.4	31,000	210	99.3
10/15/2008	10/17/2008	3,600	72 (1)	98.0	26,000	250	99.0
11/10/2008	11/12/2008	2,800	97	96.5	24,000	400	98.3
11/12/2008	11/14/2008	2,800	83	97.0	14,000	390	97.2
12/08/2009	12/10/2009	15,000 (1,5)	74 (1)	99.5	18,000	180	99.0
12/10/2009	12/12/2009	2,600	41	98.4	20,000	270	98.7
01/26/2009	01/28/2009	48 (1)	30	37.5	6,400	210	96.7
01/28/2009	01/30/2009	110 (2)	27 (1,2)	75.5	3,700	290	92.2
02/16/2009	02/18/2009	1,600 (1)	110	93.1	6,300	300	95.2
02/18/2009	02/20/2009	3,000	130	95.7	5,600	320	94.3
03/09/2009	03/11/2009	4,100 (1,3)	930 (1,3)	77.3	36,000 (3)	400 (3)	98.9
05/18/2009	05/20/2009	21,000 (1,4)	5,500 (1,4)	73.8	31,000 (4)	11,000 (4)	64.5
05/20/2009	05/22/2009	10,000 (4)	5,700 (4)	43.0	20,000 (4)	8,600 (4)	57.0
06/22/2009	06/24/2009	4,800	99 (1)	97.9	18,000	180	99.0
06/24/2009	06/26/2009	2,500	72	97.1	6,200	380	93.9
07/20/2009	07/22/2009	2,200	62	97.2	25,000	220	99.1
07/22/2009	07/24/2009	4,800	130	97.3	20,000	360	98.2
08/17/2009	08/19/2009	2,100 (1)	190 (1)	91.0	18,000	290	98.4
08/19/2009	08/21/2009	4,000	7 (1)	99.8	8,200	160	98.0
09/21/2009	09/23/2009	2,400	26 (1)	98.9	21,000	200	99.0
09/23/2009	09/25/2009	3,700	44 (1)	98.8	21,000	320	98.5
10/19/2009	10/21/2009	4,100 (1)	57 (1)	98.6	28,000	240	99.1
10/21/2009	10/23/2009	2,400(1)	110 (1)	95.4	20,000	400	98.0
Number of Samples		22	22	22	22	22	22
Mean		3,300	75	97.7	17,500	270	98.4
Median		2,700	72	97.2	20,000	280	98.4
Maximum		15,000	190	99.8	31,000	400	99.9
Minimum		27	7	37	3,700	25	92.2
Standard Deviation		2,900	44.1	NA	8,032	95.5	NA

NA - not applicable

(1) Dissolved oxygen depletion for these BOD_5 results was less than the 2 mg/L guidance when adjusted for the seeded blank. Results should be considered an estimate of the BOD_5 concentration. See QA Section 4.5.3 for discussion.

(2) Lab reported data as influent of 27 mg/L and effluent of 110 mg/L. It is believed that the BOD_5 samples were incorrectly labeled based on review of the other sample results - e.g. TSS and COD.

(3) March 2009 data is excluded from the summary statistics as the BOD_5 effluent data is suspect or, if correct, indicate an upset occurred. There were no samples collected in April 2009.

(4) Per protocol, data from May 2009 when an upset occurred are not included in the summary statistics, but are reported for informational purposes.

(5) Influent sample on 12/8/2008 missed holding time by one day due to snow storm delivery delay.

Table 4-3. TSS and FOG Results

Date		TSS (mg/L)			FOG (mg/L)		
Influent	Effluent	Influent	Effluent	Removal (%)	Influent	Effluent	Removal (%)
9/22/2008	9/24/2008	26,000	29	99.9	2,200 (1)	<3	99.9
9/24/2008	9/26/2008	14,000	170	98.8	680 (1)	13	98.1
10/13/2008	10/15/2008	28,000	23	99.9	120	<3	97.5
10/15/2008	10/17/2008	13,000	60	99.5	110	<3(2)	97.3
11/10/2008	11/12/2008	15,000	84	99.4	34	<3	91.2
11/12/2008	11/14/2008	11,000	74	99.3	140	<3(2)	97.9
12/8/2009	12/10/2009	13,000	10	99.9	37	<3(2)	91.9
12/10/2009	12/12/2009	15,000	55	99.6	350	<3(2)	99.1
1/26/2009	1/28/2009	4,400	22	99.5	54(2)	<3	94.4
1/28/2009	1/30/2009	7,100	23	99.7	36	<3	91.7
2/16/2009	2/18/2009	3,700	31	99.2	120(2)	<3	97.5
2/18/2009	2/20/2009	5,800	34	99.4	380	<3	99.2
3/9/2009	3/11/2009	70,000 (3)	73 (3)	99.9	130 (3)	9.4 (3)	92.8
5/18/2009	5/20/2009	2,100 (4)	220 (4)	89.5	240 (4)	3.3 (4)	98.6
5/20/2009	5/22/2009	20,000 (4)	170 (4)	99.2	240 (4)	3.5 (4)	98.5
6/22/2009	6/24/2009	13,000	62	99.5	170	<3	98.2
6/24/2009	6/26/2009	3,900	68	98.3	270	<3	98.9
7/20/2009	7/22/2009	14,000	18	99.9	140	3.6	97.4
7/22/090	7/24/2009	13,000	150	98.8	490	<3	99.4
8/17/2009	8/19/2009	14,000	50	99.6	140	28(2)	80.0
8/19/2009	8/21/2009	15,000	28	99.8	2,100(2)	13(2)	99.4
9/21/2009	9/23/2009	23,000	19	99.9	190	<3	98.4
9/23/2009	9/25/2009	18,000	66	99.6	96	<3	96.9
10/19/2009	10/21/2009	18,000	35	99.8	76(2)	<3	96.1
10/21/2009	10/23/2009	14,000	97	99.3	110	<3	97.3
Number of Samples		22	22	22	22	22	22
Mean		13,700	55	99.6	370	5.1	98.6
Median		14,000	43	99.6	140	3	97.5
Maximum		28,000	170	99.9	2,200	28	99.9
Minimum		3,700	10	98.3	34	3	80.0
Standard Deviation		6,482	42	NA	600	5.9	NA

Note: Values below the detection limit are set equal to the DL for calculating statistics.

NA - not applicable

(1) Analyzed 5-7 days beyond 28 day hold time. Data were considered useable given the high concentrations, nature of the FOG from septage and maintained under refrigeration. Data could be biased slightly low.

(2) Lab control sample and/or lab control sample duplicate has low recovery. See QA section 4.5.3.

(3) March 2009 data is excluded from the summary statistics as the BOD_5 effluent data is suspect or if correct indicate an upset occurred.

(4) Per protocol the data from May 2009 when an upset occurred are not included in the summary statistics, but are reported for informational purposes.

4.2.3 Nitrogen Reduction Performance

Table 4-4 present the results for the TKN, NH_3-N, NO_2+NO_3 in the influent and effluent during the verification test. Total nitrogen (TN) results are also presented in Table 4-4. TN is calculated by adding the TKN (organic plus ammonia nitrogen) and nitrite-nitrate nitrogen concentrations.

The influent wastewater had a mean TKN concentration of 440 mg/L with a median concentration of 470 mg/L and a range of 170 to 550 mg/L. The influent mean NH_3-N concentration was 93 mg/L with a median concentration of 88 mg/L and a range of 8 to 160 mg/L. These high concentrations were expected based on the type of waste materials received. The nitrite plus nitrate concentration in the influent was typically low with a mean concentration of 3.2 mg/L and a range of <0.05 to 15 mg/L.

The effluent mean TKN concentration was 83 mg/L with a median value of 78 mg/L and a range of 42 to 170 mg/L. The effluent NH_3-N mean concentration was 60 mg/L with a median of 64 mg/L and a range of 14 to 120 mg/L. The nitrite plus nitrate mean concentration was 3.8 mg/L with a median concentration of 3.0 mg/L.

The mean removal of total nitrogen over the verification test period was 80% with a median removal of 80%. The verification test was designed to measure overall performance and did not include intermediate process samples to differentiate which processes were removing the nitrogen from the system. However, review of all of the nitrogen data suggests that most of the nitrogen removal was in the solids separation process with the nitrogen being removed with the biosolids.

The data indicate that a large percentage of the total nitrogen was organic nitrogen. Comparing the mean influent TKN (440 mg/L) with the mean influent ammonia concentration of 93 mg/L shows that the organic nitrogen represented approximately 79% of the nitrogen in the untreated septage material. Nitrite-nitrate was low at 3.2 mg/L. The largest reduction in nitrogen content appears to be due to the removal of organic nitrogen with the biosolids removed by the screw press. This conclusion is based on reviewing the ammonia and nitrite-nitrate data, which indicate that there was no appreciable nitrification occurring in the biological system aeration tanks. If nitrification were occurring, it would be expected that the nitrite-nitrate concentration would increase significantly. However, as shown in Table 4-4, the effluent nitrite-nitrate concentration showed only a minor increase based upon comparing either the mean values or the individual batch data. Based on the indication that nitrification was not occurring to any large extent, the lowering of the ammonia levels from a mean of 93 mg/L in the influent to a mean of 60 mg/L in the effluent is also likely due to some removal of ammonia in the biosolids along with the organic nitrogen.

Removal of a large amount of the nitrogen in the biosolids production step is beneficial to their use as a soil amendment. Further, removal of the organic nitrogen and some ammonia with the solids means that it is not converted to nitrite-nitrate in downstream aerobic process (e.g., municipal treatment system) or require a full nitrification-denitrification system. A moderately high concentration of total nitrogen, particularly ammonia nitrogen, does remain in the effluent,

Table 4-4. Influent and Effluent Nitrogen Data

Event Composite[1]	TKN-N (mg/L as N)		NH_3-N (mg/L as N)		NO_2+NO_3-N (mg/L as N)		Total Nitrogen (mg/L as N)		
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Removal (%)
09/26/08	550	55	160	83	<0.05 [2]	<0.05 [2]	550	55.1	90.0
10/17/08	460	42	61	14	<0.05	13	460	55.0	88.0
11/14/08	510	100	91	77	0.71	<0.50	511	NR	NC
12/12/09	500	170	64	59	<0.05	0.44	500	170	65.9
01/30/09	170	45	7.7 [3]	27	0.56	3.5	171	48.5	71.6
02/20/09	340	71	38	42	<0.3	5.6 [4]	340	76.6	77.5
03/11/09 [5]	260	64	47	42	7.6	<0.3	268	64.3	76.0
05/22/09 [6]	470	50	38	5.1	<0.3[4]	<0.3[4]	470	50.0	89.4
06/26/09	480	67	140	63	4.6[7]	<3.0[4]	485	70.0	85.6
07/24/09	430	110	130	120	<0.5	2.8	431	113	73.8
08/21/09	430	89	160	24	15	<1.2	445	90.2	79.7
09/25/09	480	92	98	81	<0.5	7	481	99.0	79.4
10/21/09	510	82	78	67	<2.5[7]	4.3	513	86.3	83.2
10/23/09	400	73	84	65	13	1.3	413	74.3	82.0
Number of samples	12	12	12	12	12	9	12	12	12
Mean	440	83	93	60	3.2	3.8	440	85	80
Median	470	78	88	64	0.5	3.0	470	77	80
Maximum	550	170	160	120	15.0	13.0	550	170	90
Minimum	170	42	8	14	<0.05	<0.05	171	49	66
Std. Dev.	100	35	48	30	5.3	3.7	100	34.4	7.2

Note: Values below the detection limit (DL) are set equal to the DL for calculating statistics.

