FORCE

YEAR 5 FEEDSTOCK COMPOSTING PROJECT FINAL REPORT

August 2006

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SECTION 1.0
BACKGROUND & METHODOLOGY

As part of its Year 5 Operating Plan, the Florida Organics Recycling Center for Excellence (FORCE) conducted composting trials at the Sumter County Solid Waste Composting Facility (SCSWCF). The purpose of the Year 5 Organic Feedstock Project (Feedstock Project) was to evaluate various organic feedstocks that could be added to the composting operations at the Facility. These trials were performed in the Sumter County digester and on the finishing building floor.

Prior to beginning the Feedstock Project, FORCE staff developed a written Research and Testing Methodology (Methodology) as a guideline for composting procedures, monitoring, sampling and analysis. The Methodology incorporated procedures from the Scientific Advisory Council (SAC) Protocol developed in July 2002 and the Florida FDEP Requirements for Field and Analytical Work (FDEP-QA-002/02), both of which provided direction to the County in meeting its requirements for analytical testing described in SW204 contract with the Florida Department of Environmental Protection (FDEP).

During the course of the trials, Sumter County changed its standard operating procedures for the SCSWCF, and thus the Project Methodology. In addition, FORCE staff encountered several operational problems during the course of the Project, which caused deviations from the Project Methodology. The following paragraphs describe the Project Methodology and changes that occurred during the course of the Project.

1.1 Staffing

FORCE staff was responsible for operations and management of the Project. Test America performed laboratory analyses. Kessler Consulting provided assistance to ensure that contractual and reporting requirements were met.

1.2 Test Recipes

The test recipes were generally based on the SCSWCF's normal daily procedures for composting MSW. For tests that did not include biosolids, the target amount of additive was 50 percent of MSW weight. For tests that included biosolids, the target amount was 25 percent of MSW weight for additive and biosolids. For all recipes the target amount of inoculant was 10 percent of the total weight of other materials (MSW, additive & biosolids). The test recipe was designed to yield the following daily quantities:

- 68 to 69 tons MSW (725 cubic yard of MSW off the tip floor @ 190 lbs/cy)
- 34 to 35 tons of additive and biosolids (50 percent of MSW tons)
- 10 to 11 tons of inoculant (10 percent of MSW, additive & biosolids)
- 112 to 115 tons per day loaded in the digester

In addition, FORCE staff added water to the recipe on an as needed basis to approximate the 55 percent moisture content target.

Using the recipe as a guideline, FORCE staff recorded quantities loaded into the digester using standard SCSWCF operating procedures. It is important to note FORCE staff was unable to measure the actual quantity of MSW going into the digester; MSW is conveyed directly from the tipping floor through the MRF and into the digester. Instead, staff counted the number of cubic yards loaded off the tipping floor into MRF. In the MRF, large contaminants and some recyclables were removed from the MSW prior to it being loaded into the digester. FORCE staff estimates the weight of MSW going into the digester by assuming it has a bulk density of 190 lbs/cubic yard.

FORCE staff was able to measure the actual quantity of additives and biosolids going into the digester because these are loaded directly on a dedicated conveyor.

1.3 Digester Loading – Days per Week and Schedule

Protocol 1

At the beginning of the Feedstock Project, the SCSWCF loaded the digester four days per week on Monday, Tuesday, Thursday and Friday. Thus, the original methodology stipulated that each feedstock trial would consist of four daily batches. In order to achieve a minimum 72 hours residence time in the digester (as required by FDEP permit), materials were unloaded as follows: Monday's load unloaded on Friday, Tuesday's load unloaded on Monday, Thursday's load unloaded on Tuesday, and Friday's load unloaded on Thursday.

Protocol 2

In June, during the course of Feedstock Project, the SCSWCF changed its standard operating procedures in two ways: (1) reducing the number of days it loaded the digester from four days per week to two days per week and (2) reducing the daily base quantity of MSW from 725 to 500 cubic yards.

Consequently, the number of batches in each feedstock test was reduced to two and the daily quantity was reduced as well. In order to achieve a minimum 72 hours residence time, batches were loaded on Thursday (unloaded on Monday) and Friday (unloaded on Tuesday). Thus, the test recipe was modified to yield the following daily quantities:

- 47 to 48 tons MSW (500 cubic yard of MSW off the tip floor @ 190 lbs/cy)
- 23 to 24 tons of additive and biosolids (50 percent of MSW tons)
- 7 to 8 tons of inoculant (10 percent of MSW, additive & biosolids)
- 77 to 80 tons per day loaded in the digester

Protocol 3

In November, the procedure for digester loading was modified again. A review of digester records under Protocol 2 showed that feedstocks spread out quickly in the digester to a shallow depth, which is not conducive to thermophillic composting. Therefore, the following procedure was adopted for subsequent feedstock tests.

On Friday a plug of inoculant was loaded and the digester turned off. Test feedstock batches were loaded on Monday and Tuesday. On Wednesday, another plug of inoculant was loaded and the initial plug was unloaded. The test batches were unloaded on Thursday and Friday – 72 hours after loading.

1.4 Description of Feedstock Tests

The following table summarizes the feedstock tests and the additives tested, the dates when they were initiated, and the protocol used.

Table 1 – Feedstock Testing Schedule

Test #	*Additives*	*Start Loading*	*Protocol Used*
1	Inoculant only (water, old compost)	18-Apr-2005	P1
2	Chicken manure	25-Apr-2005	P1
3	Chicken Manure & Biosolids	2-May-2005	P1
4	Chicken Mortalities & Biosolids	16-May-2005	P1
5	Chicken Mortalities	23-May-2005	P1
6	Cow Manure & Biosolids	13-Jun-2005	P1
7	Cow Manure	23-Jun-2005	P2
8	Citrus Sludge	30-Jun-2005	P2
9	Citrus Sludge & Biosolids	7-Jul-2005	P2
10	Biosolids	14-Jul-2005	P2
11	Biosolids & No Inoculant	21-Jul-2005	P2
12	Biosolids & No Inoculant w/ Dygest506	5-Dec-2005	P3
13	Citrus Sludge w/ Dygest506	12-Dec-2005	P3
14	Biosolids w/ Dygest506	19-Dec-2005	P3
15	Biosolids w/ Ortec	30-Jan-2006	P3
16	Citrus Sludge w/ Ortec	2-Feb-2006	P3
17	Biosolids & No Inoculant w/ Ortec	13-Feb-2006	P3

Notes:
All tests contained MSW, except Test #1. All tests contained inoculant, except Test #11, #12, and #17

1.5 Description of Feedstocks and Additives

The source and general characteristics of each feedstocks and additive used in the Project are summarized below. Lab analyses of feedstocks were not conducted to determine specific characteristics.

Biosolids – Biosolids were obtained from the Wildwood wastewater treatment plant located less than 10 miles from the SCSWCF. The plant receives residential wastewater primarily although there are also several industrial discharges connected to the plant. A pre-treatment program is in place in order control levels of regulated pollutants (i.e. heavy metals). The plant produces aerobically digested Class A biosolids.

Chicken Manure and Mortalities – Chicken manure and mortalities were obtained from a Hillandale Farms facility in Bushnell. Hillandale is a major national egg producer. County trucks were used to pick up and deliver these feedstocks to the SCSWCF. The County paid for the feedstock.

Cow Manure – Cow manure was obtained from H&C Dairy located in Lakeland Florida. Manure was delivered to the facility by a private trucker – R&M Trucking. The County also paid for the feedstock.

Citrus Sludge – Citrus sludge was obtained from Cutrale's manufacturing facility located in Lessburg. The sludge is the residue remaining after extraction of juice and other products from citrus fruit. The citrus sludge was dewatered at the Cutrale facility and delivered by truck to the SCSWCF.

Dygest506 – This compost additive is marketed in the U.S. by RKB Enterprises. According to RKB, the product contains amino acids, sulfates, minerals, protein derivatives, natural carbohydrate surfactants, and special nitrates. It is intended to change the biochemistry in the compost and is ideal for static and aerated static pile facilities. The product was utilized, in accordance with RKB recommended application procedures, by mixing Dygest506 in the water added to feedstocks prior to loading in the digester. The application rate was approximately 2 fluid ounces of concentrated Dygest506 per ton of feedstock.

Ortec – According to Ortec Ltd, this compost additive is a biocatalysts designed to control odors and improve decomposition of organic wastes. Product application procedures and rates for the Project were developed according to Ortec recommendations. The application rate was approximately 1 milliliter per ton of feedstock.

1.6 Windrow Composting

Once removed from the digester, batches were screened using the 2-inch rotary trommel screen at the SCSWCF. Screen overs were disposed and screen unders were placed in windrows for further composting. The Project Methodology called for managing windrow composting according to SCSWCF standard operating procedures, i.e., weekly turning (Friday) using a SCARAB windrow turner. The Methodology specified that materials were to remain in windrow compost for 28 days after reaching 131ºF (55ºC), after which the compost was to be processed through the 3/8-inch rotary trommel screen at the SCSWCF. Screen overs were disposed and screen unders (compost) were placed in separate stockpiles on-site at the SCSWCF.

Actual operations during the Project differed from the intended protocol. There were periods of time when the SCARAB windrow turning machine was inoperable and windrows were not turned.

Feedstock tests resumed in December using the Dygest506 activator. According to RKB Enterprises (the Dygest506 supplier) the recommended procedure for Dygest506 is to not turn the windrows. Therefore, weekly turning was suspended for this series of three tests.

The three tests using Ortec's compost additive were conducted using the weekly turning protocol. The SCARAB was operational when these tests were conducted in February and March 2006.

1.7 Process Monitoring

FORCE staff performed the following monitoring activities during the Feedstock Project.

Digester Loading

- Feedstock loading:
  - MSW – calculated cubic yards and tons
  - Additives - cubic yards and calculated tons
  - Inoculant – cubic yards and calculated tons
  - Water – gallons
- Hourly records of quantities loaded

Digester Composting

In each of the three compartments in the digester, measurements of:
- Material depth (twice daily)
- Temperature (twice daily)
- Moisture content (once daily)

Digester Discharge

- Screen Overs – calculated cubic yards and tons
- Screen Unders – calculated cubic yards and tons

Windrow Composting

- Initial windrow dimensions
- Temperature (daily)
- Moisture (daily)
- Windrow turning events

1.8 Laboratory Analysis

Laboratory analyses were performed on samples from each of the feedstock tests. FORCE staff collected samples according to the following schedule:

- Screen unders after discharge from the digester
- Windrow Day 10 (after reaching 131ºF)
- Windrow Day 15
- Windrow Day 21
- Windrow Day 28

Samples were ice packed and shipped by overnight courier to the TestAmerica lab in Orlando where analyses were performed according to FDEP requirements and the SAC Protocol. The following table lists the parameters for which materials were tested.

Table 2 – Parameters for Compost Analyses

Parameter	*Test Units*	*Parameter*	*Test Units*
N Ammonia	mg/kg dw	Arsenic	mg/kg dw
N Nitrate	mg/kg dw	Cadmium	mg/kg dw
N Nitrite	mg/kg dw	Chromium	mg/kg dw
TKN	mg/kg dw	Copper	mg/kg dw
Total N	mg/kg dw	Lead	mg/kg dw
Phosphorus	mg/kg dw	Mercury	mg/kg dw
Potassium	mg/kg dw	Molybdenum	mg/kg dw
Total Organic Carbon	mg/kg	Nickel	mg/kg dw
C:N ratio	x:1	Selenium	mg/kg dw
		Zinc	mg/kg dw
Moisture	%		
Total Solids	mg/kg	Fecal Coliform	MPN/g dw
Total Fixed Solids	mg/kg		
Total Volatile Solids	mg/kg		
Foreign Matter	%		
Specific Oxygen Uptake Rate	mg/hr/g dw		
Specific Conductivity	µS/cm		
pH			

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SECTION 2.0
RESULTS & DISCUSSION

KCI compiled and evaluated feedstock test results gathered by FORCE staff. Results and discussion are presented below. First, we summarize the recipes used for each test. Then we present and discuss the Project results for the following issues:

- Laboratory analysis procedures
- Compost process performance (carbon ratios, volatile solids, moisture content, digester aeration, depth in digester, and temperature)
- Compost characteristics – regulatory parameters
- Compost characteristics – macro-nutrients (nitrogen, phosphorus, potassium)
- Compost characteristics – market related parameters.

2.1 Compost Recipes

Summaries of the recipes are provided in the following tables based on FORCE staff loading records.

Table 3 - Protocol 1 Compost Recipes As Recorded by FORCE Staff

#1 - Inoculant only		*#2 - Chicken Manure*		*#3 - Chicken Manure & Biosolids*	
Monitored Batch #	*57*	*Monitored Batch #*	*61*	*Monitored Batch #*	*65*
Feedstock	*Tons*	*Feedstock*	*Tons*	*Feedstock*	*Tons*
MSW	275.5	MSW	275.5	MSW	275.5
Inoculant	128.8	Chicken Manure	140.3	Chicken Manure	60.8
		Inoculant	65.7	W.W. Sludge	76.1
				Inoculant	61.6
Water	110.7	Water	106.9	Water	76.7
Total w/o Water	404.3	Total w/o Water	481.4	Total w/o Water	474.0
Total w/ Water	515.0	Total w/ Water	588.3	Total w/ Water	550.7

#4 – Chicken Mortalities & Biosolids		*#5 - Chicken Mortalities*		*#6 - Cow Manure & Biosolids*	
Monitored Batch #	*73*	*Monitored Batch #*	*75*	*Monitored Batch #*	*86*
Feedstock	*Tons*	*Feedstock*	*Tons*	*Feedstock*	*Tons*
MSW	275.5	MSW	68.9	MSW	190.0
Chickens	59.5	Chickens	34.0	Cow Manure	47.4
W.W. Sludge	75.3	Inoculant	14.6	W.W. Sludge	47.1
Inoculant	60.3			Inoculant	44.6
Water	66.9	Water	9.6	Water	28.2
Total w/o Water	470.6	Total w/o Water	117.4	Total w/o Water	329.0
Total w/ Water	537.5	Total w/ Water	127.0	Total w/ Water	357.3

Table 4 - Protocol 2 Compost Recipes As Recorded by FORCE Staff

#7 - Cow manure Monitored Batch # 87		#8 - Citrus Sludge Monitored Batch # 88		#9 - Citrus Sludge & Biosolids Monitored Batch # 89	
Feedstock	Tons	Feedstock	Tons	Feedstock	Tons
MSW	53.2	MSW	95.0	MSW	95.0
Cow Manure	26.8	Citrus Sludge	47.1	Citrus Sludge	24.5
				W.W. Sludge	23.1
Inoculant	12.8	Inoculant	22.2	Inoculant	22.4
Water	19.8	Water	11.0	Water	0.0
Total w/o Water	92.7	Total w/o Water	164.3	Total w/o Water	165.1
Total w/ Water	112.5	Total w/ Water	175.3	Total w/ Water	165.1

#10 – Biosolids Monitored Batch # 90		#11 - Biosolids & No Inoculant Monitored Batch # 91	
Feedstock	Tons	Feedstock	Tons
MSW	79.8	MSW	95.0
W.W. Sludge	40.2	Biosolids	47.1
Inoculant	17.6		
Water	0.0	Water	0.0
Total w/o Water	137.6	Total w/o Water	142.1
Total w/ Water	137.6	Total w/ Water	142.1

Table 5 - Protocol 3 Compost Recipes As Recorded by FORCE Staff

#12 – Biosolids & No Inoculant w/ Dygest506 Monitored Batch # 109		#13 – Citrus Sludge w/ Dygest506 Monitored Batch # 111		#14 – Biosolids w/ Dygest506 Monitored Batch # 113	
Feedstock	Tons	Feedstock	Tons	Feedstock	Tons
MSW	95.0	MSW	95.0	MSW	95.0
Biosolids	47.1	Citrus Sludge	47.8	Biosolids	47.9
		Inoculant	19.6	Inoculant	19.0
Water	4.2	Water	5.5	Water	4.5
Total w/o Water	142.1	Total w/o Water	162.4	Total w/o Water	161.9
Total w/ Water	146.2	Total w/ Water	167.9	Total w/ Water	166.4

#15 – Biosolids w/ Ortec Monitored Batch # 1 & 2		#16 – Citrus Sludge w/ Ortec Monitored Batch # 3 & 4		#17 - Biosolids & No Inoculant w/ Ortec Monitored Batch # 5 & 6	
Feedstock	Tons	Feedstock	Tons	Feedstock	Tons
MSW	95.0	MSW	95.0	MSW	95.0
Biosolids	48.8	Citrus Sludge	47.8	Biosolids	48.8
Inoculant	20.4	Inoculant	23.5		
Water	4.6	Water	3.3	Water	9.0
Total w/o Water	164.2	Total w/o Water	166.3	Total w/o Water	143.8
Total w/ Water	168.7	Total w/ Water	169.6	Total w/ Water	152.8

2.2 Laboratory Analysis Procedures

Lab work was conducted by TestAmerica, which is a national company certified by the state of Florida, as required under FORCE's contract with FDEP. The company utilized test methodologies recommended by the SAC and FDEP. However, TestAmerica had little experience in compost analysis prior to this project, although it is generally regarded in the organics recycling community that it is best to utilize labs with such experience in order to ensure procedures adapted the unique nature of compost.