NC - not calculated; NR - not reported

(1) Influent sample is a composite of two grab samples from the holding tank representing two batches processed. Effluent sample is a composite of the two composite samples from the two batches processed.

(2) Analyzed 6-8 days beyond 28-day hold time. Data were considered useable given that no detectable nitrate-nitrite was found and sample was preserved with refrigeration. Data could be biased slightly low.

(3) Reanalyzed with a result of 4.3 mg/L; TKN is lower than NH_3 - lab not sure what the nature of the analytical problem is- other analyses appear normal.

(4) Samples exceeded holding time of 48 hours on unpreserved sample. Times were 48 hours beyond holding time for samples in data not used in statistics.

(5) Only one batch processed in March; data is excluded from the summary statistics as the BOD_5 effluent data is suspect or if correct indicate an upset occurred.

(6) Per protocol, the data from May 2009 when an upset occurred are not included in the summary statistics, but are reported for informational purposes.

(7) Samples exceeded holding time by 10-11 hours (48-hour hold time). Data was considered useable as it would not be expected that significant denitrification would occur in a refrigerated oxygenated sample in a few hours beyond the holding time.

which can have an impact on downstream wastewater treatment plants receiving the effluent. However, the levels should be more manageable than the full strength untreated septage.

4.2.4 Total Phosphorus Removal Performance

Table 4-5 presents the results for TP in the influent and effluent during the verification test. Table 4-5 also presents a summary of the data (mean, median, maximum, minimum, standard deviation).

The influent had a mean TP concentration of 128 mg/L and median concentration of 115 mg/L with a range of 2.6 to 280 mg/L. The effluent mean concentration over the 13-month test was 3.3 mg/L with a median of 3.3 mg/L and a range of 0.1 to 7.1 mg/L. The mean TP removal was 95.3% with a median removal of 97.3%.

As was the case with nitrogen, the verification test did not collect process specific data to try to identify which process(s) removed the most phosphorus. Rather the verification test was designed to measure overall performance. However, basic knowledge of phosphorus removal processes would suggest that the majority of the phosphorus is removed in the biosolids dewatered by the screw press. The only chemical treatment, namely lime, occurs in the lime holding tank prior to the screw press. It would be expected that the treatment with lime and subsequently with polymer before the thickener and screw press would encourage phosphorus precipitation and removal with the biosolids. Assuming this is the case, the phosphorus would be a benefit to the soil amendment/fertilizer value of the finished biosolids product.

There may also be some uptake of phosphorus in the aeration system as part of the biological treatment step. The amount of phosphorus uptake was not measured and would be expected to be negligible compared with the large amount of phosphorus present in the septage and removed by the system.

Table 4-5. Total Phosphorus

Event Composite [1]	TP (mg/L as P) Influent	Effluent	Removal (%)
09/26/08	160	2.0	98.8
10/17/08	53	1.9	96.4
11/14/08	75	2.0	97.3
12/12/09	11	3.0	72.7
01/30/09	0.45	<0.01	>97.8
02/20/09	2.6	<0.05	>98.1
03/11/09 [2]	18	1.4	92.2
05/22/09 [3]	350	9.0	97.4
06/26/09	280	3.6	98.7
07/24/09	260	4.1	98.4
08/21/09	120	4.8	96.0
09/25/09	97	4.4	95.5
10/21/09	220	7.1	96.8
10/23/09	150	4.2	97.2
Number of samples	12	12	12
Mean	128	3.3	95.3
Median	115	3.3	97.3
Maximum	280	7.1	98.8
Minimum	2.6	<0.05	72.7
Standard Deviation	90	1.8	7.2

Note: Values below the DL are set equal to the DL for calculating statistics.

(1) Influent sample is a composite of two grab samples from the holding tank representing two batches processed. Effluent sample is a composite of the two composite samples from the two batches processed.

(2) Only one batch processed in March; March 2009 data is excluded from the summary statistics as the BOD_5 effluent data is suspect or if correct indicate an upset occurred.

(3) Per protocol, the data from May 2009 when an upset occurred are not included in the summary statistics, but are reported for informational purposes.

4.2.5 Other Operating Parameters – pH, Alkalinity, Sodium, Chloride, Dissolved Oxygen, and Temperature

Several operating parameters including pH, temperature and dissolved oxygen were measured on a regular basis by the operating staff. The data obtained on verification sample collection days are presented in Tables 4-6 through 4-8. Total alkalinity, sodium and chloride were monitored as part of the verification test. These results are also shown in Tables 4-6 through 4-8.

The pH of the influent ranged from 6.7 to 8.9 with a median value of 7.8. The effluent data showed a median pH of 7.8 with a range of 7.3 to 8.4. Dissolved oxygen was generally very low

in the influent samples from the holding tank as would be expected. Typically, dissolved oxygen was less than 1.0 mg/L. The effluent DO had a mean of 5.2 mg/L with a median of 4.8 mg/L.

Temperature can impact biological systems by slowing growth rates, particularly in cold northern climates, in areas such as Charlevoix. One of the benefits of the totally enclosed Big Fish System, with all tanks buried underground and inside a building, is the control of temperature in the winter. The influent temperature ranged from 51° F to 80° F. Effluent temperature, indicative of the aeration system temperature, ranged from 53° F to 85° F. There was no noticeable temperature impact on the system over the 13-month test period.

The influent had a mean total alkalinity concentration of 710 mg/L as $CaCO_3$, and the median concentration was 770 mg/L as $CaCO_3$. The effluent had a lower mean alkalinity concentration of 290 mg/L as $CaCO_3$ and median of 300 mg/L as $CaCO_3$. Sodium and chloride concentrations were also monitored during the test. The mean chloride concentration in the influent was 270 mg/L and the effluent was 310 mg/L. The mean sodium concentration in the influent was 170 mg/L and the effluent mean concentration was slightly lower at 130 mg/L.

Table 4-6. pH and Total Alkalinity Results

Date		pH		Alkalinity (mg/L as $CaCO_3$)	
Influent	Effluent	Influent	Effluent	Influent	Effluent
09/22/08	09/24/08	7.9	8.0	920	210
09/24/08	09/26/08	8.0	7.9	820	340
10/13/08	10/15/08	7.8	7.6	540	250
10/15/08	10/17/08	7.8	7.3	810	250
11/10/08	11/12/08	7.7	7.7	920	350
11/12/08	11/14/08	7.7	7.8	690	360
12/08/09	12/10/09	7.5	8.2	600	250
12/10/09	12/12/09	8.9	8.2	750	240
01/26/09	01/28/09	8.3	8.0	530	310
01/28/09	01/30/09	6.7	7.8	600	190
02/16/09	02/18/09	6.8	7.8	500	170
02/18/09	02/20/09	7.6	7.8	520	290
03/09/09 (1)	03/11/09	6.5	8.3	1300	230
05/18/09 (2)	05/20/09	7.9	6.6	NR	430
05/20/09 (2)	05/22/09	8.0	6.9	430	380
06/22/09	06/24/09	7.8	7.9	970	330
06/24/09	06/26/09	8.2	7.5	980	310
07/20/09	07/22/09	6.8	8.4	130	280
7/22/090	07/24/09	7.4	7.6	760	280
08/17/09	08/19/09	8.5	7.9	860	360
08/19/09	08/21/09	8.4	8.1	230	360
09/21/09	09/23/09	7.1	7.9	1,100	350
09/23/09	09/25/09	6.9	7.3	770	340
10/19/09	10/21/09	7.9	7.5	840	280
10/21/09	10/23/09	8.0	7.8	780	320
Number of samples		22	22	22	22
Mean		NA	NA	710	290
Median		7.8	7.8	770	300
Maximum		8.9	8.4	1100	360
Minimum		6.7	7.3	130	170
Standard Deviation		NA	NA	240	57

NR - not recorded/not analyzed

NA - not applicable

(1) March 2009 data is excluded from the summary statistics as the BOD_5 effluent data is suspect or if correct indicate an upset occurred.

(2) Per protocol, the data from May 2009 when an upset occurred are not included in the summary statistics, but are reported for informational purposes.

Table 4-7. Chloride and Sodium Results

Event Composite	Chloride (mg/L)		(Sodium mg/L)	
	Influent	Effluent	Influent	Effluent
09/26/08	740	770	280	180
10/17/08	280	210	240	160
11/14/08	110	150	130	85
12/12/09	73	130	250	120
01/30/09	350	350	200	180
02/20/09	300	590	210	150
03/11/09 (1)	320	110	150	170
05/22/09 (2)	9.9	18	94	72
06/26/09	160	430	50	97
07/24/09	100	23	12	110
08/21/09	470	77	320	96
09/25/09	160	270	110	92
10/21/09	350	570	150	190
10/23/09	160	210	82	140
Number of samples	12	12	12	12
Mean	271	315	170	133
Median	220	240	175	130
Maximum	740	770	320	190
Minimum	73	23	12	85
Standard Deviation	192	232	96	38

(1) March 2009 data is excluded from the summary statistics as the BOD_5 effluent data is suspect or if correct indicate an upset occurred.

(2) Per protocol, the data from May 2009 when an upset occurred are not included in the summary statistics, but are reported for informational purposes.

Note: Chloride data in February, June, August, and September 2009 did not balance between influent and effluent as well as might be expected. This may be due to the nature of the batch system, where there is a large quantity of wastewater in the aeration tanks that is displaced by treated influent filtrate exiting the screw press. Therefore, the influent grab from before lime treatment and processing through the screw press does not match exactly to the effluent from the aerobic treatment as there is mixing with previously treated batches.