In the process of compiling and reviewing lab reports from TestAmerica a number of anomalies were noted by KCI where results fell outside the range of anticipated results, including the following:

- Total solids, volatile solids, and/or fixed solids
- Ammonia
- C:N ratio

These issues were brought to the attention of TestAmerica personnel, who re-issued corrected lab reports to address the initial anomalies that we noted. In the process of discussions and without compost experience, it became clear that TestAmerica's lab procedures may reduce the level of confidence one can have in the carbon and nitrogen lab results:

- Incoming material may not be fully homogenized to increase the probability of representative samples
- The size of samples subjected to testing is small; for example, 01. to 0.5 gram for total organic carbon and 0.2 gram for total nitrogen

Given the heterogeneous nature of compost (various feedstocks, physical contamination, and variations in particle size) it can be difficult to obtain representative samples without compensating for the issues listed above. Because the protocol did not call for duplicate sampling and analysis, it is not possible to adequately quantify the standard deviation and assess the level of confidence one can have in the lab results. If future testing is conducted, procedures should be modified to address these issues.

2.3 Composting Process

Carbon Ratios

The microorganisms responsible for thermophillic composting require certain balances of chemical elements. It is generally acknowledged that optimal conditions for composting include the following ratios of carbon to nitrogen and phosphorus:

- Carbon to Nitrogen (C:N) ratio <50:1
- Carbon to Phosphorus (C:P) ratio <250:1

Composting will occur at ratios higher than these, but biological activity may be suppressed. With regard to C:N ratio, the optimal ratios are between 20:1 and 30:1, especially for composting in a digester where rapid temperature increases are required.

Unfortunately, there was a flaw in the Total Organic Carbon (TOC) methodology followed by TestAmerica. The lab measured TOC after removing inorganic carbon and drying the sample, which cannot be related back to TOC in the original sample because the quantities of inorganic carbon and moisture were not measured. Thus, the carbon ratios cannot be considered reliable measures of actual conditions in the trials.

However, based on visual assessment of the feedstock mixtures and approximate calculations of C:N ratios based on common characteristics of the feedstocks, it appears that C:N ratios were higher than that desired for digester composting, i.e. greater than 30:1.

Volatile Solids

The amount of volatile solids in a compost mixture is another key driver of the composting process. Volatile solids are a measure of the food available for decomposition. Based on the lab reports from TestAmerica, it appeared all of the feedstock tests had sufficient volatile solids to enable rapid thermophillic composting, provided that other conditions are met, e.g, C:N ratio.

Table 6 - Volatile Solids Content

Feedstock Test #	*Discharge*	*Day 10*	*Day 15*	*Day 21*	*Day 28*
#1 Inoculant Only	79%	77%	68%	65%	
#2 Chicken Manure	66%	63%	69%	58%	54%
#3 Chicken Manure & Biosolids	72%	70%	71%	67%	70%
#4 Chicken Mortalities & Biosolids	74%	74%	77%	76%	75%
#5 Chicken Mortalities	71%	73%	67%	75%	75%
#6 Cow Manure & Biosolids	76%	70%	73%	76%	67%
#7 Cow Manure	72%	69%	72%	72%	72%
#8 Citrus Sludge	76%	76%	79%	77%	86%
#9 Citrus Sludge & Biosolids	41%	60%	77%	76%	75%
#10 Biosolids	76%	80%	80%	79%	79%
#11 Biosolids-No Inoculant	73%	78%	78%	80%	25%
#12 Biosolids-No Inoculant w/ Dygest506	79%	72%	76%	76%	74%
#13 Citrus Sludge w/ Dygest506	78%	74%	95%	8%	77%
#14 Biosolids w/ Dygest506	76%	7%	79%	80%	77%
#15 Biosolids w/ Ortec	80%	79%	79%	75%	77%
#16 Citrus Sludge w/ Ortec	82%	78%	77%	78%	76%
#17 Biosolids-No Inoculant w/ Ortec	82%	78%	81%	81%	82%

Moisture Content

Maintaining proper moisture content is another critical parameter for composting. In general, moisture content in the range of 40 percent to 60 percent is acceptable. However, the preferred moisture content for a rotary digester is 60 percent and up to 65 percent is acceptable. Moisture content below 50 percent is not desirable for the digester – although it is acceptable for windrow composting.

Based on results compiled by FORCE staff, moisture content in digester for all the feedstock tests was acceptable, although several of the tests were a little on the dry side (Tests #2, #5 and #11). At the SCSWCF it is important that compost does not become too dry (e.g., < 50 percent) before final screening. If compost becomes drier than this, it becomes light and difficult to screen. This results in insufficient weight for the fine material to pass through the screen and large quantities of dust are generated.

With regard to the windrow composting, moisture content between 50 percent and 60 percent is preferable. And the results indicate that windrow moisture content was acceptable for all tests. The charts in Appendix B depict moisture content for each of the tests.

Depth of Compost in Digester

The quantity of material in the digester can impact the composting process. The digester must have sufficient mass and depth of material in order for it to heat up quickly. FORCE staff took twice daily depth measurements during the Project. The general recommended guideline for operating the SCSWCF digester (14 feet diameter) is to keep it approximately 2/3 full, or about 9 feet deep.

For Tests #1 - #5 depths of compost ranged in the digester ranged from 6 to 10 feet, which is below optimum conditions but acceptable. For Tests #6 - #17 depths ranged from 2 to 6 feet. The reason for this change was the switch to Protocol 2 and 3. Test #6 was based on using 500 cy of MSW and four days of loading. And the rest of the tests were based on 500 cy of MSW and two days of loading. Consequently, this smaller volume of material readily spread out in the digester and quickly moved to the last chamber where it built up to greater depth. Protocol # 3 was implemented as an attempt to increase the depth, but this was unsuccessful. It appears that the only way to maintain proper depth is to run the digester continuously and load it based on its design capacity.

Aeration

Aeration was provided in the digester according to standard operating procedures for the SCSWCF, namely on a 15 minute cycle with the blower operating for 3 minutes and off for 12 minutes. This level of aeration falls within acceptable ranges for the digester. However, it is possible that the aeration was too high given the shallow depth of material in the digester, and thus heat was blown out of the material faster than it could build up.

Forced aeration was not part of the standard operating procedures at the SCSWCF. Weekly turning with the SCARAB windrow turner is intended to prevent anaerobic conditions and provide sufficient oxygen for composting. However, as noted above the turning machine was inoperable at various times during the Project, therefore windrows were not consistently turned and aerated.

Temperature

Ultimately temperature is the simplest indicator of whether conditions for composting are proper. In designing the Feedstock Project, it was anticipated that tests would compost for 72 hours in the digester at 131ºF as required by the SCSWCF permit. However, this temperature was not achieved at any time during the Project. Temperatures in the digester ranged from 96ºF to 129ºF. Appendix A provides temperature charts for each of the tests.

Once placed into windrow all of the feedstock tests heated up and sustained temperatures above 131ºF for many days. In fact, temperatures were 147ºF or greater for all tests when they were removed from windrow and screened. Thus the tests had not yet completed thermophillic composting. The reader should note that, according to FORCE staff records, three tests (inoculant only, chicken manure, and chicken manure & biosolids) were removed from windrow and screened only 21 days after achieving temperature. All other tests remained in windrow for at least 28 days after achieving temperature. (See Appendix A.)

Discussion

Although data are not sufficient to make a definitive conclusion, it is possible to deduce the following based on monitoring records and lab reports:

- C:N ratios were probably above the optimal range of 20:1 to 30:1 for most if not all tests. Therefore, this is likely the primary factor behind the temperature problems in the digester.

- During the trials digester aeration rates were kept at standard levels even though the depth of material in the digester was less than optimal. Therefore, it is possible that materials were over aerated, which can inhibit thermophillic temperatures.

- Volatile solids content was sufficient and therefore not a limiting factor. This was confirmed by the fact that all tests sustained high temperatures during the windrow phase of composting.

- Moisture content was acceptable (although a little on the dry side for a few tests). Therefore, this may have been a secondary or minor factor contributing to digester temperature problems.

- Composting temperature problems can be caused by either too little or too much aeration. Too little air will suppress thermophillic composting microorganisms and cause cool temperatures and anaerobic conditions. Too much air can blow all the heat out of the compost. Aeration rate in digester was acceptable and thus would not have been a cause for low temperature.

- The depth of compost in the digester was marginally acceptable for the first 5 tests and then too low for the remaining tests. Without sufficient depth in the digester there is not enough thermal mass to initiate or sustain thermophillic conditions. Therefore, this would have been a secondary factor contributing to slow temperature rise and inability to meet 131ºF in the digester.

- Another possible reason for low digester temperatures may have been the lack of sufficient biological inoculant. In order to rapidly achieve high temperatures, there must be a strong population of microorganism present in the feedstock (assuming other compost parameters are met, e.g., C:N ratio and moisture). Typically, the use of recycled raw compost as inoculant in the recipe provides this biological culture. In addition, a certain amount of material always remains in the digester and helps to inoculate fresh material. It is possible that the inoculant and "carry-over" material in the SCSWCF digester did not provide sufficient biological culture.

In summary, although it is not possible to conclusively determine the reason for low temperatures in the digester, the most likely primary factor was that C:N ratios were too high. Other possible secondary factors were aeration, marginal moisture content, insufficient depth and mass in the digester, and insufficient biological culture.

Once compost was placed in windrows, all the tests eventually achieved and sustained thermophillic conditions and the composting process appeared to have progressed successfully. However, according to FORCE staff records, windrows were not turned weekly, and in all cases temperatures were still in the thermophillic range when the tests were removed from active composting and screened.

2.4 Compost Characteristics – Regulatory Parameters

Lab tests performed by TestAmerica analyzed the biological and chemical characteristics with regard to specific parameters necessary to comply with Florida regulations. Tests were conducted to measure levels of fecal coliform and heavy metals.

Fecal Coliform

Fecal coliform is used as an indicator organism for determining if human pathogens have been killed, and thus whether compost is safe for general distribution to the public. Florida regulations generally conform to Federal regulations regarding pathogen reduction in biosolids. A variety of composting processes are defined in the regulations and the general pathogen reduction standard is to achieve fecal coliform below 1,000 Most Probable Number per gram total solids dry weight (MPN/gm TS dw).

TestAmerica analyzed for fecal coliform and the results are summarized graphically in Appendix B for each test. Typically one would expect to see test results decline as composting progresses with final levels of fecal coliform well below the regulatory standard. However, results for several of the feedstock tests appear to be counterintuitive initially. The following table summarizes the results.

Table 7 - Fecal Coliform Levels (MPN/gm TS dw)

Feedstock Test #	*Discharge*	*Day 10*	*Day 15*	*Day 21*	*Day 28*
#1 Inoculant Only	3	5	<3.86	<3	
#2 Chicken Manure	4	11	4	4.53	**>2935.8**
#3 Chicken Manure & Biosolids	6	<4.25	<5.1	**3800**	10
#4 Chicken Mortalities & Biosolids	10	**>4570**	**>3532**	**3300**	8
#5 Chicken Mortalities	540	**1200**	960	16	4
#6 Cow Manure & Biosolids	**>4060**	9	**2000**	550	110
#7 Cow Manure	**>4030**	560	**>3300**	**1100**	**>3340**
#8 Citrus Sludge	**2300**	**>4600**	630	<5	**1300**
#9 Citrus Sludge & Biosolids	**4200**	62	740	**>3800**	54
#10 Biosolids	800	<4.94	560	**3600**	500
#11 Biosolids-No Inoculant	**>1600**	**>3486**	**1900**	**>3376**	520
#12 Biosolids-No Inoculant w/ Dygest506	578	503	91	48	230
#13 Citrus Sludge w/ Dygest506	610	580	**20900**	**2980**	191
#14 Biosolids w/ Dygest506	**2630**	44	3010	44	45
#15 Biosolids w/ Ortec	551	5	5	**4**	615
#16 Citrus Sludge w/ Ortec	203	118	5	399	16
#17 Biosolids-No Inoculant w/ Ortec	18	4	4	104	154

Note: Results in **bold** exceed regulatory standard for compost for general public use

For several tests, pathogen levels varied widely with little correlation to temperatures being above 131ºF (the regulatory temperature standard for pathogen reduction). The most likely explanation for the problems in achieving consistent pathogen reduction during the tests is the fact that the windrows were not turned by staff. According to regulatory standards the acceptable procedure for pathogen reduction in turned windrows is to maintain temperatures above 131ºF for 15 days during which time the windrows are turned five times. The procedure ensures that materials on the surface of the windrow are subjected to high temperatures in the core of the windrow in a short enough period of time to prevent continual pathogen growth in the surface material.

Therefore, what most likely occurred during the Project was that samples taken from inside the windrow either included or were contaminated with material from the surface of the windrow, thus introducing viable pathogens into the sample.

Heavy Metals

Florida regulations establish maximum concentrations allowable in compost for various heavy metals. State standards are summarized in the following tables.

Table 8 - Ceiling Concentrations for Solid Waste Compost Not Containing Biosolids (mg/kg dw)

	Concentration Codes			
	1	*2*	*3*	*4*
Cadmium	<15	15 – <30	30 – 100	>100
Copper	<450	450 – <900	900 – 3,000	>3,000
Lead	<500	500 – <1,000	1,000 – 1,500	>1,500
Nickel	<50	50 – <100	100 – 500	>500
Zinc	<900	900 – <1,800	1,800 – 10,000	>10,000

Table 9 - Ceiling Concentrations for Class AA Compost Containing Biosolids (mg/kg dw)

	Concentration
Arsenic	41
Cadmium	39
Copper	1,500
Lead	300
Mercury	17
Nickel	420
Selenium	100
Zinc	2,800

All of the tests conducted in the Feedstock Project complied with the most stringent state heavy metal regulatory standards. Appendix B provides the heavy metal results for each test.

2.5 Compost Characteristics – Macro-nutrients

One purpose of the Feedstock Project was to evaluate the composts produced from the various feedstocks with regard to nutrient content. While compost does not typically have high levels of nutrient and is generally not marketed as a fertilizer; its nutritive value is essential for assessing its agronomic value and determining application rates.

Compost samples were analyzed for the three macro-nutrient nitrogen (nitrate, nitrite, ammonia, Total Kjeldhal nitrogen, and total nitrogen), phosphorus and potassium. The following bullets summarize the results. Appendix C includes a chart for each test depicting N, P and K content.

- *Nitrogen (N)* – Total nitrogen content were consistently between 1 percent and 2 percent for all tests, except Test #5 – Chicken Mortalities. (Note: Test #11 – Biosolids Day 28 had elevated nitrogen that is assumed to be due to sampling or testing error.)

- *Phosphorus (P)* – Phosphorus content was equal to or less than 1 percent for all tests.

- *Potassium (K)* – Potassium content was less than 1 percent for all tests, except for Test #2 Chicken Manure which had several results equal to or slightly greater than 1 percent. (Note: Test #2 – Chicken Manure Day 28 had elevated potassium that is assumed to be due to sampling or testing error.)