Table 4-8. Temperature and Dissolved Oxygen Results

Date		DO (mg/L)		Temp (^{o}F)	
Influent	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
09/22/08	09/24/08	0.3	6.1	70	73
09/24/08	09/26/08	4.8	4.5	79	81
10/13/08	10/15/08	0.3	5.6	68	78
10/15/08	10/17/08	4.2	4.7	77	75
11/10/08	11/12/08	0.3	4.5	67	64
11/12/08	11/14/08	0.2	4.5	65	65
12/08/09	12/10/09	0.5	4.8	59	71
12/10/09	12/12/09	4.3	4.8	70	70
01/26/09	01/28/09	0.2	5.1	57	61
01/28/09	01/30/09	0.1	4.5	58	60
02/16/09	02/18/09	0.1	4.7	54	60
02/18/09	02/20/09	0.5	4.2	60	60
03/09/09	03/11/09	0.2	4.7	51	53
05/18/09	05/20/09	2.4	4.2	65	72
05/20/09	05/22/09	1.1	4.8	64	69
06/22/09	06/24/09	0.1	7.3	66	78
06/24/09	06/26/09	0.4	4.6	80	77
07/20/09	07/22/09	0.4	6.5	72	82
7/22/090	07/24/09	0.4	6.5	75	79
08/17/09	08/19/09	0.2	5.1	80	85
08/19/09	08/21/09	0.3	5.4	77	79
09/21/09	09/23/09	0.3	4.8	74	76
09/23/09	09/25/09	0.3	6.3	73	74
10/19/09	10/21/09	0.8	5.4	66	67
10/21/09	10/23/09	0.5	6.1	65	67
Number of samples		25	25	25	25
Mean		1.2	5.2	68	71
Median		0.4	4.8	67	72
Maximum		7.2	7.3	80	85
Minimum		0.1	4.2	51	53
Standard Deviation		1.9	0.8	8.2	8.3

4.2.6 Biosolids Production and Quality

The Big Fish System is designed with a main objective to produce EQ Class A Biosolids which are regulated under the Federal rules 40 CFR Part 503, more commonly referred to as the "503 Rules." These Rules establish several options to meet the Class A Biosolids designation, with all options including treatment methods to reduce pathogens and provide vector control. In addition, a monitoring program to demonstrate that biosolids meet fecal coliform standards is required for Class A designation and the measurement of heavy metals is required to meet the EQ limits shown in Table 4-11. The treatment options used by the Big Fish System are a combination of elevated pH for vector control and elevated temperature (time-temperature combination) for pathogen control.

A summary of the pH data for all of the batches of biosolids produced during the verification test is shown in Table 4-9. As can be seen, the pH met the 503 Rule requirements at all times. The PLC records were provided by Big Fish to the TO for review. These data show that the proper 38 rpm screw-press rate was maintained at all times ensuring the minimum contact time in the screw press at elevated temperature was achieved. Big Fish typically operates the screw press such that the biosolids achieve a temperature of 90° to 100° C, well above the 503 Rule minimum requirement. A screw press setting of 38 rpm provides approximately 20 minutes of contact time. Under the time-temperature relationship requirements of the 503 Rule Option A, a minimum time requirement at 90° C is less than one minute. The screw press operating data is summarized in Table 4-10.

In addition to monitoring the pH and the thermal treatment process, Big Fish also collects samples of the biosolids to demonstrate that the fecal coliform is below the Class A standard of 1000 MPN per gram - dry weight. These data were obtained from Big Fish and show that the biosolids meet the fecal coliform requirement. The data are presented in Appendix A, containing vendor supplied information and data.

Based on the data collected during the verification test and the fecal coliform data presented in Appendix A, all batches of biosolids produced met the requirements to be classified as EQ Class A Biosolids.

Table 4-9. Biosolids - pH of Lime-Treated Biosolids at 2 and 24 hour Holding Periods

Date	pH		
	Initial	After 2 hours	After 24 hours
09/22/08	12.5	12.3	12.2
09/24/08	12.1	12.1	12.0
10/13/08	12.2	12.3	12.5
10/15/08	12.4	12.0	11.8
11/10/08	12.2	12.3	12.3
11/12/08	12.1	12.2	11.9
12/08/08	12.2	12.4	12.5
12/10/08	12.5	12.5	12.6
01/26/09	12.3	12.3	12.3
01/28/09	12.3	12.5	12.5
02/16/09	12.4	12.5	11.8
02/18/09	12.3	12.5	12.6
03/09/09	12.5	12.5	12.6
05/18/09	12.1	12.2	11.6
05/20/09	12.5	12.2	12.3
06/23/09	12.2	12.2	11.9
06/25/09	12.3	12.6	12.5
07/20/09	12.1	12.9	12.8
07/22/09	12.3	12.4	12.3
08/17/09	12.5	12.3	11.6
08/19/09	12.0	12.0	11.5
09/21/09	12.2	12.2	11.7
09/23/09	12.0	12.0	11.6
10/19/09	12.2	12.3	12.2
10/21/09	12.1	12.1	11.6

Table 4-10. Screw Press Operating Data Summary Temperature and rpm

Batch Date	Temperature (^{o}C) Mean	Maximum	Minimum	% Motor setting (1)
09/22/08	99	100	91	0.38
09/24/08	99	100	90	0.38
10/13/08	100	101	90	0.38
10/15/08	100	101	91	0.38
11/10/08	100	102	94	0.38
11/12/08	101	102	89	0.38
12/08/08	100	101	92	0.38
12/10/08	99	101	93	0.38
01/26/09	99	101	76	0.38
01/28/09	99	102	93	0.38
02/16/09	100	101	92	0.38
02/18/09	100	101	97	0.38
03/09/09	99	102	86	0.38
05/18/09	100	102	88	0.38
05/20/09	99	102	89	0.38
06/23/09	98	100	79	0.38
06/25/09	97	99	84	0.38
07/20/09	100	101	97	0.38
07/22/09	100	102	92	0.38
08/17/09	98	101	79	0.38
08/19/09	98	100	85	0.38
09/21/09	99	101	89	0.38
09/23/09	100	102	92	0.38
10/19/09	99	100	91	0.38
10/21/09	99	101	93	0.38

(1) Percent motor setting is related to rpm which sets the time the solids are in the heated screw press.

Table 4-11. Biosolids Metals Results

Analyte	Units	3/13/2009	6/18/2009	Pollutant Concentration Limits for EQ Biosolids
Arsenic	mg/kg	3.5	4.4	41
Cadmium	mg/kg	2.4	2.2	39
Chromium	mg/kg	18	19	1,200
Copper	mg/kg	430	260	No standard
Lead	mg/kg	21	23	300
Mercury	mg/kg	0.33	0.22	17
Nickel	mg/kg	12	12	420
Selenium	mg/kg	5.9	2.6	36
Zinc	mg/kg	1300	990	7,500
Total Solids	%	50	60	NA

NA - not applicable

The volumes of biosolids produced during the verification test were estimated based on the size and number of hoppers of biosolids that were filled from the screw press. When a hopper was filled, it was then emptied by placing the biosolids in the storage area outside the main building. Table 4-12 shows the volume of biosolids produced form each batch of material treated during the verification test runs.

4.3 Operation and Maintenance

The O&M performance of the Big Fish System was monitored throughout the verification test by the TO during regular visits to the site. Big Fish operators were responsible for routine O&M of the system. Various data and observations were recorded by the Big Fish operators as part of their normal work practices. The field logs used to collect the operating data are included in Appendix F.

There were no major mechanical component failures during the verification test. There were also no major downtime periods during the test due to maintenance requirements.

4.3.1 Chemical Use

Lime was used to raise the pH to meet the requirements for vector reduction in the biosolids and to aid in the dewatering processes. Lime can also enhance phosphorus removal. Lime use was monitored for each batch of waste material processed, and the quantity of lime used and the volume of waste pumped to the lime treatment tank were recorded. Table 4-13 presents the lime usage data and the volume of waste treated.

Table 4-12. Volume of Biosolids Produced

Date		Biosolids Volume Produced
Start Batch	End Batch	(cubic yards)
09/22/08	09/24/08	4.5
09/24/08	09/26/08	3.0
10/13/08	10/15/08	4.0
10/15/08	10/17/08	2.3
11/10/08	11/12/08	3.3
11/12/08	11/14/08	5.5
12/08/09	12/10/09	2.8
12/10/09	12/12/09	2.5
01/26/09	01/28/09	2.0
01/28/09	01/30/09	1.8
02/16/09	02/18/09	2.0
02/18/09	02/20/09	2.0
03/09/09	03/11/09	3.0
05/18/09	05/20/09	3.0
05/20/09	05/22/09	3.0
06/22/09	06/24/09	3.0
06/24/09	06/26/09	3.8
07/20/09	07/22/09	4.3
7/22/090	07/24/09	3.3
08/17/09	08/19/09	3.0
08/19/09	08/21/09	3.3
09/21/09	09/23/09	5.0
09/23/09	09/25/09	4.8
10/19/09	10/21/09	6.0
10/21/09	10/23/09	5.5

Polymer was added to the lime-treated waste material after the 24 hour holding period as it was being pumped from the holding tank to the thickener. A cationic polymer, Aquaben HF 748E, was used from September 2008 through July 2009. A different source material, ERC Associates ERC840HX cationic polymer was used from August through October 2009. The quantity of polymer used is shown in Table 4-13. The volume recorded was the amount of concentrated liquid polymer consumed. The concentrated polymer was diluted within the injection system used to feed the polymer to the waste material.

Muriatic acid was used to neutralize the overflow liquid from the thickener and the filtrate from the screw press as it was pumped from the thickener and screw press to the aerobic processing tanks. The acid was fed from the containers that were received from the supplier without intermediate dilution. Table 4-13 shows the acid used for each batch of material processed. The

records indicate that no acid was used for five of the batches processed. This data is considered suspect, as the pH of the lime treated material for those batches was above 12 for four of the batches and above 11.5 for the other batch. Effluent pH was in the usual range (6.6 to 8.2) for these batches. It would appear that some acid must have been added to these batches to lower the pH, but the records do not reflect the acid addition.

4.3.2 Electric Power and Natural Gas Usage

The electric power and natural gas use during the verification test was monitored using the facility electric and gas meters. These meters measured total use for the facility. The steam for heating the biosolids in the screw press was generated on-site with a gas fired boiler. The impact of the boiler to heat the screw press was seen in the twice per week spike in natural gas use. Electrical use did not vary widely as the daily demands of the aeration system and recirculation pumps, which run 24 hours per day appear to dominate the electric requirements. Table 4-14 shows the electric and gas use for the verification test periods.