2.6 Compost Characteristics – Market Parameters

Lab analyses by TestAmerica considered several other parameters of importance for compost users: pH, percent contamination (foreign matter), and salinity (conductivity). There are no regulations regarding these parameters, however they provide important information to compost users regarding proper and acceptable uses of the compost.

It is important to note that tests were performed on samples taken during the composting process (on Days 0 [digester discharge], 10, 15, 21, and 28). No tests were performed on the finished compost, i.e., after final screening and curing. All of the parameters discussed below would likely be different in finished compost.

pH

pH is a measure of acidity/alkalinity. Neutral pH equals 7.0. pH below 7.0 is acid while a pH above 7.0 is alkaline. Slightly acid to slightly alkaline (pH between 6.0 and 8.0) is generally regarded as acceptable for compost. During active composting, pH tends to be slightly acid due to production of organic acids. pH typically then increases slightly towards the end of compost and in stable finished compost.

pH levels measured during the Project were generally within acceptable market parameter (slightly acid to slightly basic). Tests tended to be slightly acidic as would be expected for active compost. Lab results for several of the tests had pH below 6.0 (Tests #1, #4 and #9); but none had results below pH 5.0. Test #7 was distinctly alkaline with tests resulting in pH between 8.0 and 9.0. Appendix E provides a chart for each of the tests displaying pH results.

Foreign Matter

The presence of foreign matter impacts compost quality. Visible contaminants such as plastic, glass or metal not only detract from the visual quality of compost, but also may pose a hazard or nuisance to humans and the environment. Florida composting regulations (FAC 62-709) uses foreign matter as one of the criteria for classifying compost. Type A compost must have foreign matter levels that are below 2 percent and are not able to cause injury (e.g., sharp glass fragments). Type A compost is unrestricted in terms of distribution and use. All other compost classifications, which allow higher levels of foreign matter, have restriction placed on their distribution and use.

In the Feedstock Project, samples from Days 15, 21 and 28 were analyzed for foreign matter. The primary source of foreign matter was MSW. Levels ranged from negligible to 10 percent. (See Appendix D.)

Results were not consistent within tests (ie., all results for a single test being approximately the same). The most likely reason for the lack of consistent results is the composting protocol and sampling technique. Samples were taken from compost that had passed through a 2 inch screen, and relatively small amounts were analyzed. Therefore it was possible that the compost analyzed for foreign matter had relatively large contaminants in it.

Conductivity

Electrical conductivity is used to measure the level of soluble salts in compost. Salinity is an important parameter because many plants have low tolerance for soluble salts. In fact, conductivity greater than 3.0 µS/cm may be pytotoxic.

Samples from Days 21 and 28 were analyzed for specific conductivity. All tests had levels above 3.0 µS/cm, with the exception of Test #1 (Inoculant Only). Levels ranged from over 3.0 to nearly 9.0 µS/cm. These results are within the range of what would be expected for compost derived primarily from MSW. One strategy for reducing levels of soluble salts in compost is to cure and store it out of doors where the salts can be leached out by rain. Also mixing compost into soil and allowing time for natural leaching before planting with salt-sensitive plants can help.

Stability

Compost stability is an important criterion for most end uses. Stable compost has completed the biological decomposition process. Unstable compost can damage plants because the continuing decomposition process can bind essential nutrients and produce organic acids detrimental to plant germination and growth.

In order to measure stability, each of the tests was analyzed for specific oxygen uptake rate (SOUR) on Days 21 and Day 28. A low SOUR indicates that all readily biodegradable materials have been decomposed, whereas a high SOUR indicates that a significant amount of readily degradable material remains and further composting is required. In general, SOUR below 1.0 mg /gm VS/hour indicates stable compost. The following table summarizes the stability results for the tests.

Table 10 - Specific Oxygen Uptake Rate (mg/gm VS/hour)

Feedstock Test #	*Day 21*	*Day 28*
#1 Inoculant Only	3.42	
#2 Chicken Manure	4.33	29.61
#3 Chicken Manure & Biosolids	5.95	1.80
#4 Chicken Mortalities & Biosolids	3.39	1.55
#5 Chicken Mortalities	0.55	1.14
#6 Cow Manure & Biosolids	68.07	1.18
#7 Cow Manure	0.29	43.75
#8 Citrus Sludge	1.47	12.70
#9 Citrus Sludge & Biosolids	0.04	3.61
#10 Biosolids	2.39	1.27
#11 Biosolids-No Inoculant	0.05	1.28
#12 Biosolids-No Inoculant w/ Dygest506	6.84	4.43
#13 Citrus Sludge w/ Dygest506	4.48	6.62
#14 Biosolids w/ Dygest506	6.74	6.7
#15 Biosolids w/ Ortec	4.94	4.95
#16 Citrus Sludge w/ Ortec	2.87	4
#17 Biosolids-No Inoculant w/ Ortec	5.82	4.33

Based on the results, the tests were not stabilized after 28 days of windrow composting. This result is not unexpected especially given the fact that none of the tests achieved thermophillic composting in the digester and all tests were still composting at temperatures above 131ºF after 28 days in windrow. Further composting, turning and curing would be necessary before the tests would achieve stability levels acceptable for most common horticultural uses.

SECTION 3.0
SUMMARY AND CONCLUSIONS

The FORCE Feedstock Project tested a variety of different compost feedstock at the SCSWCF. The purpose of the Project was to evaluate whether these feedstocks can be successfully integrated into operations at the SCSWCF.

During the course of the Project, several operational issues at the SCSWCF led to deviations from intended operating procedures, and so the methodology used was not consistent throughout the Project. Temperatures in the digester never reached anticipated levels. Part way through the Project the digester loading protocol was changed from 4 days to 2 days of material per test. This altered the amount and depth of materials in the digester and thus may have had different affects on the composting process. Another major deviation was that the windrow turning machine was inoperable for part of the Project. These problems limited the ability to analyze and compare the tests.

Nevertheless, a number of conclusions can be made based on the available data:

- *Compostability of Additives* – The Project demonstrated that all of the additives can be composted at as part of a MSW composting operation. Although problems were encountered, all of the tests achieved sustained thermophillic composting, and the lab analyses indicated that resulting finished compost would meet the fundamental requirements for general distribution and use.

- *C:N Ratio* – It is likely that most of the recipes did not have sufficient nitrogen to promote rapid composting, i.e. greater than 30:1. Therefore higher amounts of additives not only would be possible, but actually necessary to achieve optimum conditions.

- *Digester Temperature* – Based on the available data, it is not possible to determine why temperatures in the digester did not achieve 131ºF. A number of factors could have contributed to this problem. The most likely causal factors are high C:N ratio, over aeration, and insufficient depth of compost. A series of diagnostic batches and ultimately "recharging" of the digester may have rectified this problem.

- *Windrow Temperature & Compost Stability* – All of the tests were still at temperatures above 147ºF or greater for all tests when they were completed, removed from windrow and screened. Thus the tests had not yet completed thermophillic composting and were not yet stabilized. Therefore windrow composting would need to continue for more than 28 days. Based on the results, it is not possible to determine how much additional time would be needed to complete composting.

- *Pathogen Reduction* – As indicated by fecal coliform results, a number of the tests did not achieve pathogen reduction standards. Temperatures were not met in the digester. And subsequently in windrows, none of the tests complied with process standards (time, temperature and turnings) sufficient to achieve pathogen reduction standards. So while it is very likely that the initial protocol would have achieved acceptable pathogen reduction, the results are insufficient to make such a conclusion.

- *Heavy metal content* – The lab results clearly demonstrate that Sumter County's MSW and all of the additives contain very low levels of regulated heavy metals. The results fall well below the most stringent regulatory standards in Florida.

- *Macro-nutrients* – lab results suggest that compost produced from the recipes tested by this Project would have low nutritive value with N-P-K analysis at 1-2 percent nitrogen and less than 1 percent phosphorus and potassium. These results are comparable to what would be expected for compost produced from these feedstocks. And compost's ultimate value is focused as much on its agronomic and horticultural benefit as its low nutrient value.

- *Market-based parameters* – The compost produced in the tests was assessed in terms of several market-based criteria. In general, the compost produced had acceptable pH; had elevated soluble salts that may require some further management or restricted use; had high levels of foreign matter that would likely be removed in final screening; and was instable and needing further active composting and curing prior to use.

SECTION 4.0
RECOMMENDATIONS FOR SUBSEQUENT RESEARCH

When FORCE conducts composting trials in the future, several issues should be addressed in order to improve operations and increase the quantity/quality of data, and thus enhance the value of the research. These recommendations concern the protocol and procedures for such projects and not the types of trials that might be conducted.

Recipe Formulation and Tracking

Future composting research should utilize recipes that are directly based on feedstock characteristics, instead of generic recipes like those used for this Project. FORCE should require that feedstocks be first analyzed, and the results used to formulate recipes and finalize the research protocol. Also, future research should look at varying combinations of the same feedstocks; for example a trial that compares three different mixtures (e.g., 20 percent, 40 percent and 60 percent) of a single feedstock. This type of research can yield more information than a single trial of a given feedstock or additive. Lastly, the actual quantities used in trials needs to be accurately tracked. By tracking accurate, actual feedstock data FORCE will help improve the ability for others to adapt research results at other composting technologies and facilities.

Digester Operations

Future FORCE feedstock trials that use the digester should focus on large volumes of high moisture and nitrogen (i.e., difficult to manage) organic materials such as food processing residuals, industrial sludges, biosolids, and mortalities. The digester is designed for continuous operations. If tests are to be conducted in the digester, they should be conducted using continuous loading and the 200 ton per day design capacity of the digester. Given the comparatively high operating cost of the digester technology it is inappropriate to utilize it for handling feedstocks that can be more economically handled by less costly technologies.

The digester is not suited for small batch experiments. Smaller tests may be conducted cost effectively using different technologies such as static pile, windrow, and small in-vessel.

Extended Monitoring

Based on the Project Methodology, the composting process and compost characteristics were monitored for only 28 days of windrow composting. As a result no data were obtained for screened, cured, or finished compost; nor is it known how long it actually would take to produce stable and mature compost from these trials. Such information would ultimately be valuable to Sumter County and the Florida organics recycling community. Therefore, monitoring of future FORCE feedstock trials should be extended through the entire process (unless the research objectives clearly indicate otherwise). For example, data on temperature, volatile solids, SOUR, and pH tracked over 90 to 120 days may yield valuable insights. And ultimately, once finished compost is produced, analysis of its characteristics would help in assessing its marketability.

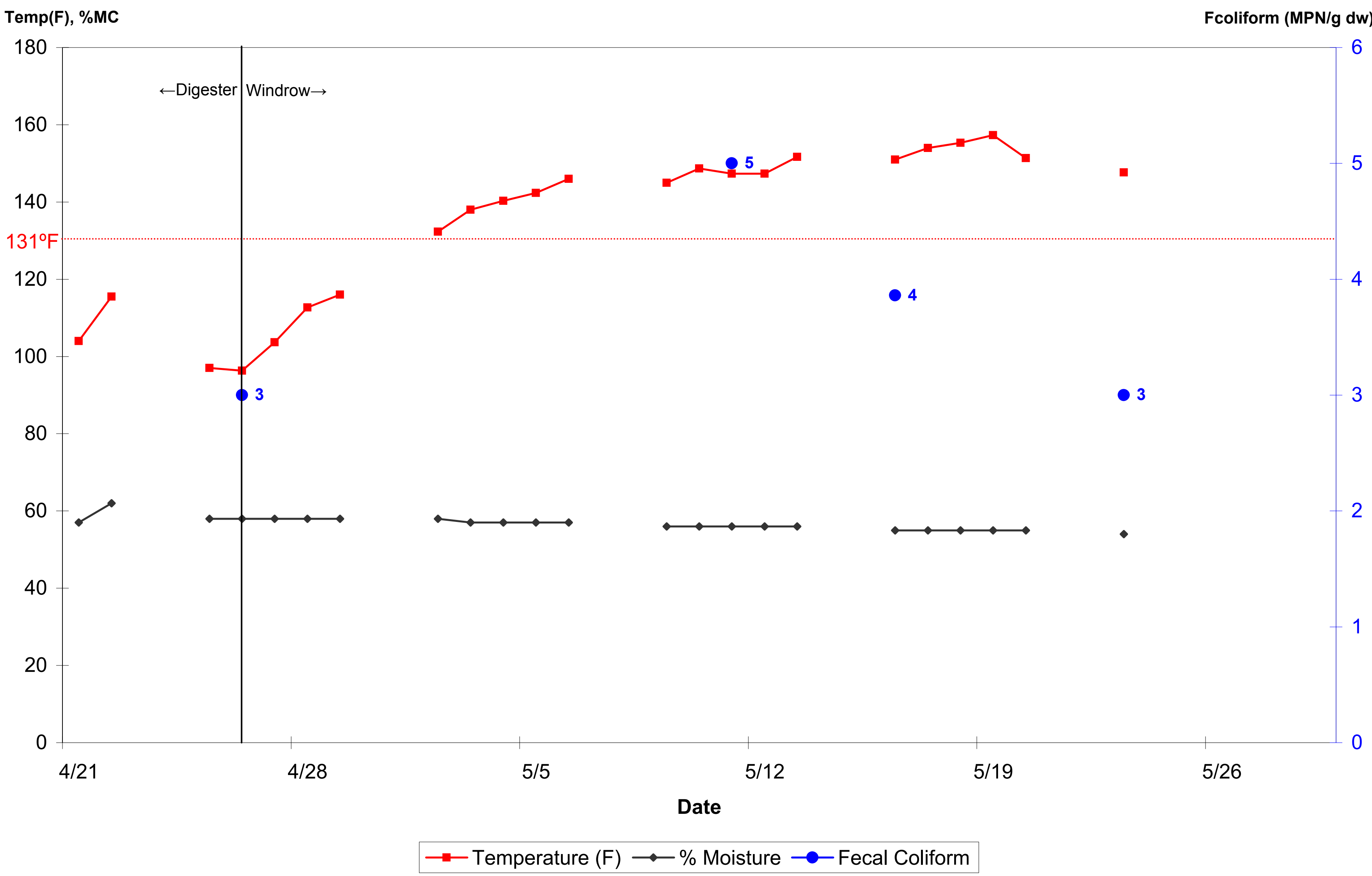
Laboratory Testing

When future research is conducted, the laboratory procedures should be reviewed and modified to ensure they conform to best practices as defined in the United States Composting Council's Testing Methods for the Examination of Composting and Compost (TMECC). Procedures should include duplicate sampling as well as blind testing of known material so that it may be possible to assess the level of confidence one can have in the results. In addition, it is recommended that lab analyses be conducted by a facility that has extensive experience with compost.