Table 4-13. Chemical Use

Date		Lime Tank	Lime Fed	Polymer	Acid
Start Batch	End Batch	Volume (gal)	(lbs)	(gal)	(gal)
09/22/08	09/24/08	18,865	160	6.84	7.62
09/24/08	09/26/08	11,685	122	9.4	0.8
10/13/08	10/15/08	19,342	192	11.97	3.175
10/15/08	10/17/08	7,578	32	12.83	1.59
11/10/08	11/12/08	11,797	164	6.84	1.56
11/12/08	11/14/08	15,333	160	8.55	3.175
12/08/09	12/10/09	9,628	128	6.84	0
12/10/09	12/12/09	7,987	176	9.4	0
01/26/09	01/28/09	11,259	128	5.13	0
01/28/09	01/30/09	16,290	176	8.55	20.3
02/16/09	02/18/09	18,993	192	8.21	19.05
02/18/09	02/20/09	17,693	192	6.84	0
03/09/09	03/11/09	18,221	208	6.2	4.76
05/18/09	05/20/09	11,532	128	5.13	0
05/20/09	05/22/09	16,508	128	7.7	12.7
06/22/09	06/24/09	13,392	112	12.83	7.9
06/24/09	06/26/09	8,636	128	9.4	12.7
07/20/09	07/22/09	19,170	212	14.54	7.14
7/22/090	07/24/09	12,312	64	10.26	14.22
08/17/09	08/19/09	17,561	272	11.1	5.6
08/19/09	08/21/09	13,051	192	13.68	7.1
09/21/09	09/23/09	15,377	160	17.1	8.7
09/23/09	09/25/09	10,344	128	16.2	4.8
10/19/09	10/21/09	18,817	192	20.5	7.9
10/21/09	10/23/09	9,830	160	18.8	9.5

Table 4-14. Electricity and Natural Gas Use

Date	Electricity (kWh)	Natural Gas (ft^3)	Date	Electricity (kWh)	Natural Gas (ft^3)
09/22/08	736	NR	05/18/09	712	3
09/23/08	752	NR	05/19/09	663	46
09/24/08	751	NR	05/20/09	602	0
09/25/08	648	NR	05/21/09	642	71
09/26/08	597	NR	05/22/09	730	6
10/13/08	638	0	06/22/09	636	3
10/14/08	767	47	06/23/09	656	41
10/15/08	690	3	06/24/09	634	0
10/16/09	697	36	06/25/09	607	40
10/17/08	689	3	06/26/09	603	0
11/10/08	934	34	07/20/09	679	3
11/11/08	903	53	07/21/09	723	54
11/12/08	929	4	7/22/090	669	2
11/13/08	1053	78	07/23/09	687	49
11/14/08	493	0	07/24/09	662	39
12/08/09	773	8	08/17/09	647	0
12/09/08	966	50	08/18/09	832	55
12/10/09	571	5	08/19/09	495	0
12/11/08	798	50	08/20/09	844	38
12/12/08	562	0	08/21/09	807	45
01/26/09	383	0	09/21/09	672	3
01/27/09	810	46	09/22/09	680	49
01/28/09	605	4	09/23/09	644	0
01/29/09	719	55	09/24/09	652	39
01/30/09	492	0	09/25/09	609	1
02/16/09	673	0	10/19/09	612	3
02/17/09	839	47	10/20/09	710	56
02/18/09	787	1	10/21/09	603	0
02/19/09	521	77	10/22/09	722	57
02/20/09	521	0	10/23/09	565	80
03/09/09	391	0			
03/10/09	103	78			
03/11/09	500	0			

NR- not recorded

4.3.3 Operation and Maintenance Observations

The O&M of the Big Fish System was observed by the TO representatives who were on site for several days each month to collect samples and review operating records. The goal of these observations was to develop information on the system operability, complexity, and degree of maintenance required. These observations serve as the basis for the qualitative performance information provided herein.

The Big Fish System is a relatively simple system to operate, as it is a batch-type operation that involves mostly mechanical equipment, such as tanks, pumps, valves, aerators, level controllers, etc. The screw press has a programmable logic controller to control the operation and record data on temperature, speed, etc. The procedures and description for equipment O&M are described in the O&M manual provided by Big Fish (Appendix C).

The potentially more complicated part of the system is the biological system. As with most biological treatment systems, when the facility is running smoothly, the operation is straightforward. Monitoring and controlling flows (for Big Fish this is controlling batch size and ensuring recycle flows are operating), DO/aeration, pH, and observing biomass condition are sufficient to maintain good treatment. However, if an upset occurs or the wastes are highly variable, biological systems require a reasonable level of expertise to understand and correct the problem.

The Big Fish startup was straightforward and accomplished in less than 3 weeks. The system also recovered from the May upset caused by an extreme shock load in less than 4 weeks. The operator's ability to stop treating new batches, and not discharge during these periods allowed the microbial population to recover while operating in the standard re-circulation mode. This relative ease of the startup and recovery from upsets seems to be because of the larger volume of aeration capacity with continuous recycle providing a buffer to upsets and allowing for quick recovery. Further, the batch style operation and large holding tanks provide capacity to hold incoming material and respond to changing conditions. In addition, the system is designed to maintain a "hatchery" or source of biomass that can be used to augment the system should a problem occur. The simulated startup demonstrated that in the "worst case" the entire system could be emptied and cleaned in 2-3 days. Restart is then accomplished by adding processed (lime treated) waste to the aeration tanks and seeding with biomass from the on-site supply.

As with any biological treatment system, operator skill and knowledge are important, particularly during startups and if an upset occurs. It would be expected that in a stand-alone facility a licensed wastewater operator with basic biological treatment knowledge and mechanical skills would be required to operate the system. If the Big Fish System were installed at a municipal treatment plant with several levels of operators, the system could easily be operated by an entry-level operator as long as an operator with biological treatment experience was available if a problem or upset occurs.

The Big Fish System with the incoming waste loading conditions that occurred during the verification test (two or three, 20,000 to 30,000 gal batches of waste per week) can be operated

by one operator. In fact, the system was run by one operator during most of the verification test. The largest demand on the operator's time is performing the laboratory and field tests (pH, DO, temp, BOD, NH_3, TSS, NO_3, TP, etc.), plus collecting and maintaining the operating records. Based on observation of the operation at a load of two batches per week, it would appear that if the processing load increased to three or more batches per week (>30,000 gal per week), an additional part time helper would be needed to assist the main operator. If the system were at a municipal treatment facility, one operator could handle the system at full capacity if the laboratory work and some record keeping were performed by others at the larger plant.

4.4 Quality Assurance/ Quality Control

The VTP included a Quality Assurance Project Plan (QAPP) that identified critical measurements and established Data Quality Objectives (DQO). The verification test procedures and data collection followed the QAPP, and summary results are reported in this section. The laboratory reported QA/QC data with each set of sample results as part of the laboratory reports. Each report included the results of blanks, laboratory duplicates, spikes, and other lab control sample results for the various analyses. These QA data are incorporated with the laboratory reports presented in Appendix F.

4.4.1 Audits

NSF conducted an audit of the RTI laboratory prior to the verification test. The laboratory audit found that RTI followed approved analytical methods and documented the methods and QA/QC in an acceptable manner. The audit also provided the opportunity to explain the ETV program and the requirements for a successful verification test to the participants.

The laboratory had a firmly established QA/QC program, and observation of the analyses and a records review found that appropriate QC data was being performed with the analyses. All members of the testing team were reminded that ETV requires that copies of all logs and raw data records be delivered to NSF at the end of the project.

NSF conducted a field audit at the Big Fish site on September 25, 2009 to review test procedures, review documentation, and observe the sampling collection and shipment procedures. The field audit found that all critical procedures were being appropriately followed and in accordance with QAPP and the Test Plan. The audit identified that the sample volume being placed in the sample bottles was not being recorded, but sample volume had been adequate for the laboratory. It was also noted that a neighbor odor complaint had not been recorded in the operating log. Corrections were made to address these comments. It was also noted that the composite samples over multiple days were not exact flow proportional composites, but it was demonstrated that the method being used and the consistent batch sizes and flows meant that there was little or no difference in the methods for compositing over multiple days. All issues raised were resolved.

4.4.2 Precision

4.4.2.1 Laboratory Duplicates

The analytical laboratory performed sample duplicates for all parameters at a frequency of at least one duplicate for every ten samples analyzed or one per batch if less than ten samples in a batch. The results of laboratory duplicates were reported with all data reports received from the laboratory. Table 4-15 shows the acceptance limits used by the laboratory.

The Relative Percent Difference (RPD) was calculated using the standard formula:

$$RPD = [(C_1 - C_2) \div ((C_1 + C_2)/2)] \times 100\%$$

Where:

C_1 = Concentration of the compound or element in the sample
C_2 = Concentration of the compound or element in the duplicate

Table 4-15. Laboratory Precision Limits

Parameter	Acceptance Limits (RPD)
TSS	20
Alkalinity	25
BOD_5	25
COD	25
TKN	25
NH_3-N	20
NO_2/NO_3	20
Total P	20
Na	25
Chloride	25

The laboratory precision for all parameters, as measured by the laboratory duplicates, was found to meet the QA objectives for the verification test.

4.4.2.2 Field Duplicates

Field duplicates were collected on three sets of samples. There were not specific quality objectives set for field duplicates, but these were included in the plan for informational purposes. Precision is often highly variably for field duplicates as these samples account for all factors that can impact sample collection in addition to laboratory handling and analysis.

Tables 4-16 and 4-17 show the results from the field duplicate samples collected during the verification test. Most of the results are within expected ranges. There are a couple of results that were investigated to see if the cause for the lack of precision could be identified. The first influent TKN duplicate had a very low TKN of 4.4 mg/L, which was 100 times below the sample, below the typical values for the influent, and lower than the corresponding ammonia values (TKN includes ammonia plus organic nitrogen). The lab reanalyzed the sample and the result was 4.3 mg/L. The laboratory control sample (LCS) spike recovery for the analytical set was 101% and the analytical set duplicate was within normal precision limits. The cause of the discrepancy was not found and subsequent sample duplicates showed reasonable precision.

A similar situation occurred with nitrite-nitrate on the first effluent duplicate. The duplicate was four times higher than the effluent sample and much higher than the typical values found in the effluent samples. An investigation did not find the cause of the discrepancy. Subsequent samples were within expected precision ranges. One effluent FOG showed the sample below the detection limit, whereas the duplicate was measured at 31 mg/L. The entire sample was consumed in the analysis so it could not be rerun or checked. The other FOG duplicate tests within expected ranges, given that FOG is collected as single glass bottle grab sample and is known to vary widely in wastewater matrices.