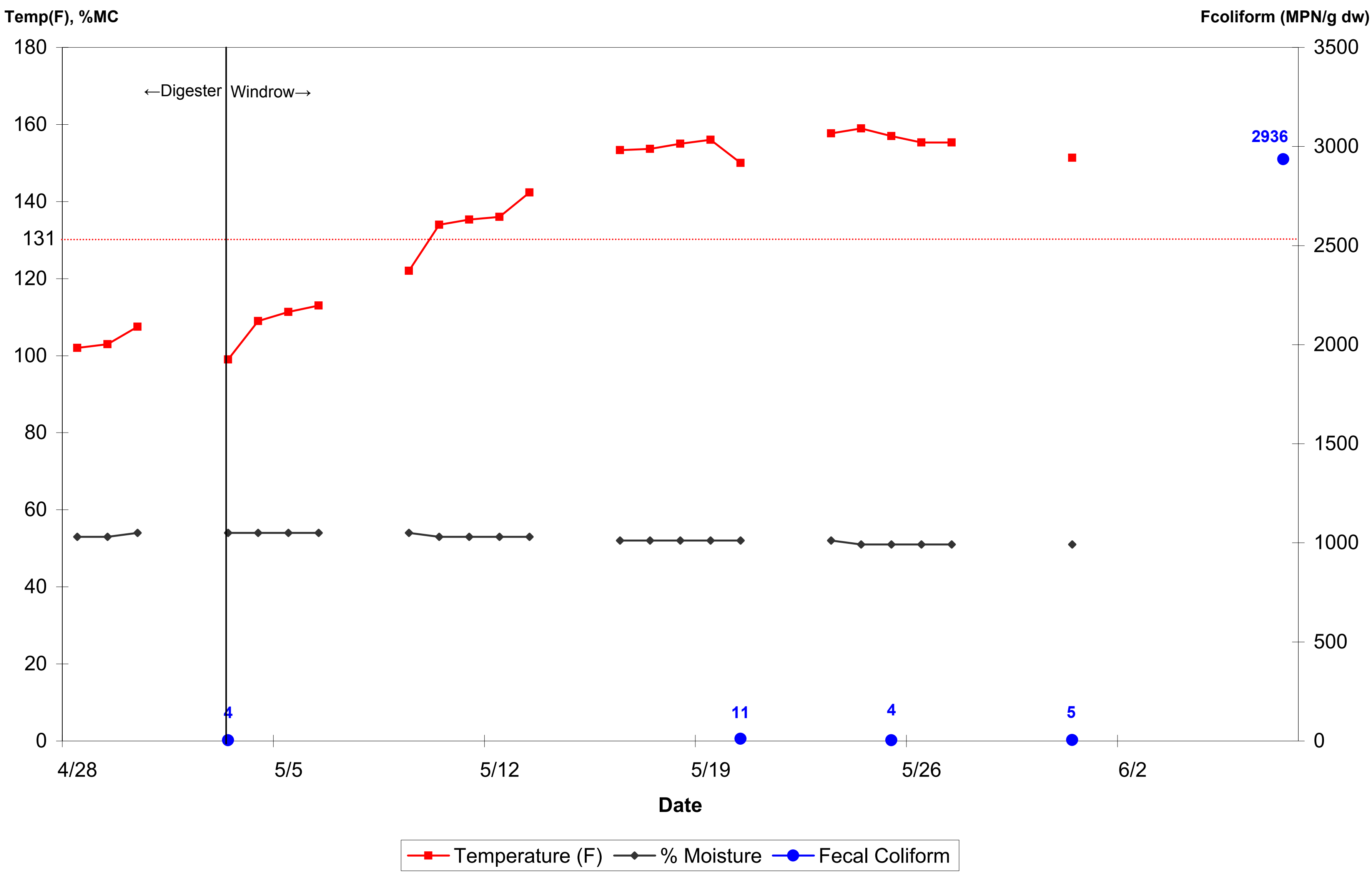
APPENDIX A

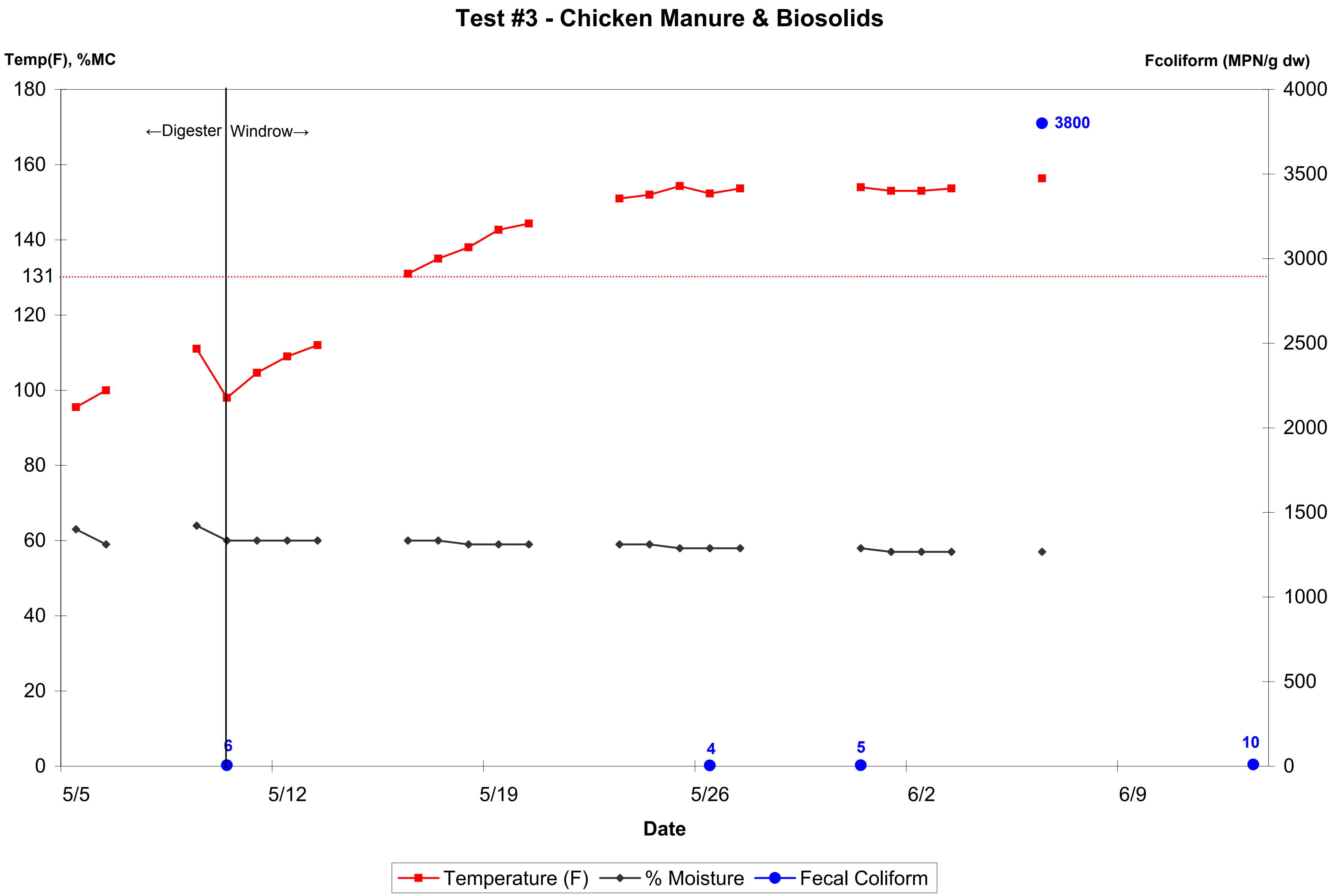
COMPOST PROCESS CHARTS

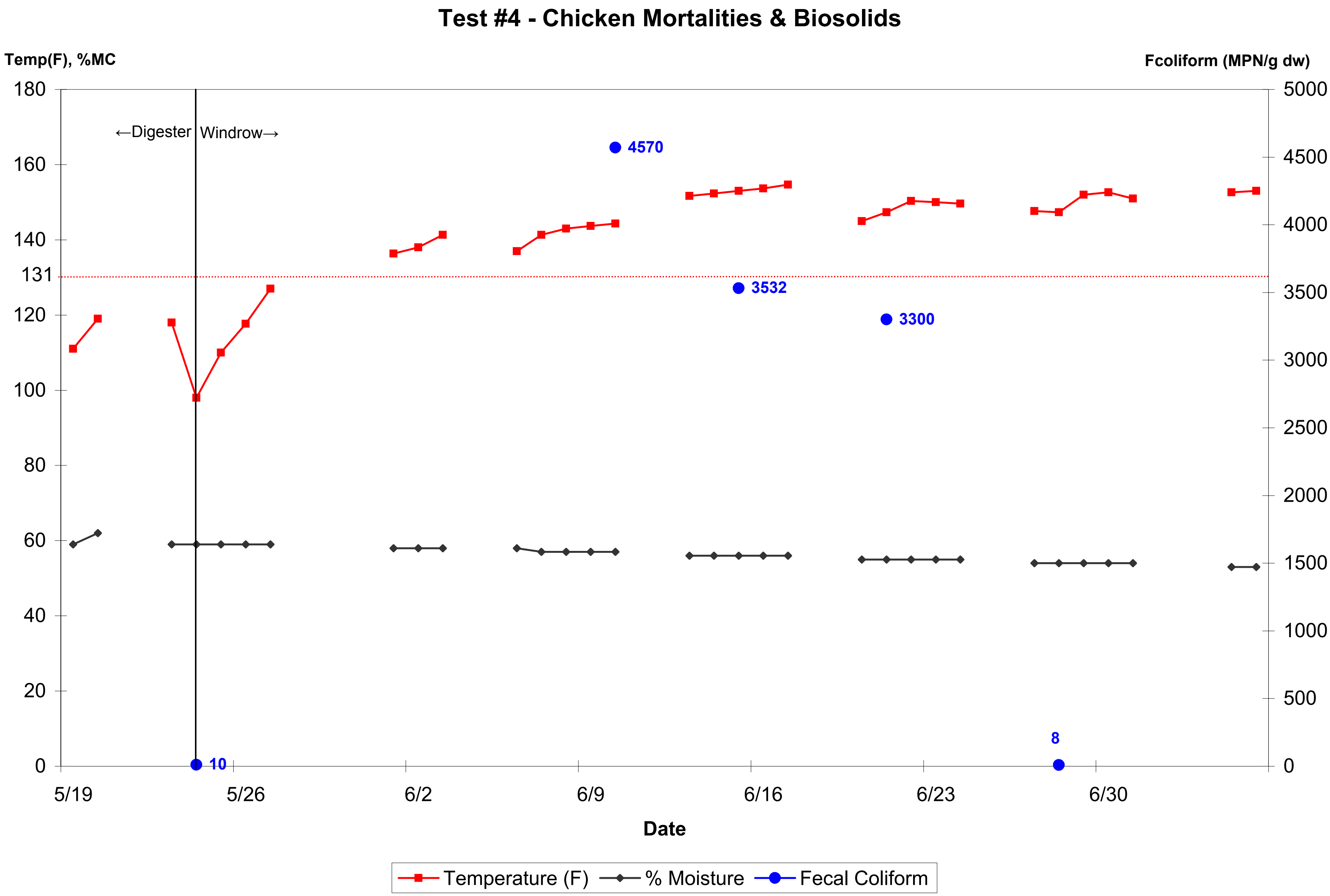
Test #1 - Inoculant Only

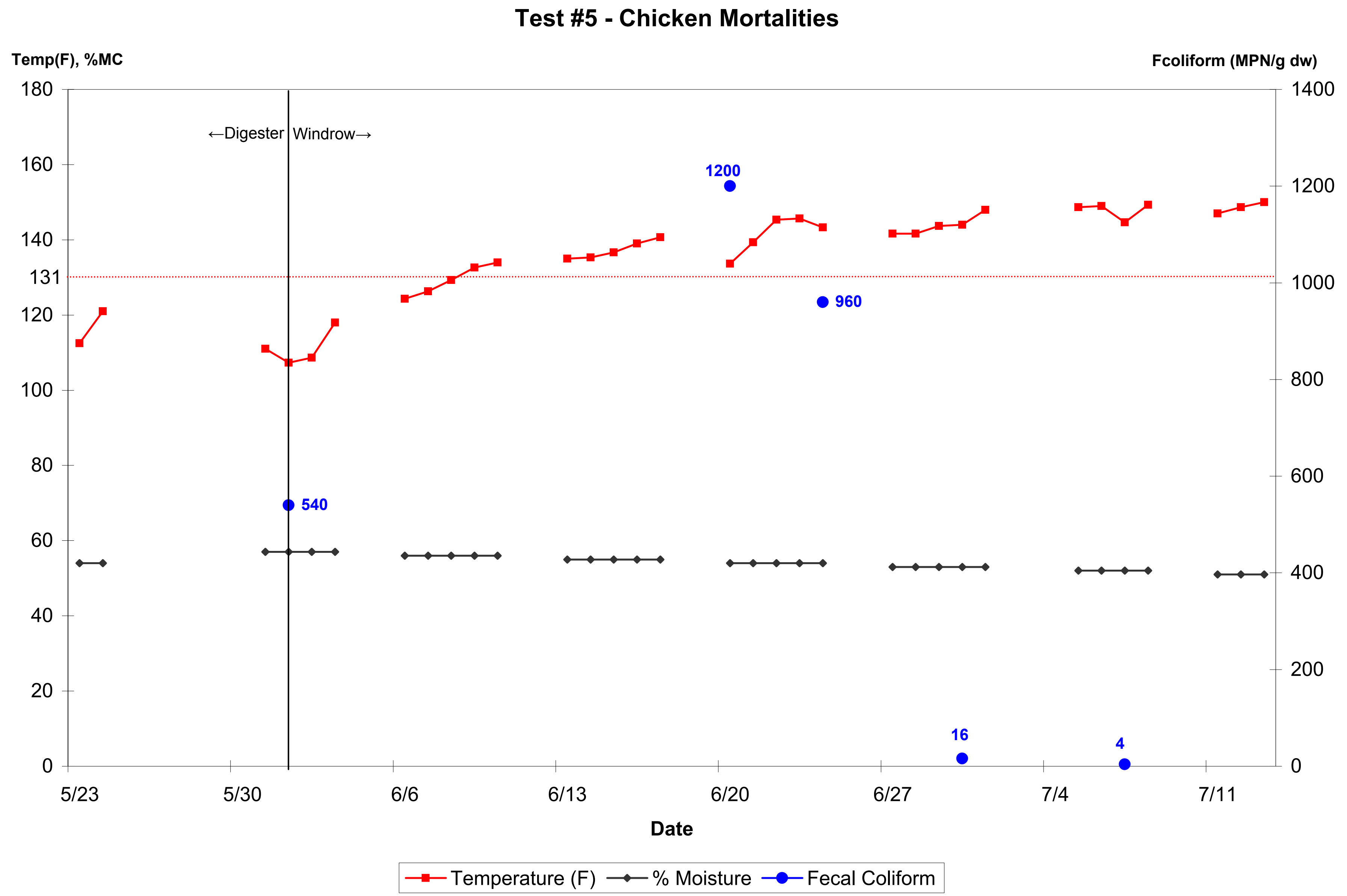


Test #2 - Chicken Manure

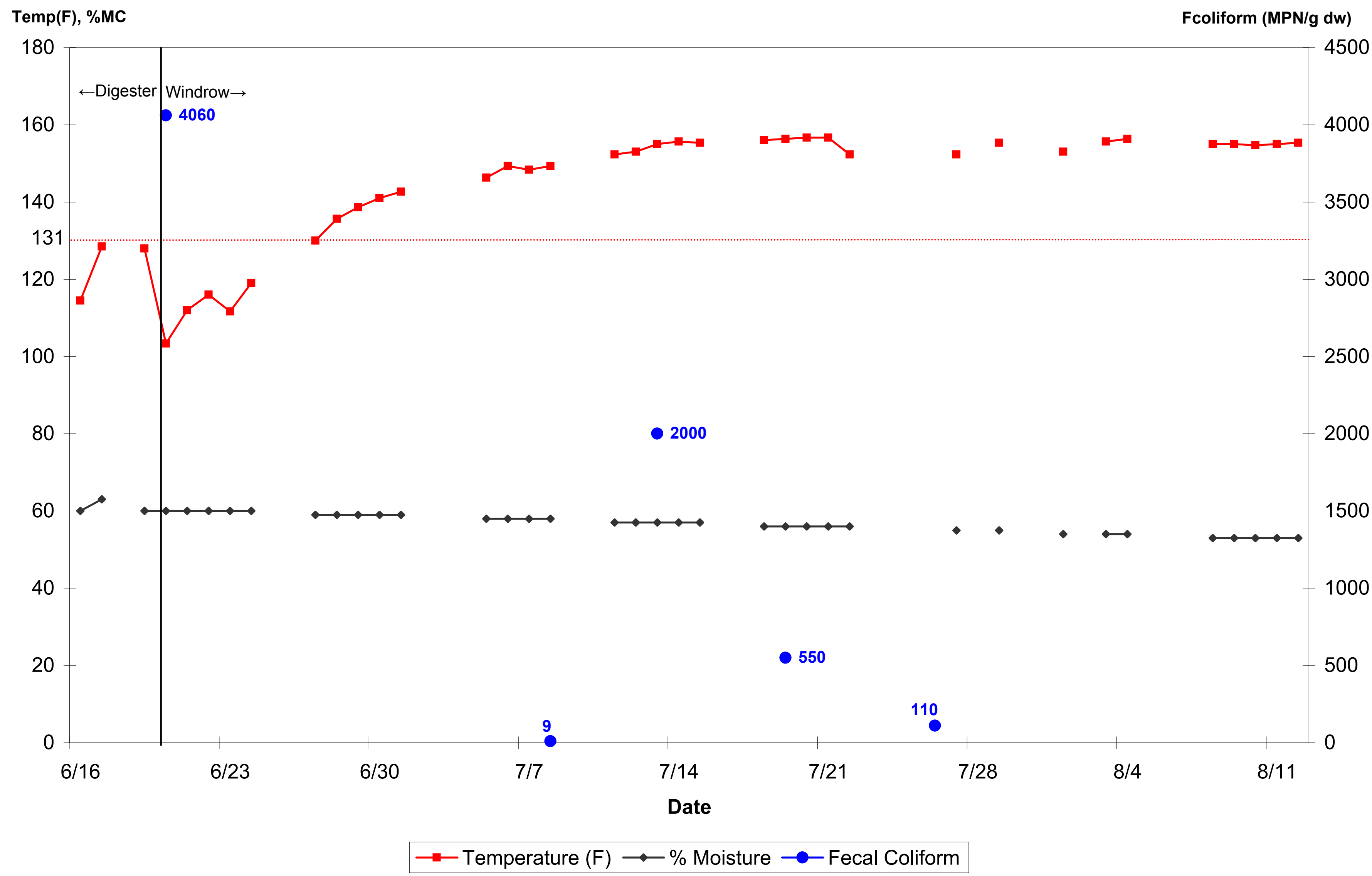


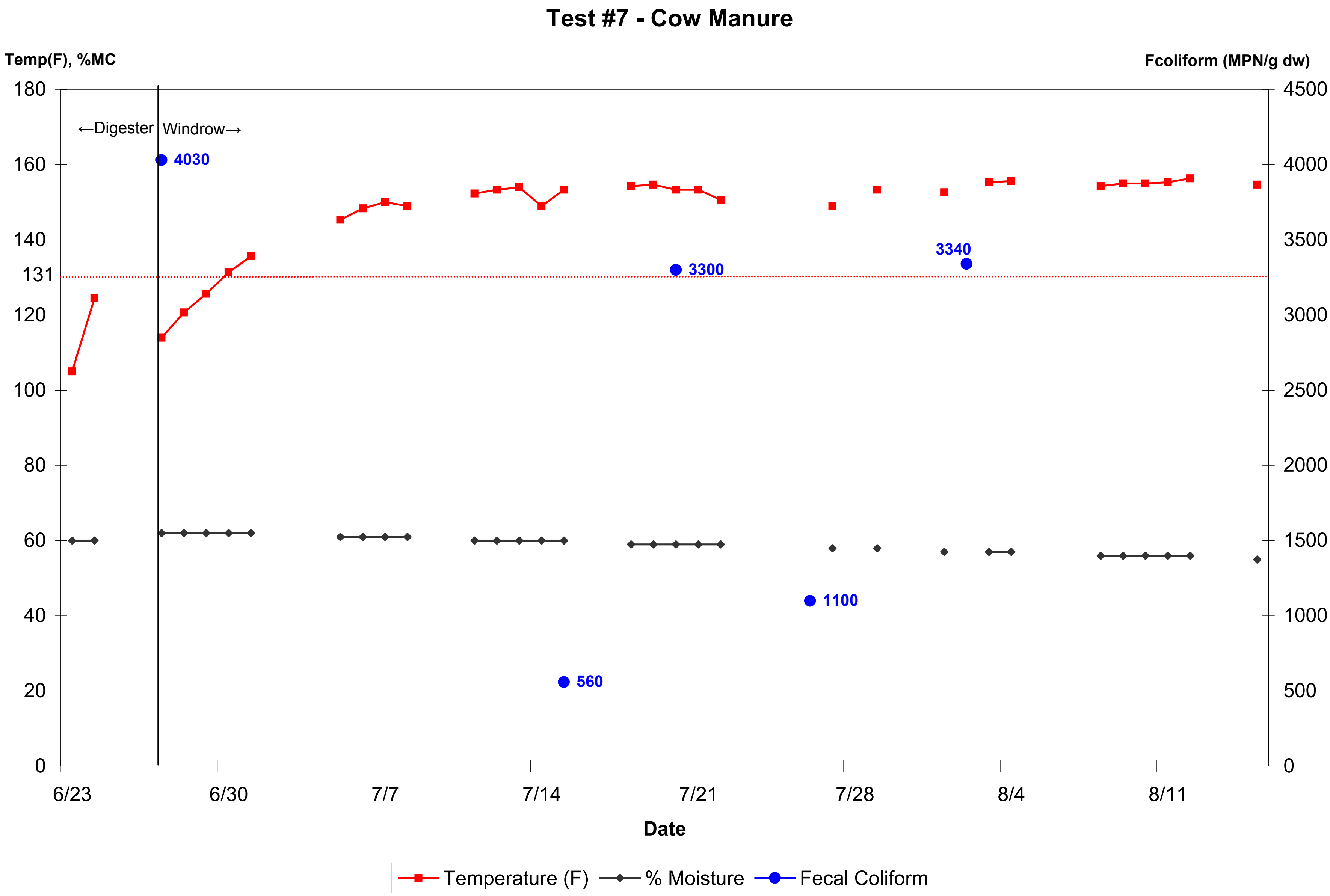

Test #3 - Chicken Manure & Biosolids
Temp(F), %MC
Fcoliform (MPN/g dw)
180
160
140
131
120
100
80
60
40
20
0
4000
3500
3000
2500
2000
1500
1000
500
0
←Digester
Windrow→
3800
6
4
5
10
5/5
5/12
5/19
5/26
6/2
6/9
Date
Temperature (F)
% Moisture
Fecal Coliform

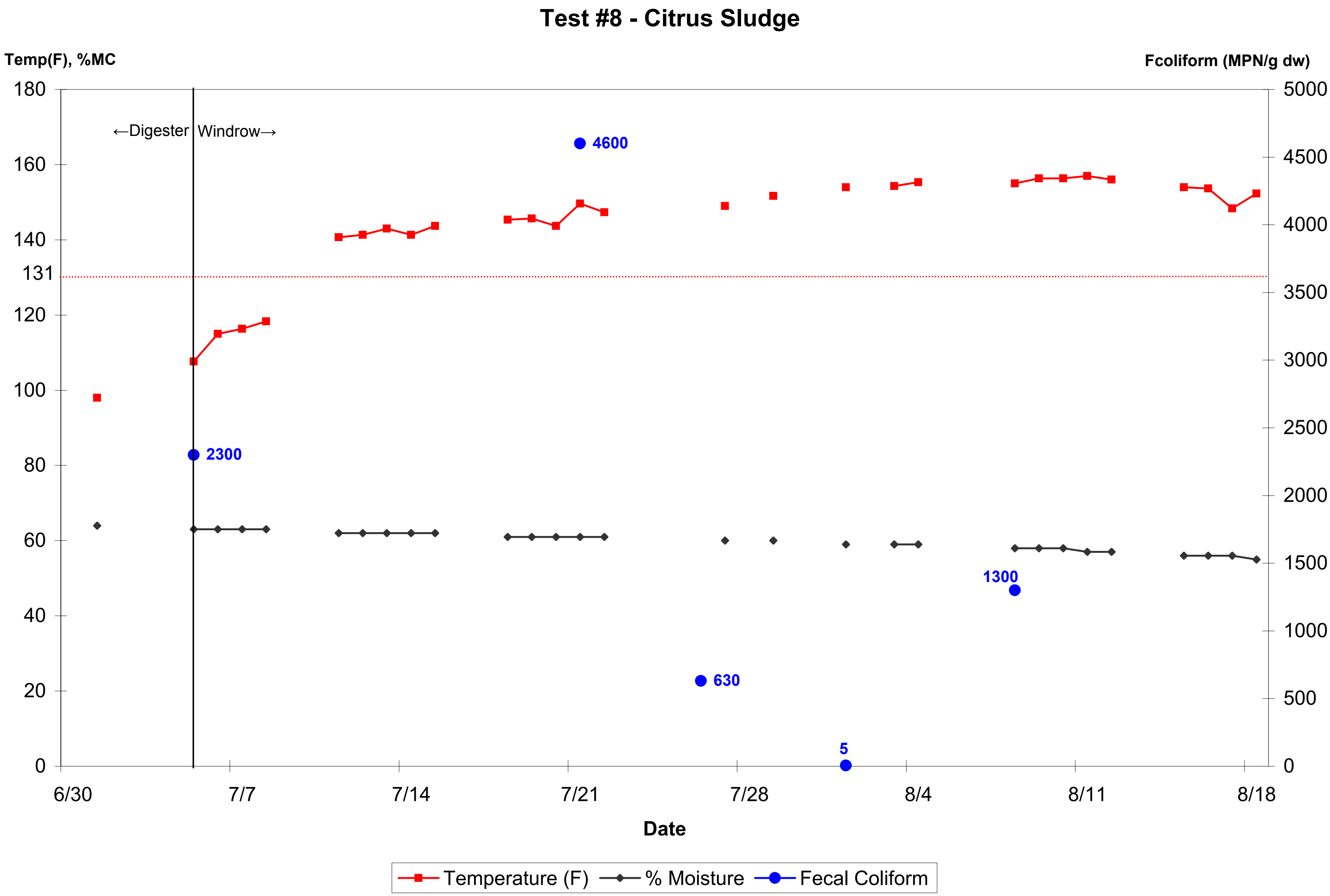

Test #4 - Chicken Mortalities & Biosolids
Temp(F), %MC
Fcoliform (MPN/g dw)
←Digester
Windrow→
4570
3532
3300
10
8
180
160
140
131
120
100
80
60
40
20
0
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
5/19
5/26
6/2
6/9
6/16
6/23
6/30
Date
Temperature (F)
% Moisture
Fecal Coliform

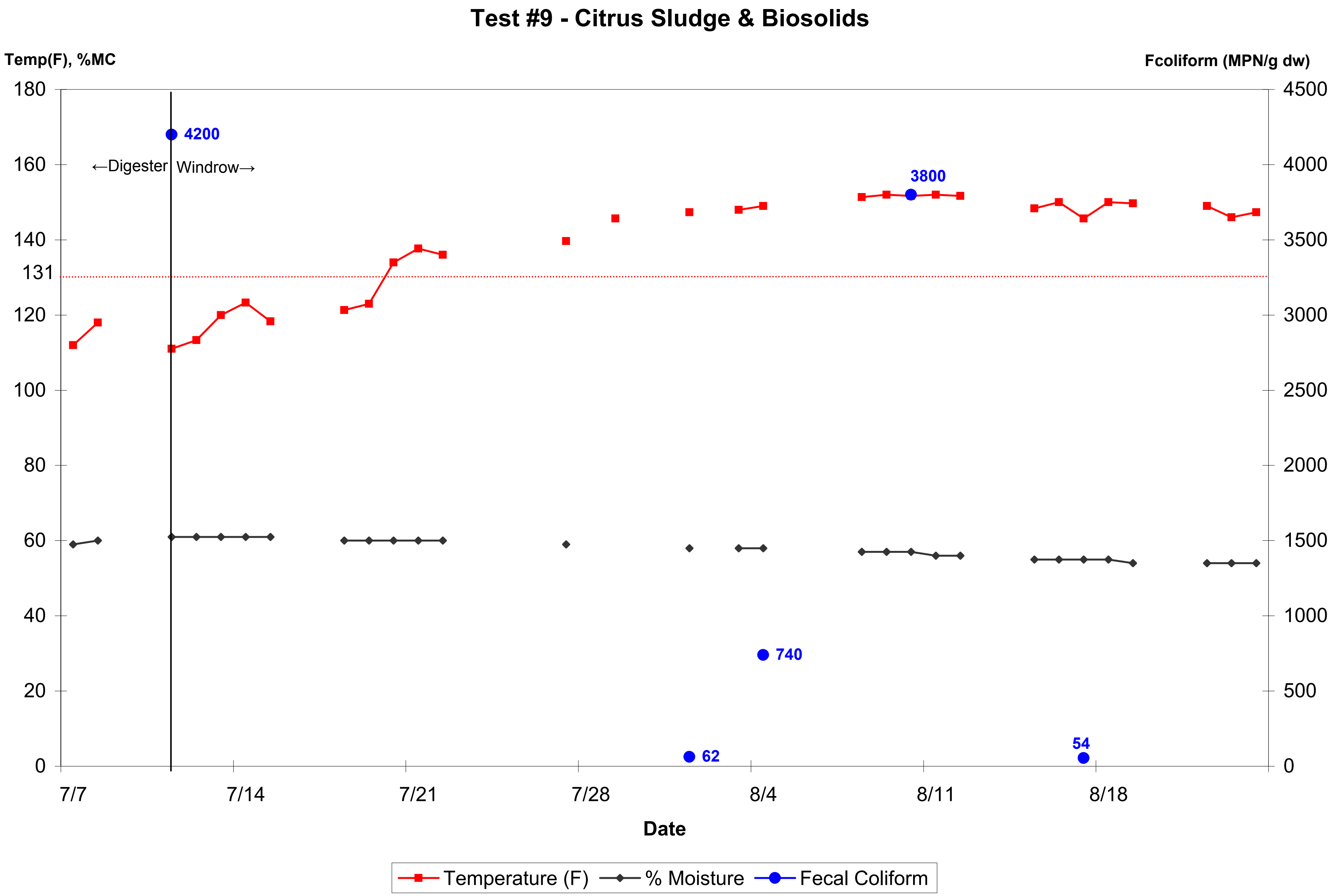

Test #5 - Chicken Mortalities
Temp(F), %MC
Fcoliform (MPN/g dw)
←Digester
Windrow→
180
160
140
131
120
100
80
60
40
20
0
1400
1200
1000
800
600
400
200
0
1200
960
540
16
4
5/23
5/30
6/6
6/13
6/20
6/27
7/4
7/11
Date
Temperature (F)
% Moisture
Fecal Coliform