Table 4-16. Duplicate Field Sample Summary – Nutrients

Sample	TKN			NH_3-N		
	Rep 1 (mg/L as N)	Rep 2 (mg/L as N)	RPD (%)	Rep 1 (mg/L as P)	Rep 2 (mg/L as P)	RPD (%)
Influent	480	4.4	197	98	89	9.6
Effluent	92	140	41	81	73	10
Influent	510	560	9.3	78	88	12
Effluent	82	80	2.5	67	68	1.5
Influent	400	420	4.9	84	84	0
Effluent	73	83	13	65	65	0
Sample	**NO_2+NO_3**			**TP**		
	Rep 1 (mg/L as N)	**Rep 2 (mg/L as N)**	**RPD (%)**	**Rep 1 (mg/L as P)**	**Rep 2 (mg/L as P)**	**RPD (%)**
Influent	<0.50	0.59	NC	97	100	3.0
Effluent	7	27	118	4.4	4.3	2.3
Influent	<2.5	<1.2	NC	220	220	0
Effluent	4.3	3.5	21	7.1	8.2	14
Influent	13	18	32	150	120	22
Effluent	1.3	1.7	27	4.2	4.8	13

NC – Can not be calculated.

Table 4-17. Duplicate Field Sample Summary – BOD_5, COD, TSS, Alkalinity, FOG

Sample	BOD_5 Rep 1 (mg/L)	BOD_5 Rep 2 (mg/L)	BOD_5 RPD (%)	COD Rep 1 (mg/L)	COD Rep 2 (mg/L)	COD RPD (%)
Influent	3,700	4,000	7.8	21,000	28,000	29
Effluent	44	50	13	320	360	12
Influent	4,100	5,800	34	26,000	28,000	7.4
Effluent	57	55	3.6	240	210	13
Influent	2,400	3,100	25	20,000	16,000	22
Effluent	110	87	23	400	360	11

Sample	TSS Rep 1 (mg/L)	TSS Rep 2 (mg/L)	TSS RPD (%)	Alkalinity Rep 1 (mg/L)	Alkalinity Rep 2 (mg/L)	Alkalinity RPD (%)
Influent	18,000	18,000	0	770	730	5.3
Effluent	66	45	38	340	330	3.0
Influent	18,000	22,000	20	840	830	1.2
Effluent	35	36	2.8	280	290	3.5
Influent	14,000	13,000	7.4	780	790	1.3
Effluent	97	86	12	320	320	0

Sample	FOG Rep 1 (mg/L)	FOG Rep 2 (mg/L)	FOG RPD (%)
Influent	96	59	48
Effluent	<3	<3	0
Influent	76	97	26
Effluent	<3	31	NC
Influent	110	67	49
Effluent	<3	<3	0

NC – Can not be calculated.

4.4.3 Accuracy

Method accuracy was determined and monitored using a combination of matrix spikes, laboratory control samples (known concentration in blank water), and proper equipment calibration and traceability depending on the analytical method. Recovery of the spiked analytes was calculated and monitored during the verification test. The laboratory used the control samples and recovery limits as shown in Table 4-18 and reported the data with each set of analytical results.

The equations used to calculate the recoveries for spiked samples and laboratory control samples are as follows:

Matrix Spike Samples:

Percent Recovery = $(Cr - C_o)/C_f \times 100\%$

Where: C_r = Total amount detected in spiked sample
C_o = Amount detected in un-spiked sample
C_f = Spike amount added to sample.

Lab Control Sample:

Percent Recovery = $(C_m / C_{known}) \times 100\%$

Where: C_m = measured concentration in the spike control sample
C_{known} = known concentration

Table 4-18. Laboratory Control Limits for Accuracy

Parameter	Method Blank	Lab Control Sample	Matrix Spike	Recovery Limits (%)
TSS	×	×	NA	NA
Alkalinity	×	×	NA	NA
BOD_5	×	× [(1)]	NA	84-115[(1)]
COD	×	×	×	80-120
FOG	×	×	NA	78-114
TKN	×	×	×	80-120
NH_3-N	×	×	×	75-125
NO_2+NO_3	×	×	×	75-125
Total P	×	×	×	75-125
Sodium	×	×	×	75-125
Chloride	×	×	NA	80-120

[(1)] Seed Control Sample

× - Denotes sample collected

NA - Not applicable

All of the specific requirements to document method accuracy are detailed in the QAPP in the VTP, which is included in Appendix B. The laboratory supporting data is included with the laboratory reports in Appendix F. Review of the laboratory data shows that the accuracy data met the quality objectives except for low LCS recoveries for some FOG analyses and some BOD_5 results did not meet the DO depletion guidance of > 2 mg/L.

It was noted during the NSF QA data review that some samples for FOG were associated with low spike recoveries in the LCS. Several of the LCS or laboratory control spike duplicate (LCSD) recoveries for FOG were below 78%, which is below the QA data quality objective of

78-114%. A total of 14 samples was associated with recoveries below the target. Six results were for sample sets with a single LCS result and eight sets had both LCS and LCSD results. Of the eight sets with both a LCS and LCSD sample, 5 sets of results had at least one of the recoveries above the minimum recovery and the other 3 sets showed low recovery for both LCS and LCSD.

All of the FOG LCS/LCSD data are shown in Table 4-19. The associated FOG data were reviewed and found to be useable data within the objectives of this test. Most of the recoveries were only slightly below the lower window established in the test plan. The actual sample results may be biased low, but given the high concentrations of FOG in the influent waste material and the low concentrations in the effluent, the data are useable to demonstrate performance for FOG removal.

Table 4-19 shows the FOG mean and median results for the data set with and without the results associated with the low recoveries. The mean concentrations of the influent and effluent are actually slightly lower when the data associated with the low recoveries removed. The overall removal of FOG by the system is not significantly impacted, with a removal of 98.6% based upon using all the data, and a removal of 98.7% based on the data set which excludes the data associated with the low recoveries. Therefore, while the low recoveries might suggest that some of the results could be biased low, comparison of the data sets with and without these data shows that system removed a large percentage of the FOG, producing an effluent with FOG concentrations generally at or below the reporting limit of 3 mg/L.

In reviewing the BOD_5 bench sheets and raw data, it was noted by NSF that 19 of the 50 BOD_5 results were based on DO depletion of less than the 2 mg/L prescribed in the test method. This depletion is based on the DO depletion in the sample and then also accounting for the depletion in the seeded blank. Overall, DO depletion of less than 2 mg/L can impact the accuracy of the BOD_5 test. All of the impacted BOD_5 data in the final ETV report in Table 4-2 have been qualified with a footnote indicating when the DO depletion was less than 2 mg/L.

Table 4-20 shows the BOD_5 and COD results with the DO depletion with and without seeded blank adjustment. The laboratory procedure was to set 4 or 5 dilutions of the each sample in order to cover a wide range of BOD_5 concentrations. However, with the variability of BOD_5 particularly in the influent, some samples even with 4-5 dilutions did not met the 2 mg/L guidance. Furthermore, BOD_5 cannot be re-run as the sample cannot be preserved and any data from reanalysis after 5 days would be suspect.

As can be seen in Table 4-20 the range of BOD_5 in the influent was from 27 to 21,000 mg/L and the effluent ranged from 7 to 190 mg/L (excluding the upset in May). The test plan included analyzing COD on every sample that was scheduled for BOD_5 as it was recognized that BOD_5 results can be variable and particularly problematic in septage-type wastes. The COD results can be used when reviewing BOD_5 data to determine if the BOD_5 results are in the "range" that would be expected. In all cases the COD data indicates that the BOD_5 results, where DO depletion was low, are reasonable estimates or representative of the expected BOD_5 concentration.

Also, the individual data sheets for each sample were reviewed and the other dilutions used for the test in most cases showed no significant DO depletion (too high a dilution) indicating that the BOD_5 concentration was equal to or less than the value calculated.

Based on the review of the COD data, the individual BOD_5 dilutions, and the overall treatment system conditions at the time of each sample, the BOD_5 data was judged to be useable for the purposes of this verification. The BOD_5 removal averaged 97.7% with the influent being very high in BOD_5 as expected, and the effluent data showed low to moderate BOD_5 concentrations. In fact, 5 of the samples with low DO depletion occurred in effluent samples for August to October 2009, when the system performance was the best and the BOD_5 concentrations were much lower than the overall average. The low BOD_5 in these samples was why the lowest dilution did not meet the DO depletion target.

When DO depletion of 2 mg/L was not achieved, the BOD_5 results were typically used as estimates of the BOD_5 concentration. Even if the BOD_5 data for these samples were over/under by 50%, it did not change the overall results that show the large reduction in BOD_5 and that the effluent BOD_5 can meet typical municipal discharge standards (250-300 mg/L).

Finally, if all of the BOD_5 data with DO depletion of < 2 mg/L and the upset periods in March and May 2009 are removed from the data set, the final results do not change significantly over the 14 month test. The BOD_5 removal using all the data was 97.7% and 97.3% for the data set with the low depletion DO samples removed. BOD_5 for the influent averaged 3,300 mg/L for all the data and 3,000 for the smaller data set. Similarly the effluent BOD_5 averaged 75 mg/L using all the data and 81 mg/L with the smaller data set.

The comparisons to the COD data, among the data sets, and review of the detailed data suggest that the BOD_5 results with low DO depletion are reasonable estimates of the actual BOD_5 concentrations, consistent with other data, and useable for this verification.

The balance used for TSS analysis was calibrated routinely with weights that were National Institute of Standards and Technology (NIST) traceable. Calibration records were maintained by the laboratory and inspected during the on-site audit. The temperature of the drying oven was also monitored using a thermometer that was calibrated with a NIST-traceable thermometer. The pH meter was calibrated using a three-point calibration curve with purchased buffer solutions of known pH. Field temperature measurements were performed using a NIST-traceable thermometer. All of these traceable calibrations were performed to ensure the accuracy of measurements.