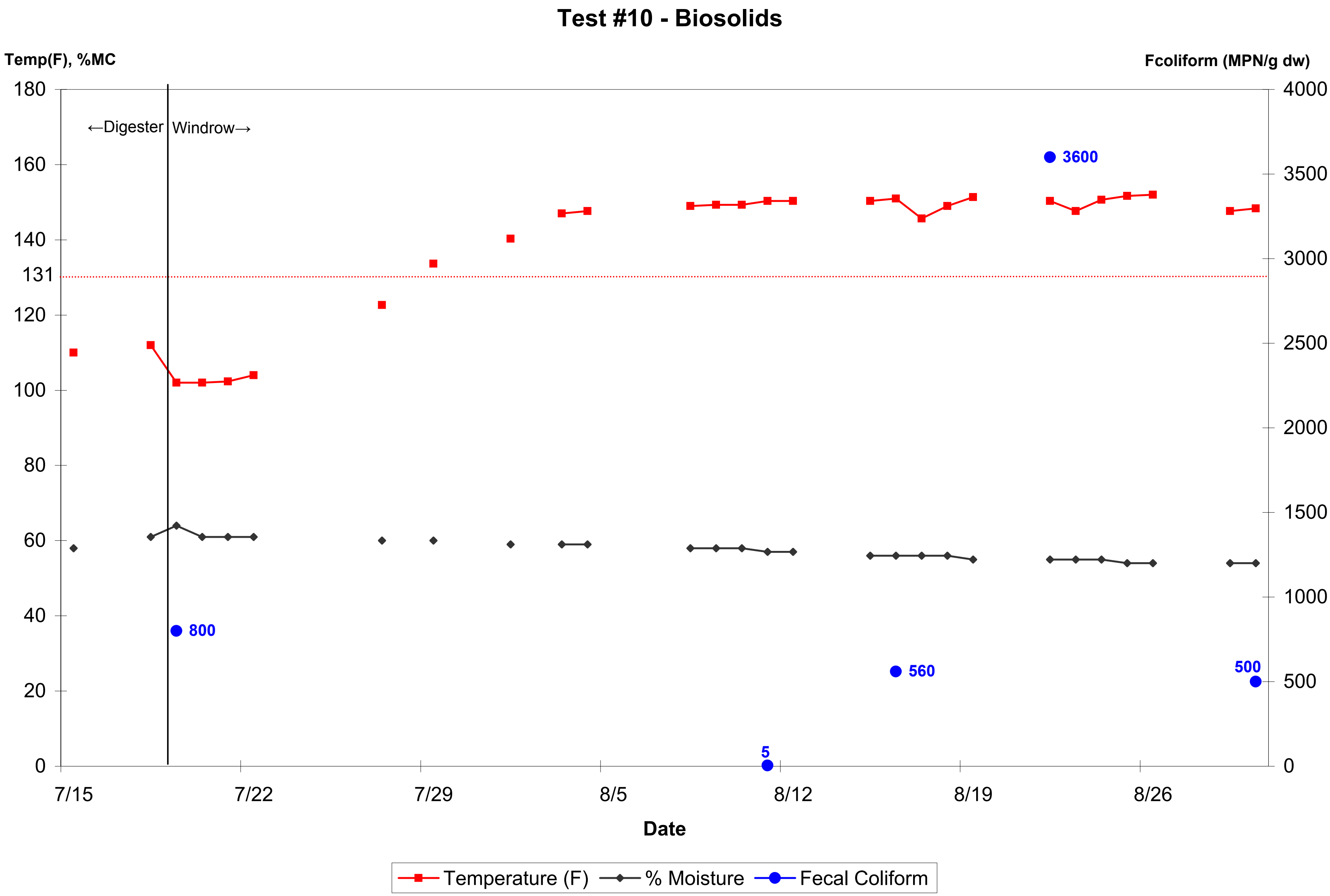
Test #6 - Cow Manure & Biosolids

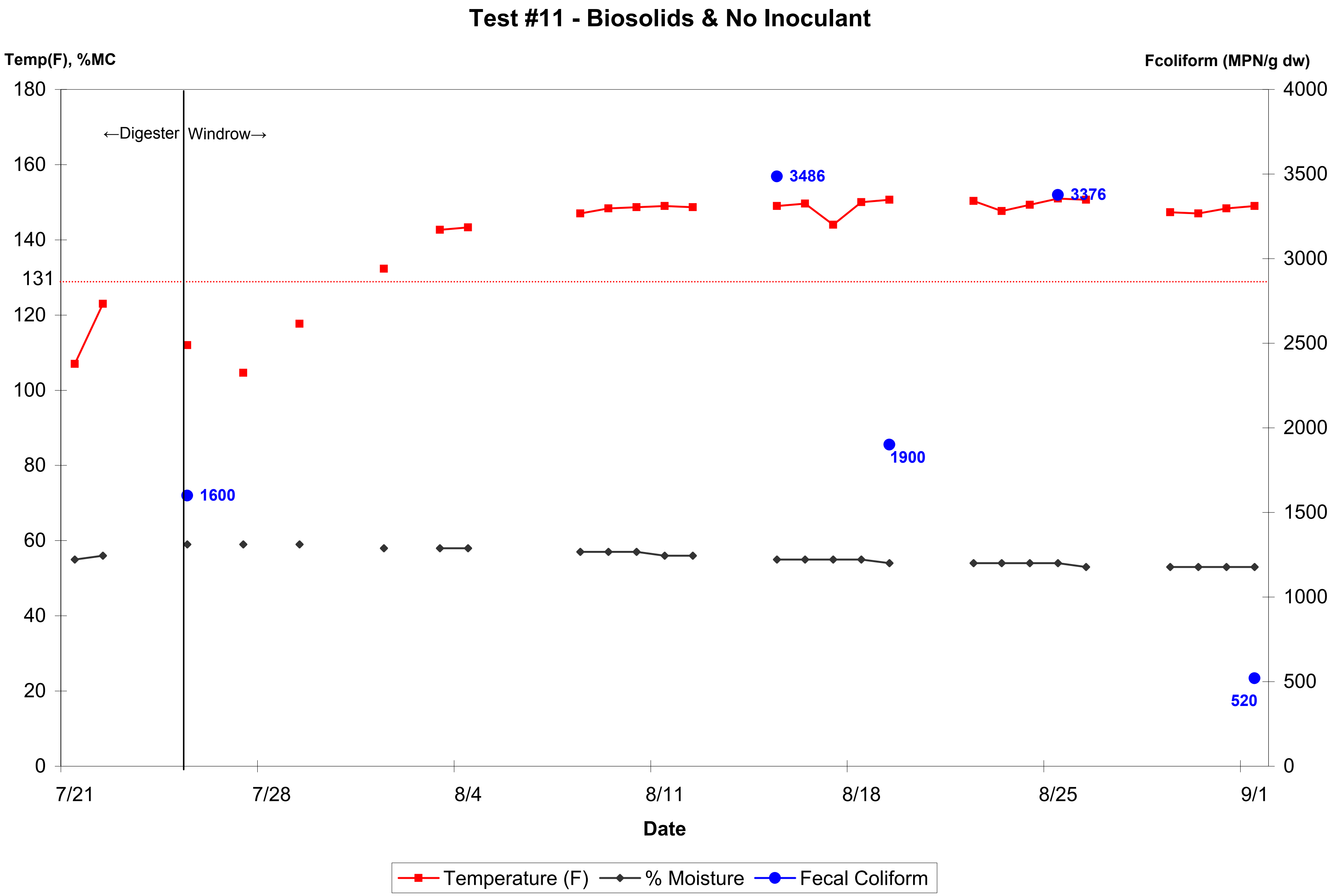


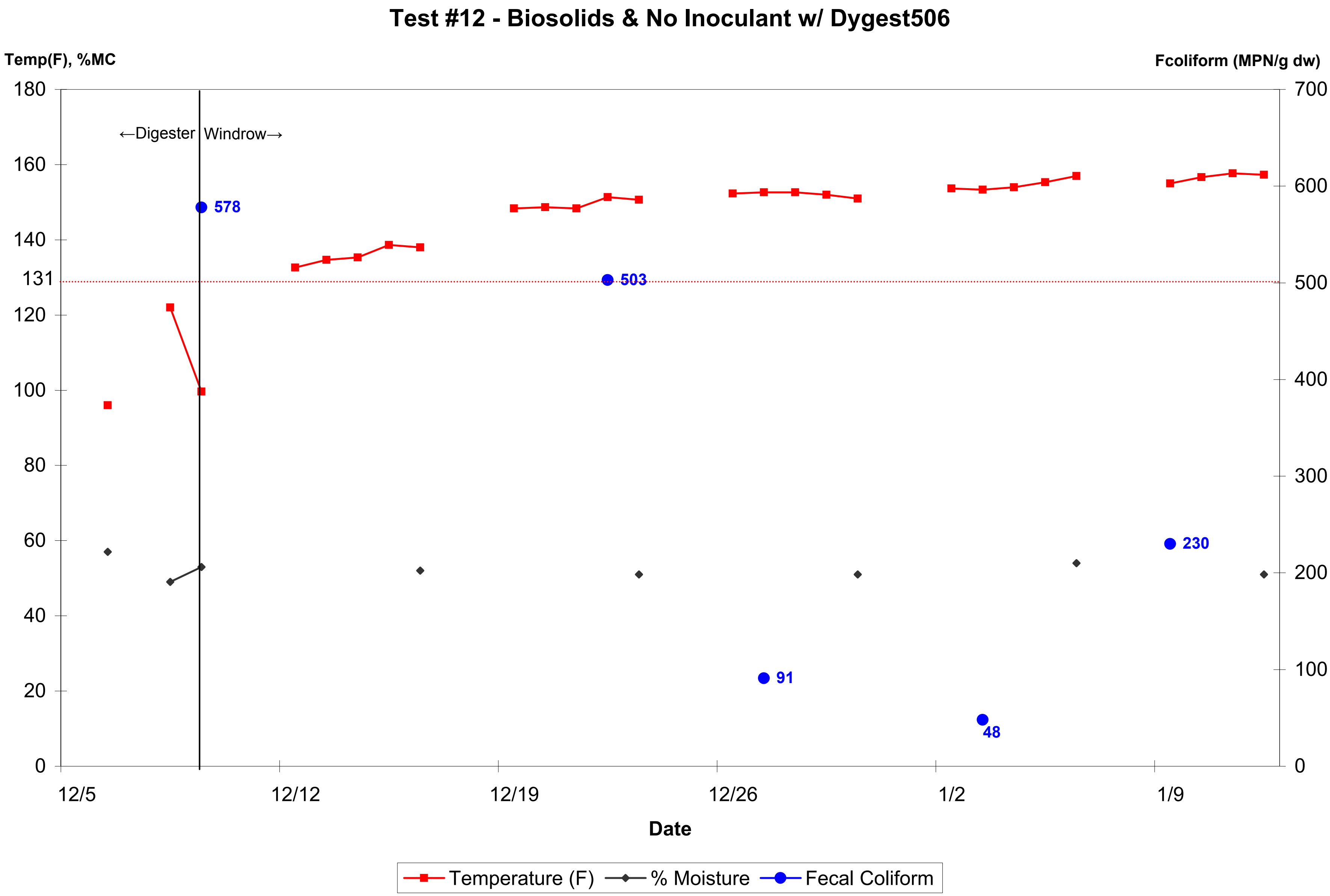

Test #7 - Cow Manure
Temp(F), %MC
Fcoliform (MPN/g dw)
←Digester
Windrow→
4030
3300
3340
1100
560
180
160
140
131
120
100
80
60
40
20
0
4500
4000
3500
3000
2500
2000
1500
1000
500
0
6/23
6/30
7/7
7/14
7/21
7/28
8/4
8/11
Date
Temperature (F)
% Moisture
Fecal Coliform


Test #8 - Citrus Sludge
Temp(F), %MC
Fcoliform (MPN/g dw)
180
160
140
131
120
100
80
60
40
20
0
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
←Digester
Windrow→
4600
2300
1300
630
5
6/30
7/7
7/14
7/21
7/28
8/4
8/11
8/18
Date
Temperature (F)
% Moisture
Fecal Coliform


Test #9 - Citrus Sludge & Biosolids
Temp(F), %MC
Fcoliform (MPN/g dw)
180
160
140
131
120
100
80
60
40
20
0
4500
4000
3500
3000
2500
2000
1500
1000
500
0
←Digester
Windrow→
4200
3800
740
62
54
7/7
7/14
7/21
7/28
8/4
8/11
8/18
Date
Temperature (F)
% Moisture
Fecal Coliform


Test #10 - Biosolids
Temp(F), %MC
Fcoliform (MPN/g dw)
180
160
140
131
120
100
80
60
40
20
0
4000
3500
3000
2500
2000
1500
1000
500
0
←Digester
Windrow→
3600
800
560
500
5
7/15
7/22
7/29
8/5
8/12
8/19
8/26
Date
Temperature (F)
% Moisture
Fecal Coliform


Test #11 - Biosolids & No Inoculant
Temp(F), %MC
Fcoliform (MPN/g dw)
180
160
140
131
120
100
80
60
40
20
0
4000
3500
3000
2500
2000
1500
1000
500
0
←Digester
Windrow→
3486
3376
1900
1600
520
7/21
7/28
8/4
8/11
8/18
8/25
9/1
Date
Temperature (F)
% Moisture
Fecal Coliform


Test #12 - Biosolids & No Inoculant w/ Dygest506
Temp(F), %MC
Fcoliform (MPN/g dw)
180
160
140
131
120
100
80
60
40
20
0
700
600
500
400
300
200
100
0
←Digester
Windrow→
578
503
91
48
230
12/5
12/12
12/19
12/26
1/2
1/9
Date
Temperature (F)
% Moisture
Fecal Coliform

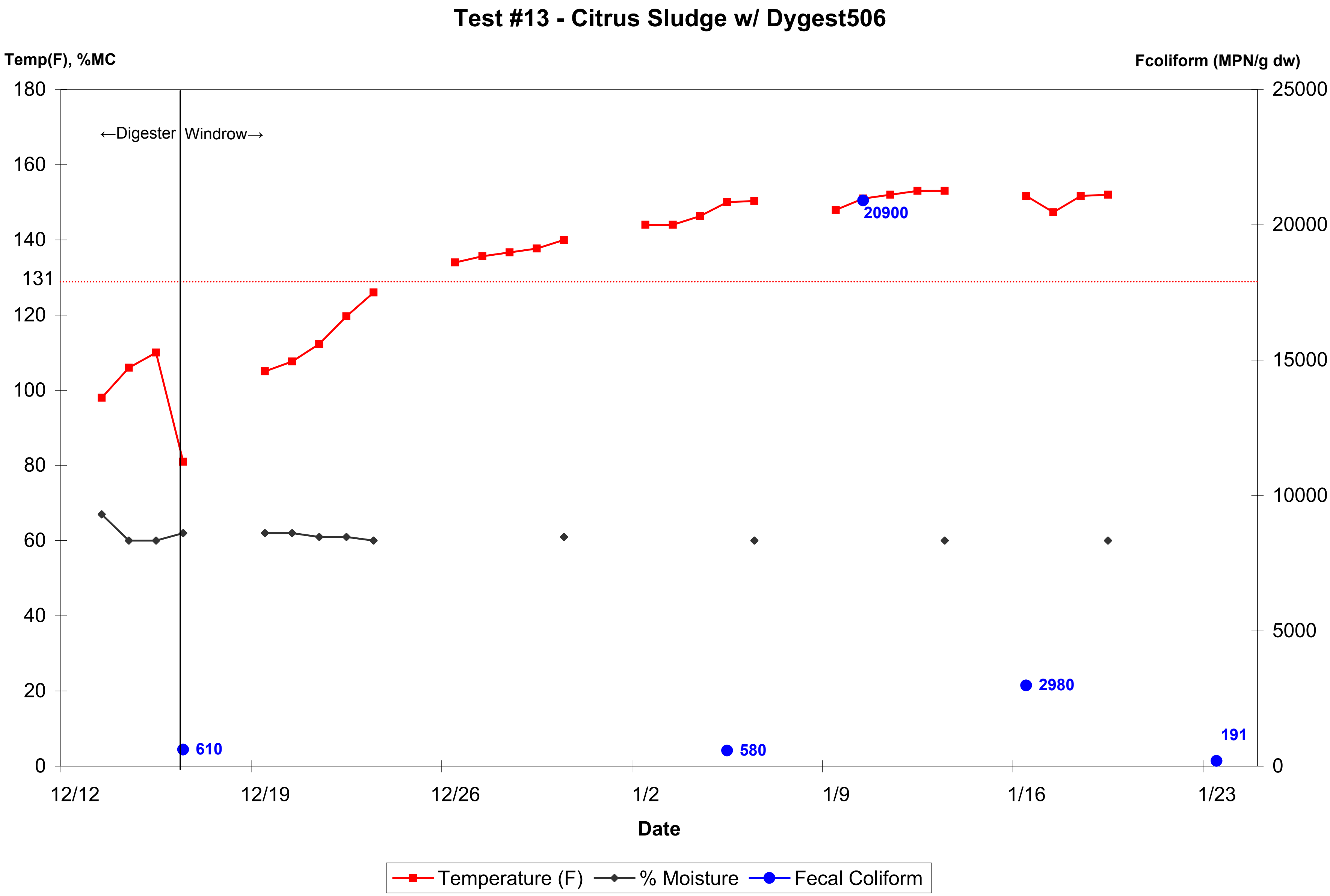
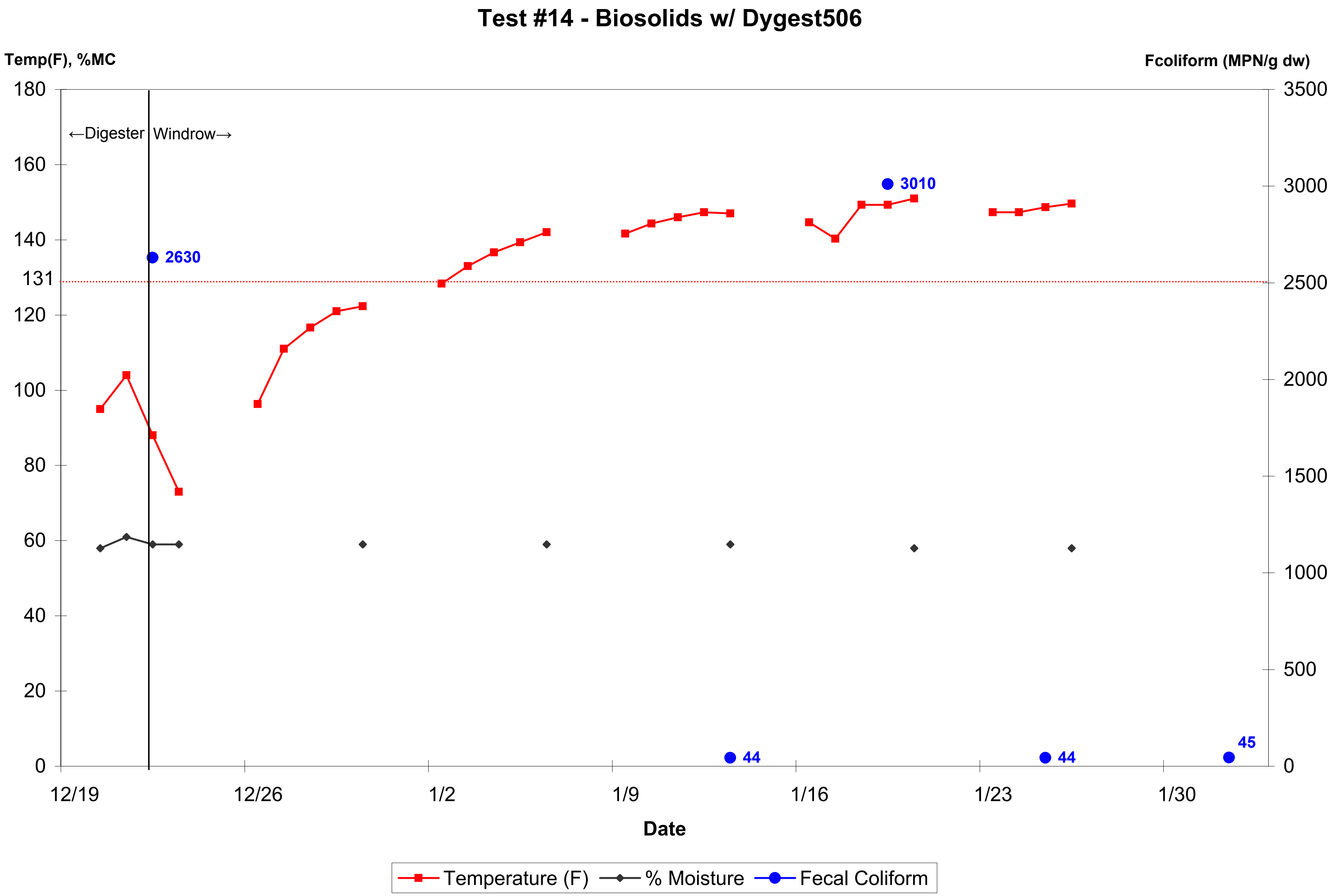
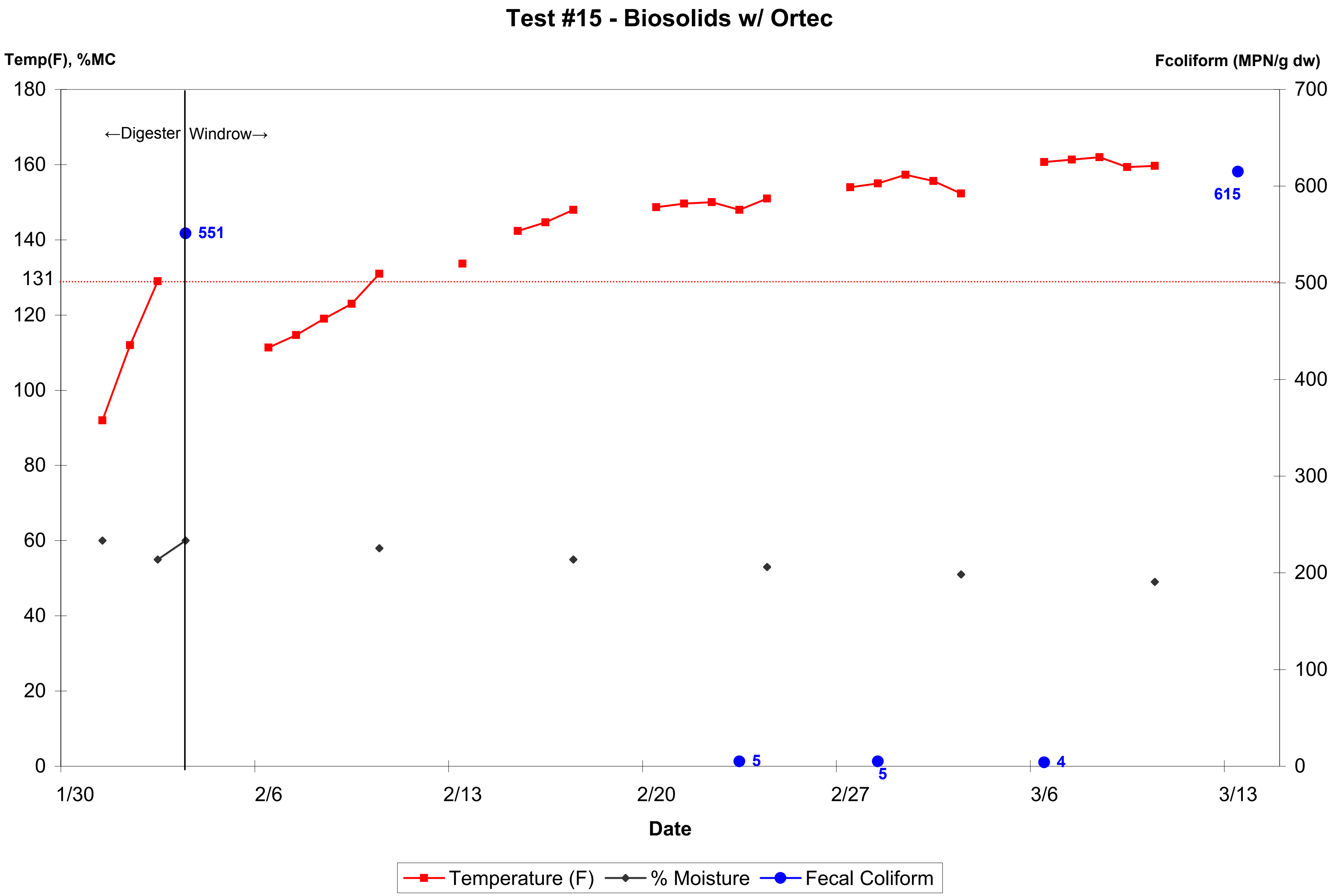
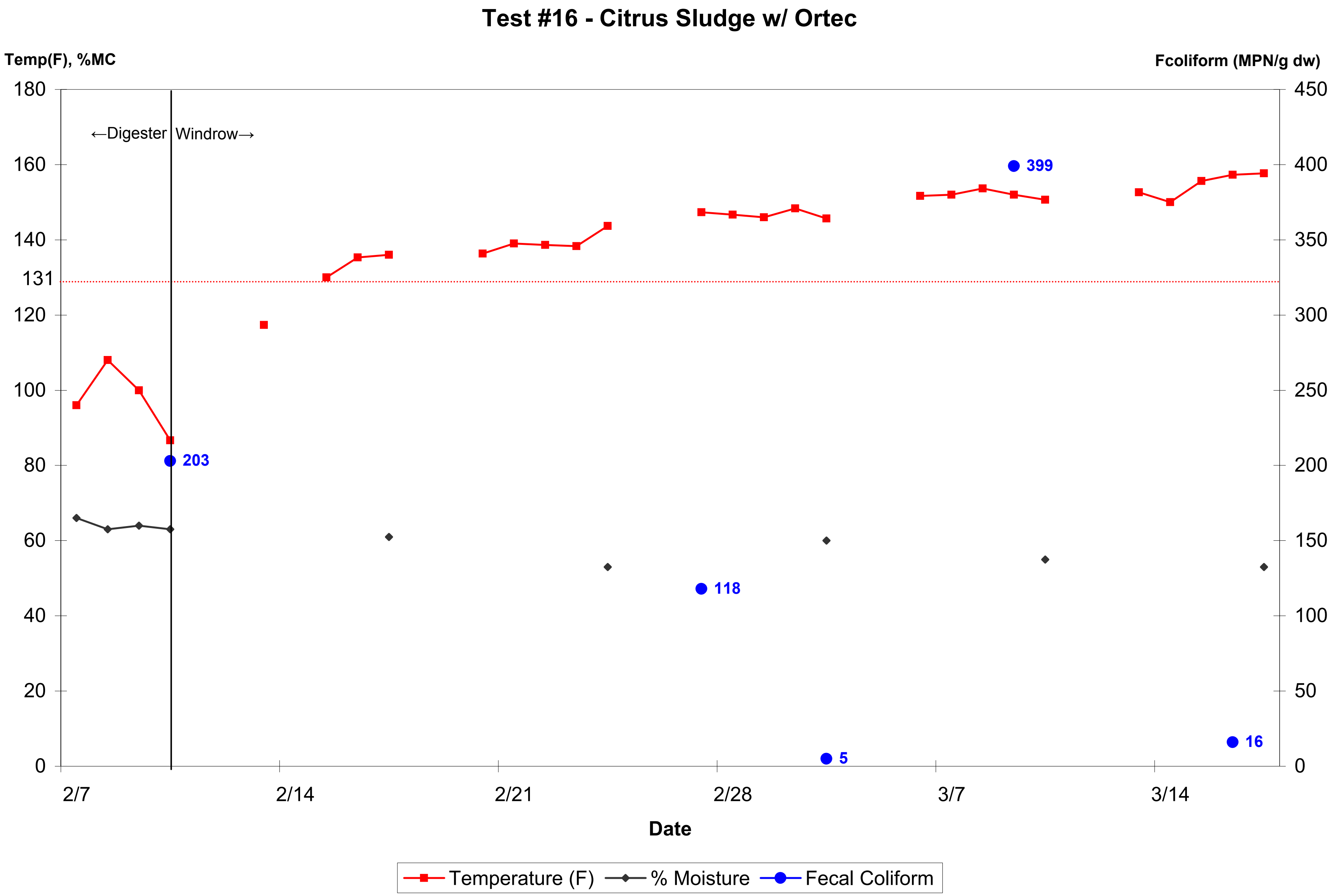
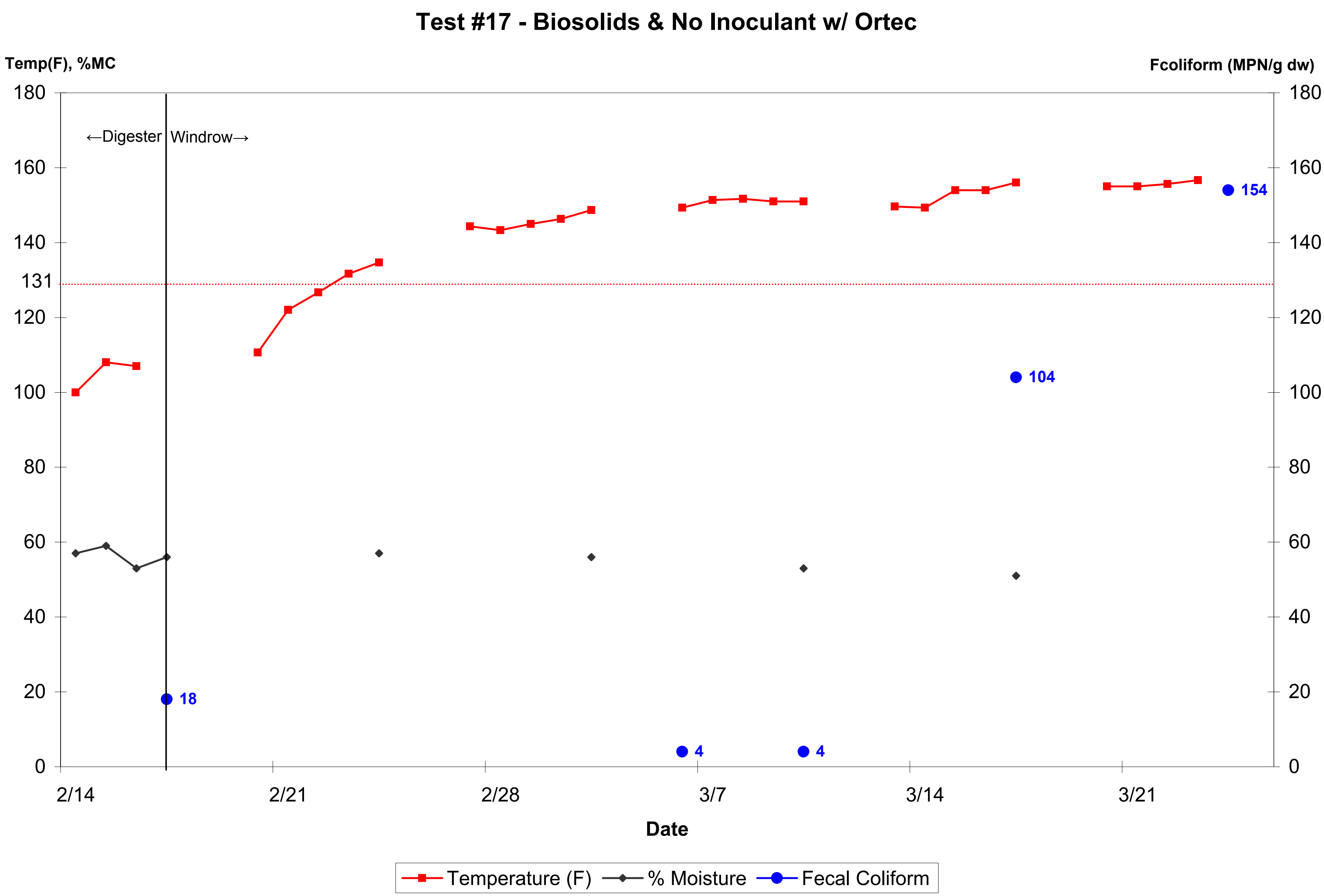

Test #13 - Citrus Sludge w/ Dygest506
Temp(F), %MC
Fcoliform (MPN/g dw)
180
160
140
131
120
100
80
60
40
20
0
25000
20000
15000
10000
5000
0
←Digester
Windrow→
20900
610
580
2980
191
12/12
12/19
12/26
1/2
1/9
1/16
1/23
Date
Temperature (F)
% Moisture
Fecal Coliform

Chart 13


Test #14 - Biosolids w/ Dygest506
Temp(F), %MC
Fcoliform (MPN/g dw)
180
160
140
131
120
100
80
60
40
20
0
3500
3000
2500
2000
1500
1000
500
0
←Digester
Windrow→
2630
3010
44
44
45
12/19
12/26
1/2
1/9
1/16
1/23
1/30
Date
Temperature (F)
% Moisture
Fecal Coliform


Test #15 - Biosolids w/ Ortec
Temp(F), %MC
Fcoliform (MPN/g dw)
180
160
140
131
120
100
80
60
40
20
0
700
600
500
400
300
200
100
0
←Digester
Windrow→
551
615
5
5
4
1/30
2/6
2/13
2/20
2/27
3/6
3/13
Date
Temperature (F)
% Moisture
Fecal Coliform


Test #16 - Citrus Sludge w/ Ortec
Temp(F), %MC
Fcoliform (MPN/g dw)
180
160
140
131
120
100
80
60
40
20
0
450
400
350
300
250
200
150
100
50
0
←Digester
Windrow→
399
203
118
5
16
2/7
2/14
2/21
2/28
3/7
3/14
Date
Temperature (F)
% Moisture
Fecal Coliform


Test #17 - Biosolids & No Inoculant w/ Ortec
Temp(F), %MC
Fcoliform (MPN/g dw)
←Digester
Windrow→
180
160
140
131
120
100
80
60
40
20
0
18
4
4
104
154
2/14
2/21
2/28
3/7
3/14
3/21
Date
Temperature (F)
% Moisture
Fecal Coliform

APPENDIX B

RESULTS OF TESTAMERICA LAB ANALYSES FOR HEAVY METALS

Test #1 - Innoculant Only

Parameter	Units	Discharge	Day 10	Day 15	Day 21	Day 28
		0	10	15	21	28
Arsenic	mg/kg dw	0.834	0.761	0.644	0.66	
Cadmium	mg/kg dw	0.634	0.777	0.543	0.552	
Chromium	mg/kg dw	12.8	14.1	15.8	11.7	
Copper	mg/kg dw	75	94.1	93	60.1	
Lead	mg/kg dw	44.4	49.7	35.6	35.6	
Mercury	mg/kg dw	0.0805	0.195	0.164	0.213	
Molybdenum	mg/kg dw	2.27	2.67	3.2	1.68	
Nickel	mg/kg dw	11.4	12.6	11.5	9.65	
Selenium	mg/kg dw	0.76	0.694	0.587	0.603	
Zinc	mg/kg dw	267	264	359	233	

Note: Day 28 test lost due to County error.