Table 4-19. FOG Samples with Low LCS Recovery

Influent Sample	Effluent Sample	Influent Sample	Effluent Sample	Removal (%)	Influent LCS (%)	Influent LCSD (%)	Effluent LCS (%)	Effluent LCSD (%)	Noted in Narrative	Influent Sample	Effluent Sample
09/22/2008	09/24/2008	2,200(1)	<3	99.9	100	83.5	83.5	83.5		2,200(1)	<3
09/24/2008	09/26/2008	680(1)	13	98.1	83.5	83.5	83.5	N/A		680(1)	13
10/13/2008	10/15/2008	120	<3	97.5	83.5	N/A	81	N/A		120	<3
10/15/2008	10/17/2008	110	<3	97.3	83.5	N/A	72.3	N/A	not noted	110	NR
11/10/2008	11/12/2008	34	<3	91.2	98.5	N/A	95	N/A		34	<3
11/12/2008	11/14/2008	140	<3	97.9	95	N/A	76.8	97.5	noted	140	NR
12/8/2009	12/10/2009	37	<3	91.9	92.5	N/A	57	N/A	noted	37	NR
12/10/2009	12/12/2009	350	<3	99.1	57	N/A	57	N/A	noted	350	NR
01/26/2009	01/28/2009	54	<3	94.4	77.7	N/A	92.2	N/A	noted	NR	<3
01/28/2009	01/30/2009	36	<3	91.7	93	N/A	92.2	N/A		36	<3
02/16/2009	02/18/2009	120	<3	97.5	64.3	N/A	96.8	N/A	noted	NR	<3
02/18/2009	02/20/2009	380	<3	99.2	96.8	N/A	85.5	N/A		380	<3
03/9/2009	03/11/2009	130(2)	9.4(2)	92.8	84	N/A	83	N/A		130(2)	9.4(2)
05/18/2009	05/20/2009	240(3)	3.3(3)	98.6	81.5	87.2	74.3	87.8	not noted	240(3)	3.3(3)
05/20/2009	05/22/2009	240(3)	3.5(3)	98.5	74.3	87.8	86.3	86.2	not noted	240(3)	3.5(3)
06/22/2009	06/24/2009	170	<3	98.2	79	88.5	71.8	79.3	not noted	170	<3
06/24/2009	06/26/2009	270	<3	98.9	71.8	79.3	71.8	79.3	not noted	270	<3
07/20/2009	07/22/2009	140	3.6	97.4	91.3	86	93.3	94.3		140	3.6
07/22/090	07/24/2009	490	<3	99.4	93.3	94.3	93.3	94.3		490	<3
08/17/2009	08/19/2009	140	28	80	81.5	83.2	65.5	72.8	noted	140	NR
08/19/2009	08/21/2009	2,100	13	99.4	65.5	72.8	65.5	72.8	noted	NR	NR
09/21/2009	09/23/2009	190	<3	98.4	83	94.3	94	96.2		190	<3
09/23/2009	09/25/2009	96	<3	96.9	94	96.2	47.3	86		96	<3
10/19/2009	10/21/2009	76	<3	96.1	72.2	61.6	83	90.7	noted	NR	<3
10/21/2009	10/23/2009	110	<3	97.3	83	90.7	83	90.7		110	<3
Number of Samples		22	22	22	25	14	25	14		21	19
Mean		370	5.1	98.6	83.2	84.9	79.4	86.5		300	4.0
Median		140	3	97.5	83.5	86.6	83	87		140	<3
Std. Dev.		600	5.9	NA	11.3	9.2	13.3	8.1		464	2.7

Notes: N/A - Not analyzed. NA - Not applicable. NR - Not reported in statistics

(1) Analyzed 5-7 days beyond 28-day hold time. Data were considered useable given the high concentrations, nature of the FOG from septage and samples were maintained under refrigeration. Data could be biased slightly low.

(2) March 2009 data is excluded from the summary statistics as the BOD_5 effluent data is suspect, or if correct indicate an upset occurred.

(3) Per protocol, the data from May 2009 when an upset occurred are not included in the summary statistics, but are reported for informational purposes.

Table 4-20. BOD_5 DO Depletion QA Table

Sample Date		BOD_5 mg/L			Influent DO Depletion Without seed/with seed adj.	Effluent DO Depletion Without seed/with seed adj.	COD mg/L	
Influent	Effluent	Influent	Effluent	Removal (%)			Influent	Effluent
09/22/2008	09/24/2008	1,300	51	96.1	2.52/2.13	2.12/1.71	22,000	25
09/24/2008	09/26/2008	2,600	110	95.8	4.75/4.34	4.12/3.72	22,000	380
10/13/2008	10/15/2008	5,200	29	99.4	4.74/4.35	5.23/4.88	31,000	210
10/15/2008	10/17/2008	3,600	72	98.0	3.32/2.97	1.5/1.2	26,000	250
11/10/2008	11/12/2008	2,800	97	96.5	2.74/2.37	3.55/3.23	24,000	400
11/12/2008	11/14/2008	2,800	83	97.0	4.95/4.63	2.99/2.76	14,000	390
12/08/2009	12/10/2009	15,000	74	99.5	1.49/1.26	1.44/1.22	18,000	180
12/10/2009	12/12/2009	2,600	41	98.4	2.41/2.19	3.73/3.40	20,000	270
01/26/2009	01/28/2009	48	30	37.5	1.41/0.80	2.72/2.51	6,400	210
01/28/2009	01/30/2009	110(1)	27(1)	75.5	2.45/2.24	2.06/1.85	3,700	290
02/16/2009	02/18/2009	1,600	110	93.1	1.70/1.33	3.78/3.52	6,300	300
02/18/2009	02/20/2009	3,000	130	95.7	2.78/2.52	2.2/2.09	5,600	320
03/09/2009	03/11/2009	4,100	930	77.3	1.97/1.69	1.81/1.55	36,000	400
05/18/2009	05/20/2009	21,000	5,500	73.8	1.99/1.75	4.93/4.56	31,000	11,000
05/20/2009	05/22/2009	10,000	5,700	43.0	4.52/4.15	4.19/3.82	20,000	8,600
06/22/2009	06/24/2009	4,800	99	97.9	4.21/3.97	2.01/1.65	18,000	180
06/24/2009	06/26/2009	2,500	72	97.1	5.50/5.14	2.71/2.39	6,200	380
07/20/2009	07/22/2009	2,200	62	97.2	4.29/3.99	2.25/2.07	25,000	220
07/22/2009	07/24/2009	4,800	130	97.3	6.40/6.22	4.59/4.41	20,000	360
08/17/2009	08/19/2009	2,100	190	91.0	2.03/1.78	1.79/1.59	18,000	290
08/19/2009	08/21/2009	4,000	7	99.8	3.55/3.35	1.30/1.11	8,200	160
09/21/2009	09/23/2009	2,400	26	98.9	4.23/3.94	1.14/0.87	21,000	200
09/23/2009	09/25/2009	3,700	44	98.8	2.74/2.47	1.66/1.45	21,000	320
10/19/2009	10/21/2009	4,100	57	98.6	1.75/1.37	1.18/0.91	28,000	240
10/21/2009	10/23/2009	2,400	110	95.4	1.88/1.61	2.02/1.75	20,000	400
Number of Samples		22	22	22			22	22
Mean		3,300	75	97.7			17,500	270
Median		2,700	72	97.2			20,000	280
Maximum		15,000	190	99.8			31,000	400
Minimum		27	7	37			3,700	25
Std. Dev		2,935	44.1	NA			8,032	95.5

NA – Not applicable.

4.4.4 Representativeness

The field procedures were designed to ensure that representative samples were collected of both influent and effluent wastewater. The composite sampling equipment was checked on a routine basis to ensure that proper sample volumes were collected to provide flow-weighted sample composites. Field duplicate samples and supervisor oversight provided assurance that procedures were being followed. There was some variability in the field duplicate samples; however, review of the overall data set for influent and effluent samples did not show specific sampling bias for any of the parameters. These data indicated that while individual sample variability may occur, the data were representative of the concentrations in the wastewater.

The laboratory used standard analytical methods and written SOPs for each method to provide a consistent approach to all analyses. Sample handling, storage, and analytical methodology were reviewed during the on-site audit to verify that standard procedures were being followed. The use of standard methodology, supported by proper QC information and audits, ensured that the analytical data were representative of the actual wastewater conditions.

4.4.5 Completeness

The QAPP set a goal of 80% completeness for sample collection in the field, and for reporting acceptable analytical results by the laboratory. The completeness goals were met for all parameters. Table 4-21 shows the number of samples/analyses anticipated and the number actually collected and analyzed during the verification test.

Table 4-21. QA Completeness

Parameter	Target Number	Actual Number Completed	Completeness %
Sampling days/batches	24	25	104
Flow/Volume	24	25	104
pH	48	50	104
Temperature	48	50	104
TSS	48	50	104
BOD_5	48	50	104
COD	48	50	104
FOG	48	50	104
Alkalinity	48	49	102
TKN	24-36 (1)	28	108 (2)
NH_3-N	24-26 (1)	28	108 (2)
NO_2+NO_3	24-36 (1)	25	96 (2)
TP	24-36 (1)	28	108 (2)
Sodium	24-36 (1)	28	108 (2)
Chloride	24-36 (1)	28	108 (2)

(1) See text for discuss of ranges per memo to NSF and EPA.

(2) Based on a target of 26 samples; 12 months at two per month and one month with one sample (see test for further explanation).

The test plan called for 12 months of sampling with two batches processed each month, for a total of 24 batches. In months with sufficient waste volume, the batches were to be consecutive and the nutrients, sodium and chloride composited from both batches into one set of samples (one influent and one effluent). It was anticipated that some low volume months would not allow for consecutive batch processing, so it was approved in the test plan to sample non-consecutive batches during those months. Nonconsecutive batch months were limited to six of the twelve months during the test. For months when batches were not consecutive, the nutrients, sodium and chloride would be sampled and analyzed for each batch; i.e., not be composited. In the test plan, it was assumed that six months would meet the consecutive batch requirement (six sets of influent and effluent samples for a total of 12 samples) and six months would be single batches generating two sets of samples per month for a total of 24 samples (two sets per month - influent and effluent for six months). The test plan table showed a target of 36 samples (12 plus 24) for nutrients, sodium and chloride. The test plan table should have set a range of target samples from the ideal where all batches were consecutive for 12 months yielding 24 samples to the maximum allowed six months with non-consecutive samples for a total of 36 samples. During the verification test, it was possible to meet the consecutive batch processing objective for 12 of the 13 months. The target number of samples for nutrients, sodium, and chloride was clarified in a memo to NSF and EPA dated September 29, 2009. EPA and NSF concurred that the target range should be 24 to 36 samples depending on the actual number of non-consecutive batch months that were sampled.

The completeness calculation for nutrients (TKN, NH_3-N, NO_2+NO_3, TP), sodium and chloride were based on 26 samples. This represents the 12 months when consecutive batches were processed (12 months at one influent and one effluent per month = 24 samples) plus the one month of March when a single batch was processed (one influent and one effluent sample = two samples).

As shown in Table 4-21, the completeness target of 80% was achieved for all parameters. Even if the upset period in May and the questionable BOD_5 data in March are removed from the total number of sample and analyses, the completeness for all analytical parameters exceeds 90%.

Chapter 5 Vendor Discussion

During the verification test, Big Fish sampled the biosolids on a periodic basis and sent the samples to the same contract laboratory used for verification testing for fecal coliform and percent moisture analyses. The data has not been independently reviewed by the TO or NSF for quality purposes but is presented in Appendix A for informational content in support of performance claims made by Big Fish Environmental, LLC.

Big Fish Environment, LLC, also arranged with Michigan State University (MSU) during the verification testing, to analyze samples of raw septage (influent) and effluent from the system for *E. coli*, enterocci, *Cryptosporidium*, and *Giardia*. A report of the findings by MSU for samples collected during the period of December, 2008 through January, 2010 was prepared and submitted to Big Fish Environmental, LLC. The report has not been reviewed by the TO or NSF for quality purposes, and is provided by Big Fish Environmental, LLC in Appendix A for additional, but non-verified information in support of performance claims made by the vendor.

Glossary of Terms

Accuracy - a measure of the closeness of an individual measurement or the average of a number of measurements to the true value and includes random error and systematic error.

Bias - the systematic or persistent distortion of a measurement process that causes errors in one direction

Comparability – a qualitative term that expresses confidence that two data sets can contribute to a common analysis and interpolation.

Completeness – a qualitative term that expresses confidence that all necessary data have been included

Precision - a measure of the agreement between replicate measurements of the same property made under similar conditions.

Protocol – a written document that clearly states the objectives, goals, scope and procedures for the study. A protocol shall be used for reference during Vendor participation in the verification testing program

Quality Assurance Project Plan – a written document that describes the implementation of quality assurance and quality control activities during the life cycle of the project.

Residuals – the waste streams, excluding final effluent, which are retained by or discharged from the technology.

Representativeness - a measure of the degree to which data accurately and precisely represent a characteristic of a population parameter at a sampling point, a process condition, or environmental condition

Source Water Protection Stakeholder Advisory Group - a group of individuals consisting of any or all of the following: buyers and users of in drain removal and other technologies, developers and vendors, consulting engineers, the finance and export communities, and permit writers and regulators.

Standard Operating Procedure – a written document containing specific procedures and protocols to ensure that quality assurance requirements are maintained

Technology Panel - a group of individuals with expertise and knowledge of decentralized wastewater treatment technologies

Testing Organization – an independent organization qualified by the Verification Organization to conduct studies and testing of technologies in accordance with protocols and test plans

Vendor – a business that assembles or sells decentralized wastewater treatment equipment.

Verification – to establish evidence on the performance of in drain treatment technologies under specific conditions, following a predetermined study protocol(s) and test plan(s).

Verification Organization – an organization qualified by USEPA to verify environmental technologies and to issue Verification Statements and Verification Reports.

Verification Report – a written document containing all raw and analyzed data, all QA/QC data sheets, descriptions of all collected data, a detailed description of all procedures and methods used in the verification testing, and all QA/QC results. The Test Plan(s) shall be included as part of this document.

Verification Statement – a document that summarizes the Verification Report reviewed and approved by USEPA.

Verification Test Plan – A written document prepared to describe the procedures for conducting a test or study according to the verification protocol requirements for the application of treatment technology. At a minimum, the Test Plan shall include detailed instructions for sample and data collection, sample handling and preservation, precision, accuracy, goals, and quality assurance and quality control requirements relevant to the technology and application.

References

(1) NSF International, *Protocol for the Verification of Wastewater Treatment Technologies*, Ann Arbor, MI, April 2001.

(2) NSF International, *Verification Test Plan for Big Fish Environmental, LLC.*, July 2008.

(3) United States Environmental Protection Agency, *Methods and Guidance for Analysis of Water*, EPA 821-C-99-008, Office of Water, Washington, DC, 1999.

(4) United States Environmental Protection Agency, *Methods for Chemical Analysis of Water and Wastes,* EPA 600/4-79-020, revised March 1983.

(5) APHA, AWWA, and WEF, *Standard Methods for the Examination of Water and Wastewater*, 19th Edition, Washington, DC, 1998.

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United States Environmental Protection Agency: *Environmental Technology Verification Program - Quality and Management Plan for the Pilot Period (1995 – 2000)*, USEPA/600/R-98/064, Office of Research and Development, Cincinnati, OH, 1998.

United States Environmental Protection Agency, *Guidance for the Data Quality Objectives Process, USEPA QA/G-4*, USEPA/600/R-96-055, Office of Research and Development, Washington, DC, 1996.

United States Environmental Protection Agency, *Plain English Guide to the EPA Part 503 Biosolids Rule,* USEPA/832/R-93/003, September 1994.

Appendices

Appendix A Big Fish Supplied Data for Fecal Coliform; % Moisture; *E. coli*; Enterococci; *Cryptosporidium*, and; *Giardia*

Big Fish Supplied Data for Fecal Coliform in Biosolids

Date	Location	Fecal Coliform (MPN/ g-dry wt)	Percent Moisture (%)
11/06/08	Pile A	< 21	53
01/27/09	Pile A	< 18	43
05/13/09	Pile A	< 13	24
05/13/09	Pile B	< 26	61
07/01/09	Pile A	< 23	57
10/06/09	Pile A	< 26	58
10/24/09	Pile A	< 9.3	57

Report on Analysis of Treated and Raw Septage Samples from Big Fish Septage Treatment Plant

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Date: 28th April 2010

1. Introduction:

The Big Fish Environmental Septage Processing System operating at Charlevoix, Michigan utilizing an aerobic biological treatment system to treat septage wastes and discharge the treated effluent to the municipal sewer system. The treatment also produces Class A biosolids after the dewatering of solids.

Septage is pumped from the trucks into screens and a de-grit chamber, which then flows into an equalization tank. The waste then goes through lime treatment process, after which it is pumped through a flocculation tank and a rotary screen thickener for biosolids production. Solids produced are processed in a FKC screw press that heats up to a minimum of 50°C for a minimum of 20minutes; the combination of lime and high temperature treatment reduces microorganisms in the solids. Water extracted during solid production is then discharged into series of aerobic treatment tanks. These large tanks have microbial generators that provide a source of microorganisms. The organic wastes are reduced from the wastewater by these organisms in combination with naturally occurring microorganism. Water then enters into settling tanks, the solid collected goes through lime treatment and screw press processes. The clarified water is aerated further after which it is discharged as effluent into the municipal sewer system.

Fecal indicator organisms are used to assess the fecal contamination of water bodies as they represent the presence of potential enteric pathogens in water. *Escherichia coli (E. coli)* and *Enterococcus* spp. are the most commonly used indicator bacteria. Septage is one of the sources of fecal contamination of water bodies; others include wastewater treatment plants, manure runoffs, wild life etc.

Our objectives were to analyze the level of indicator organisms (*E. coli* and enterococci) present in influent and treated effluent by cultivation and qPCR methods and to evaluate the microbial quality of Class A biosolids. We also evaluated the raw septage samples for *Cryptosporidium* and *Giardia* levels in order to assess the prevalence of these parasitic pathogens in the community and compare the trends of occurrence to those of sewage.

2. Methods:

2.1. Sample collection:

Triplicates of 50mL raw septage, 500mL effluent and biosolids samples were collected, placed on ice and shipped to Water Quality and Health Laboratory at Michigan State University, East Lansing, MI. Samples were collected on the following dates in 2009 for indicator analyses: June 23, June 25, June 30, July 1, July 14, July 16, November 12 in 2009 and Jan 12 in 2010. Immediately upon arrival, the samples were processed. For *Cryptosporidium* analysis, samples were collected on the following dates: Dec 17, 2008, and in 2009, Jan 28 , Feb 19, June 23, June 25, July 14, and July 21.

2.2. Sample processing:

One ml of raw septage samples was serially diluted and these dilutions were used for further bacterial indicator analysis. For effluent samples, volumes of 0.1ml, 1ml and 10ml were used for analysis. Biosolids samples were processed by dispensing 30gm of the sample in 270ml of sterile PBW and thoroughly vortexed. 10ml of this suspension was used for further analysis.

For qPCR analyses, 600µl of raw septage was directly used for DNA extraction. For effluent samples, 50ml of the sample was centrifuged at 8000g for 20 minutes. The supernatant was discarded and 1ml of the pellet was left behind. From this, 600 µl was used for DNA extraction.

2.3. Bacterial indicator analyses by cultivation method:

Samples were analyzed for *E. coli* and enterococci by using EPA membrane filtration Methods 1603 and 1600, respectively. Briefly, appropriate volumes were filtered through 0.45 µm pore size membrane filters. The filters were then placed on mTEC and mEI plates for *E .coli* and enterococci respectively. The mTEC plates were incubated at 36°C for 2 ± 0.5 hrs after which the plates are packed in a double Whirlpak bags and incubated in the waterbath at 44.5 ^{o}C for 20 ± 2.0 hrs. The mEI plates were incubated at 41°C for 24±2.0 hrs. Colonies developed were counted after the incubation period.

2.4. qPCR analysis:

The DNA extraction was carried out from processed samples using Roche MagNa Pure LC instrument (Roche Applied Sciences, Indianapolis, Ind.). The qPCR analysis was carried out for *E. coli* and enteroocci using primers and probes developed in our lab and previously described elsewhere (Frahm & Obst 2003).

2.5. *Cryptosporidium* analysis:

In brief, parasite detection was performed by processing 5 ml of septage according to EPA Method 1623. This method describes the examination of sample matrices for *Giardia* cysts and *Cryptosporidium* oocysts. Collectively, the environmental form of these parasite are termed (oo)cysts. 5 ml of septage was diluted with 5 ml of reagent water in a Leighton tube. The(oo)cysts were separated from the resuspended materials using the Dynal Immunomagnetic Separation Technique (IMS) (Dynabeads CG-combo Kit, Dynal Biotech, Inc., Lake Success, NY, USA). Modifications of the 1623 protocol included a second HCl wash step and neutralization of the IMS concentrate within a microcentrifuge tube rather than on a glass slide. When necessary, excess debris was diluted by the addition of 200 µl of sterile phosphate buffered saline (pH = 7.4). The (oo)cyst suspension was placed on slides and allowed to dry before samples were fixed with methanol and stained. The methanol also permeablized the (oo)cyst wall prior to staining with DAPI to help visualize nucleic acid content. Following the DAPI staining, an immunofluorescent assay (IFA) staining method, which uses monoclonal antibodies (EasyStain, Biotechnology Frontiers, Australia) tagged with fluorescein isothiocyanate is used to specifically stain the (oo)cyst walls. Microscopic examination of the

slides after IFA results in total counts of oocysts and cysts in the sample. Positive staining controls consisted of slides with purified *Giardia* and *Cryptosporidium* (EasyStain kit, Biotechnology Frontiers, Australia. Negative staining controls consisted of slides prepared with phosphate buffered saline in place of the sample. These control slides were fixed, stained, and read with each set of samples processed.

2.5.1. Recovery efficiency

Recovery efficiencies in laboratory reagent water were assessed by seeding 5 ml of reagent water with a known concentration of *Cryptosporidium* and *Giardia* (EasySeed, Biotechnology Frontiers, Australia). These ongoing precision and recovery (OPR) samples were processed as described above. After processing, counts of *Giardia* and *Cryptosporidium* were compared to the number of seeded organisms and a method blank of 10 ml laboratory reagent water containing no seeded *Giardia* and *Cryptosporidium* to calculate the method's efficiency. At least one method blank and one OPR were performed per week that samples were analyzed. To determine recovery efficiencies in sample matrices, duplicate septage samples were seeded with a known concentration of *Cryptosporidium* and *Giardia* (EasySeed, Biotechnology Frontiers, Australia). These matrix spike samples were processed as described above. After processing, counts of *Giardia* and *Cryptosporidium* were compared to the number of seeded organisms and the number of naturally occurring *Giardia* and *Cryptosporidium* in the associated field sample to calculate the method's efficiency in the environmental matrices. At least one efficiency test using water from sample sites was performed per week that samples were analyzed.

3. Results:

The concentrations of *E. coli* and enterococci in raw septage and effluent samples for all sampling dates as measured by cultivation methods are shown in Figures 1 & 2 respectively. The average log transformed concentrations of *E. coli* were found to be 6.47 in raw septage and 3.96 in effluent with standard deviations of 0.45 and 0.86 respectively. The average log transformed concentrations of enterococci were found to be 6.36 in raw septage and 4.07 in effluent with standard deviations of 0.82 and 0.96 respectively.

The concentrations of *E. coli* and enterococci in raw septage and effluent samples for all sampling dates as measured by qPCR methods are shown in Figures 3 & 4 respectively. The average log transformed concentrations of *E. coli* were found to be 7.33 in raw septage and 3.51 in effluent with standard deviations of 0.68 and 0.67 respectively. The average log transformed concentrations of enterococci were found to be 7.31 in raw septage and 5.32 in effluent with standard deviations of 0.36 and 0.28 respectively.

Log removal, as measured by cultivation methods, of *E. coli* during treatment ranged from 1.40 to 3.78 and that of enterococci ranged from 1.50 to 3.15. qPCR analyses showed log removal ranging from 2.88 to 4.75 of *E. coli* and that of enterococci ranged from 1.34 to 2.46. These results are summarized in Table 1.

All of the biosolid samples had concentrations of *E.coli* and enterococci below the detection limit, which is 0.33cfu/g. qPCR analyses was not performed for the biosolid samples.

Giardia was found in all untreated septage samples. *Cryptosporidium* was found in 3 out of 7 samples. *Giardia* was between 2 to 3 logs higher than *Cryptosporidium* which is a trend common in sewage. There was variability in detection of *Giardia* even though it was always detected. Variability with 2 logs was observed.

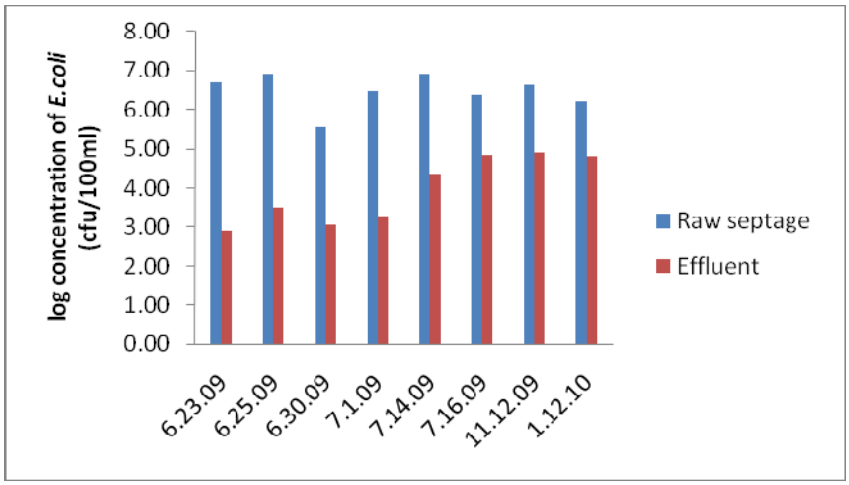

Figure 1: Comparison of log transformed concentrations of *E. coli* in raw septage and effluent by cultivation methods.

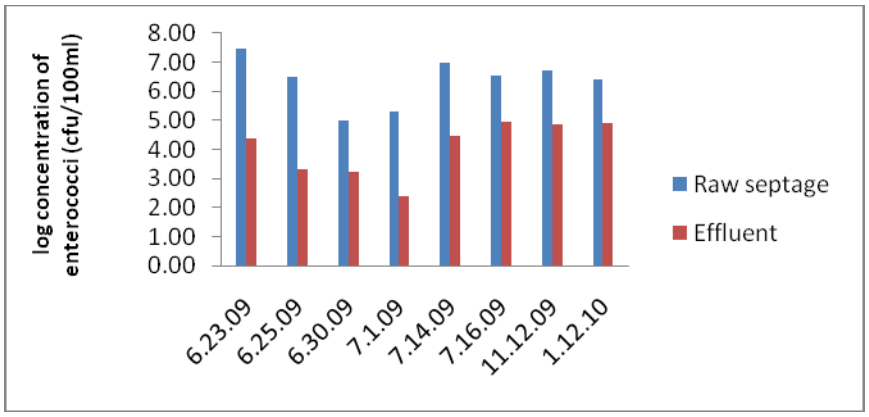

Figure 2: Comparison of log transformed concentrations of enterococci in raw septage and effluent by cultivation methods.

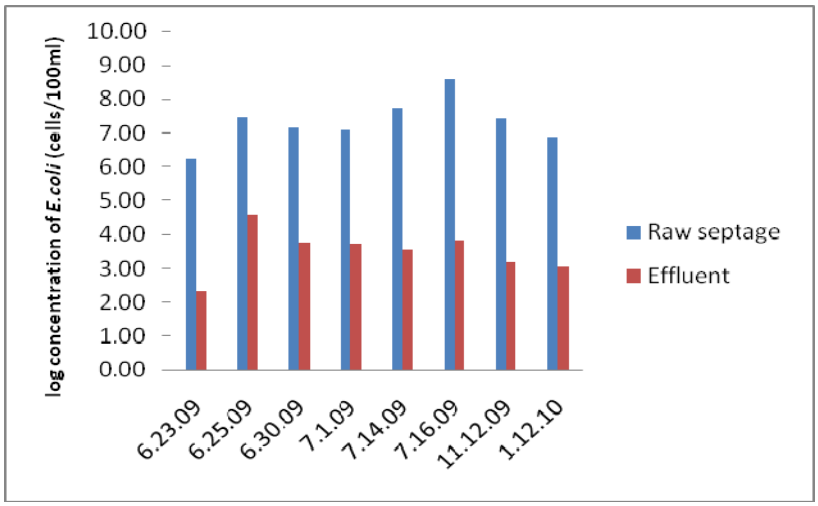

Figure 3: Comparison of log transformed concentrations of *E. coli* in raw septage and effluent by qPCR analysis.

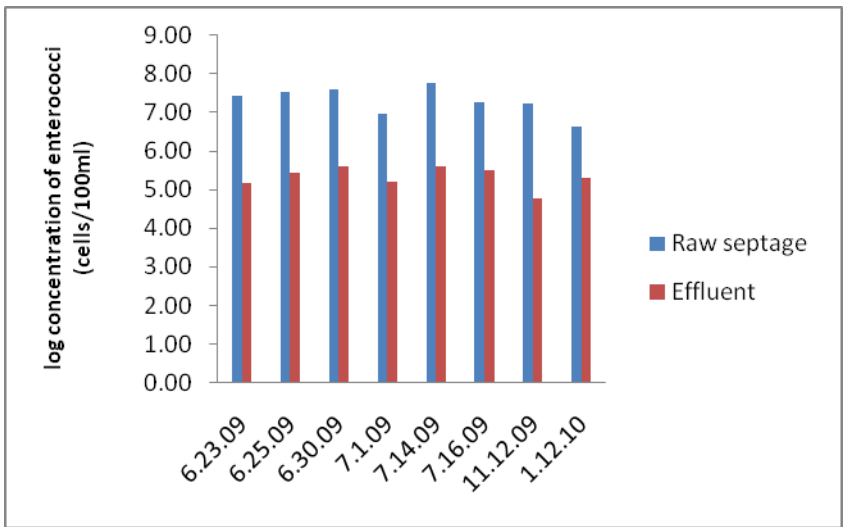

Figure 4: Comparison of log transformed concentrations of enterococci in raw septage and effluent by qPCR analysis.

Table 1: Log removal of *E. coli* and enterococci during treatment through the Big Fish Environmental Septage Processing System

Sampling dates	*E.coli* cfu/100ml	Enterococci cfu/100ml	*E.coli* cells/100ml	Enterococci cells/100ml
6.23.09	3.78	3.08	3.91	2.26
6.25.09	3.41	3.15	2.88	2.11
6.30.09	2.49	1.76	3.40	2.02
7.1.09	3.23	2.91	3.35	1.77
7.14.09	2.57	2.50	4.18	2.15
7.16.09	1.52	1.58	4.75	1.79
11.12.09	1.71	1.83	4.23	2.46
1.12.10	1.40	1.50	3.85	1.34

Table 2: Levels of *Giardia* and *Cryptosporidium* in raw septage samples

Date Collected	Volume Collected (liters)	Organism	Sample Volume Examined (mL)	Total Organisms Detected	Concentration Organisms /mL
12/17/2008	1	*Giardia* *Cryptosporidium*	5	262 0	52.4 <0.2
1/28/2009	1	*Giardia* *Cryptosporidium*	5	38 0	7.6 <0.2
2/19/2009	1	*Giardia* *Cryptosporidium*	5	1591 1	318 0.2
6/23/09	1	*Giardia* *Cryptosporidium*	5	1165 0	233 <0.2
6/25/09	1	*Giardia* *Cryptosporidium*	5	1278 1	255.6 0.2
7/14/09	1	*Giardia* *Cryptosporidium*	5	757 2	151 0.4
7/21/09	1	*Giardia* *Cryptosporidium*	5	759 0	151.8 <0.2

References:

Frahm, E., and U. Obst. 2003. Application of the fluorogenic probe technique (TaqMan PCR) to the detection of *Enterococcus spp*. and *Escherichia coli* in water samples. J. Microbiol. Methods **52**, 123–131.

Method 1600: Enterococci in Water by Membrane Filter using membrane Enterococcus Indoxyl-B-D-Glucoside Agar (mEI). 2002. EPA-821-R-02-022. Office of Water, Washington D.C.

Method 1603: *Escherichia coli* (*E. coli*) in Water by Membrane Filtration using Modified membrane-Thermotolerant *Escherichia coli* Agar (modified mTEC). 2005. EPA 821-R-04-025. Office of Water, Washington D.C.

Appendix B Verification Test Plan

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

Appendix C Big Fish Operation and Maintenance Manual

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

Appendix D Pictures of Test Site and Equipment

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

Appendix E Spreadsheets with Calculations and Data Summary

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

Appendix F Lab Data, QA/QC Data, Field Logs, and Records

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