Test #2 - Chicken Manure

Parameter	Units	Discharge 0	Day 10 10	Day 15 15	Day 21 21	Day 28 28
Arsenic	mg/kg dw	0.726	0.621	0.715	0.75	0.634
Cadmium	mg/kg dw	0.337	0.53	0.414	0.347	0.718
Chromium	mg/kg dw	13.4	17.1	16.7	28.4	53.5
Copper	mg/kg dw	48.1	84.3	78.6	68.1	71.4
Lead	mg/kg dw	16.9	26.8	42	21.2	30.1
Mercury	mg/kg dw	0.00515	0.122	0.122	0.171	0.162
Molybdenum	mg/kg dw	3.12	3.77	2.7	2.7	2.67
Nickel	mg/kg dw	7.68	12.3	10.6	10.7	10.5
Selenium	mg/kg dw	0.662	0.566	0.652	0.685	0.578
Zinc	mg/kg dw	285	361	388	325	304

Test #3 - Chicken Manure & Biosolids

Parameter	Units	Discharge 0	Day 10 10	Day 15 15	Day 21 21	Day 28 28
Arsenic	mg/kg dw	0.892	0.704	0.844	0.792	0.794
Cadmium	mg/kg dw	0.243	0.282	0.249	0.197	0.759
Chromium	mg/kg dw	13.7	12.8	15	13.2	16.3
Copper	mg/kg dw	66.4	100	97.5	89.2	91.9
Lead	mg/kg dw	18.3	31.6	24.1	191	26.1
Mercury	mg/kg dw	0.0261	0.089	0.115	0.113	0.15
Molybdenum	mg/kg dw	3.51	2.36	2.81	3.85	4.34
Nickel	mg/kg dw	7.18	9.34	9.96	8.42	11.1
Selenium	mg/kg dw	0.814	0.642	0.77	0.907	0.724
Zinc	mg/kg dw	210	370	256	222	241

Test #4 - Chicken Mortalities & Biosolids

Parameter	Units	Discharge 0	Day 10 10	Day 15 15	Day 21 21	Day 28 28
Arsenic	mg/kg dw	0.848	0.745	0.73	0.689	0.645
Cadmium	mg/kg dw	0.189	0.859	0.737	0.7	0.489
Chromium	mg/kg dw	13.6	15.5	15.9	14.4	18.7
Copper	mg/kg dw	61.7	82.6	75.2	71.5	71.4
Lead	mg/kg dw	46.5	55.6	52.1	64.4	49.4
Mercury	mg/kg dw	0.0803	0.0895	0.103	0.131	0.0617
Molybdenum	mg/kg dw	2.17	2.81	2.7	2.64	2.59
Nickel	mg/kg dw	10.3	13.2	13	12.4	12.1
Selenium	mg/kg dw	0.774	0.68	0.666	0.629	0.588
Zinc	mg/kg dw	249	334	246	326	260

Test #5 - Chicken Mortalities

Parameter	Units	Discharge 0	Day 10 10	Day 15 15	Day 21 21	Day 28 28
Arsenic	mg/kg dw	0.749	0.771	0.634	0.657	0.646
Cadmium	mg/kg dw	0.298	0.846	0.412	0.27	0.363
Chromium	mg/kg dw	12.7	15.8	15	14	16.3
Copper	mg/kg dw	55.9	110	54.3	59.7	107
Lead	mg/kg dw	32	59.4	38	40.5	50.1
Mercury	mg/kg dw	0.076	0.17	0.125	0.17	0.14
Molybdenum	mg/kg dw	2.23	3.03	2.14	1.92	2.15
Nickel	mg/kg dw	9.33	14.4	10.1	10.3	11.2
Selenium	mg/kg dw	0.683	0.704	0.578	0.599	0.59
Zinc	mg/kg dw	308	416	249	262	293

Test #6 - Cow Manure & Biosolids

Parameter	Units	Discharge 0	Day 10 10	Day 15 15	Day 21 21	Day 28 28
Arsenic	mg/kg dw	0.84	0.77	0.743	0.762	0.719
Cadmium	mg/kg dw	0.759	0.437	0.503	0.544	0.846
Chromium	mg/kg dw	13.3	15.8	14	18.9	15.6
Copper	mg/kg dw	94.5	90.3	88.4	85.7	135
Lead	mg/kg dw	22.5	29.6	24.1	34	33.4
Mercury	mg/kg dw	0.0983	0.119	0.0892	0.115	0.0845
Molybdenum	mg/kg dw	2.87	2.19	1.7	2.71	2.05
Nickel	mg/kg dw	10.1	9.69	9.62	10.7	11
Selenium	mg/kg dw	0.766	0.702	0.669	0.696	0.656
Zinc	mg/kg dw	232	279	273	336	277

Test #7 - Cow Manure

Parameter	Units	Discharge 0	Day 10 10	Day 15 15	Day 21 21	Day 28 28
Arsenic	mg/kg dw	0.834	0.77	0.673	0.709	0.687
Cadmium	mg/kg dw	0.305	0.369	0.505	0.558	0.361
Chromium	mg/kg dw	11.2	12.3	14.9	16.1	11.7
Copper	mg/kg dw	58.8	79.5	98.9	107	73.6
Lead	mg/kg dw	14.2	18.1	22.4	27.6	18.6
Mercury	mg/kg dw	0.0998	0.1	0.119	0.0726	0.148
Molybdenum	mg/kg dw	1.71	2.06	2.26	2.33	1.54
Nickel	mg/kg dw	6.98	14.5	9.43	10.5	7.82
Selenium	mg/kg dw	0.76	0.702	0.614	0.699	0.626
Zinc	mg/kg dw	215	209	320	259	171

Test #8 - Citrus Sludge

Parameter	Units	Discharge	Day 10	Day 15	Day 21	Day 28
		0	10	15	21	28
Arsenic	mg/kg dw	0.857	0.994	0.864	0.846	0.838
Cadmium	mg/kg dw	0.384	0.562	0.867	0.521	0.021
Chromium	mg/kg dw	21.6	17.3	18.3	23.8	1.11
Copper	mg/kg dw	70.6	67.2	73.6	63.9	4.79
Lead	mg/kg dw	30.6	35.2	65	39.8	3.12
Mercury	mg/kg dw	0.179	0.172	0.117	0.296	0.181
Molybdenum	mg/kg dw	2.73	2.97	2.98	2.89	2.37
Nickel	mg/kg dw	10.7	10.8	13	24.9	3.72
Selenium	mg/kg dw	0.782	0.907	0.788	0.772	0.764
Zinc	mg/kg dw	280	229	255	244	251

Test #9 - Citrus Sludge & Biosolids

Parameter	Units	Discharge 0	Day 10 10	Day 15 15	Day 21 21	Day 28 28
Arsenic	mg/kg dw	0.866	0.685	0.811	0.784	0.773
Cadmium	mg/kg dw	0.596	0.596	0.68	0.533	0.882
Chromium	mg/kg dw	20.3	16.9	19.2	21.4	23.2
Copper	mg/kg dw	89.7	74.4	83.3	83.2	94.7
Lead	mg/kg dw	59.2	44.6	53.9	64.1	58.3
Mercury	mg/kg dw	0.155	0.238	0.203	0.207	0.217
Molybdenum	mg/kg dw	3.89	2.37	3.13	3.45	3.41
Nickel	mg/kg dw	15.5	12.4	13.5	15.6	17.7
Selenium	mg/kg dw	0.79	0.625	0.74	0.715	0.705
Zinc	mg/kg dw	359	276	294	653	337

Test #10 - MSW & Biosolids

Parameter	Units	Discharge 0	Day 10 10	Day 15 15	Day 21 21	Day 28 28
Arsenic	mg/kg dw	0.885	0.817	0.77	0.752	0.692
Cadmium	mg/kg dw	0.76	0.616	0.521	0.67	0.529
Chromium	mg/kg dw	20.6	22.8	19.7	22.7	20.4
Copper	mg/kg dw	123	166	146	146	152
Lead	mg/kg dw	77.7	71	63.1	60.7	61.2
Mercury	mg/kg dw	0.137	0.152	0.13	0.146	0.158
Molybdenum	mg/kg dw	3.88	3.62	3.2	3.38	3.37
Nickel	mg/kg dw	14	16.4	15.1	13.6	15.2
Selenium	mg/kg dw	0.807	0.745	0.702	0.686	0.632
Zinc	mg/kg dw	268	451	301	319	363

Test #11 - Biosolids No Inoculant

Parameter	Units	Discharge	Day 10	Day 15	Day 21	Day 28
		0	10	15	21	28
Arsenic	mg/kg dw	0.764	0.721	0.687	0.698	0.713
Cadmium	mg/kg dw	0.935	0.0815	0.645	0.69	0.374
Chromium	mg/kg dw	21.8	12.7	20.8	26.5	19
Copper	mg/kg dw	177	91	149	163	143
Lead	mg/kg dw	57.3	16.3	57.1	59.1	45.8
Mercury	mg/kg dw	0.157	0.103	0.117	0.17	0.12
Molybdenum	mg/kg dw	3	1.76	3.14	2.88	3.65
Nickel	mg/kg dw	16.7	8.12	14.2	14.5	12.7
Selenium	mg/kg dw	0.697	0.658	0.626	0.637	0.651
Zinc	mg/kg dw	322	165	290	368	349

Test #12 - Biosolids No Inoculant w/ Dygest506

Parameter	Units	Discharge 0	Day 10 10	Day 15 15	Day 21 21	Day 28 28
Arsenic	mg/kg dw	1.18	1.12	1.11	1.17	1.03
Cadmium	mg/kg dw	0.673	0.624	0.68	0.5	0.866
Chromium	mg/kg dw	12.1	12.5	13.2	15	15.9
Copper	mg/kg dw	112	115	125	122	138
Lead	mg/kg dw	29.7	29.6	51.2	26.5	31.6
Mercury	mg/kg dw	0.128	0.142	0.152	0.165	0.13
Molybdenum	mg/kg dw	2.53	2.47	2.63	2.44	2.22
Nickel	mg/kg dw	13.3	13.4	13.6	13.6	14.4
Selenium	mg/kg dw	0.964	0.915	0.907	0.952	0.839
Zinc	mg/kg dw	231	226	223	206	329

Test #13 - Citrus Sludge w/ Dygest506

Parameter	Units	Discharge 0	Day 10 10	Day 15 15	Day 21 21	Day 28 28
Arsenic	mg/kg dw	1.29	1.24	1.14	1.12	1.17
Cadmium	mg/kg dw	0.952	1.02	0.934	0.584	1.08
Chromium	mg/kg dw	22.6	20.6	23.2	23.7	24.6
Copper	mg/kg dw	95.2	99.7	93.2	101	173
Lead	mg/kg dw	40.6	89.9	42.5	49.7	40.9
Mercury	mg/kg dw	1.93	2.19	0.891	0.712	1.41
Molybdenum	mg/kg dw	3.94	3.71	4.14	3.8	4.2
Nickel	mg/kg dw	14.1	14.5	13.2	14.8	14.4
Selenium	mg/kg dw	1.41	1.02	1.26	0.917	1.13
Zinc	mg/kg dw	283	297	257	327	321

Test #14 - Biosolids w/ Dygest506

Parameter	Units	Discharge	Day 10	Day 15	Day 21	Day 28
		0	10	15	21	28
Arsenic	mg/kg dw	1.17	1.07	1.05	1.08	2.14
Cadmium	mg/kg dw	0.856	0.904	1.27	0.981	1.04
Chromium	mg/kg dw	16.8	17.1	19.1	18.4	28.5
Copper	mg/kg dw	119	179	369	149	161
Lead	mg/kg dw	27.9	26.7	30.5	30.4	30.7
Mercury	mg/kg dw	0.347	0.277	0.274	0.25	0.343
Molybdenum	mg/kg dw	3.15	2.77	3.22	3.19	3.91
Nickel	mg/kg dw	16	15.6	17.2	18.1	18
Selenium	mg/kg dw	0.957	0.875	0.86	0.885	0.893
Zinc	mg/kg dw	223	295	354	303	299

Test #15 - Biosolids No Inoculant w/ Ortec

Parameter	Units	Discharge	Day 10	Day 15	Day 21	Day 28
		0	10	15	21	28
Arsenic	mg/kg dw	1.22	1.11	1.06	0.965	1
Cadmium	mg/kg dw	1.16	0.898	1.04	1.78	3.73
Chromium	mg/kg dw	22.8	22	25.6	24.8	21.8
Copper	mg/kg dw	106	677	137	149	128
Lead	mg/kg dw	44.6	50.4	46.9	74.7	66.1
Mercury	mg/kg dw	0.241	0.354	0.398	0.465	0.353
Molybdenum	mg/kg dw	4.13	2.75	3.4	5.77	2.46
Nickel	mg/kg dw	16.6	16.6	18.9	27.3	19.7
Selenium	mg/kg dw	1	0.909	0.866	0.787	0.82
Zinc	mg/kg dw	270	326	341	531	419

Test #16 - Citrus Sludge w/ Ortec

Parameter	Units	Discharge 0	Day 10 10	Day 15 15	Day 21 21	Day 28 28
Arsenic	mg/kg dw	1.24	1.16	1.18		1.01
Cadmium	mg/kg dw	1	0.85	0.288		0.805
Chromium	mg/kg dw	15.4	15.1	1.89		16.2
Copper	mg/kg dw	71.8	70.8	80.5		81.3
Lead	mg/kg dw	30.1	38.9	4.82		44.8
Mercury	mg/kg dw	0.32	0.454	0.564		0.547
Molybdenum	mg/kg dw	3.32	5.72	0.156		2.74
Nickel	mg/kg dw	13.1	13.7	1.58		13.9
Selenium	mg/kg dw	1.02	0.943	0.959		0.825
Zinc	mg/kg dw	196	238	265		293

Test #17 - Biosolids w/ Ortec

Parameter	Units	Discharge 0	Day 10 10	Day 15 15	Day 21 21	Day 28 28
Arsenic	mg/kg dw	1.13	1.02	1.03	1.02	0.942
Cadmium	mg/kg dw	0.526	0.616	0.345	0.395	0.632
Chromium	mg/kg dw	12.3	14.5	14.3	13.3	16.2
Copper	mg/kg dw	88.5	116	142	89.2	114
Lead	mg/kg dw	19.7	27.8	24.4	24.9	28.1
Mercury	mg/kg dw	0.139	0.172	0.205	0.249	0.123
Molybdenum	mg/kg dw	2.61	2.6	2.38	2.19	2.77
Nickel	mg/kg dw	10.8	12.6	12.2	11.1	15.5
Selenium	mg/kg dw	0.924	0.83	1.56	0.833	0.769
Zinc	mg/kg dw	158	206	240	193	225

APPENDIX C

COMPOST CHARACTERISTICS – MACRO-NUTRIENTS

Test #1 - Inoculant Only

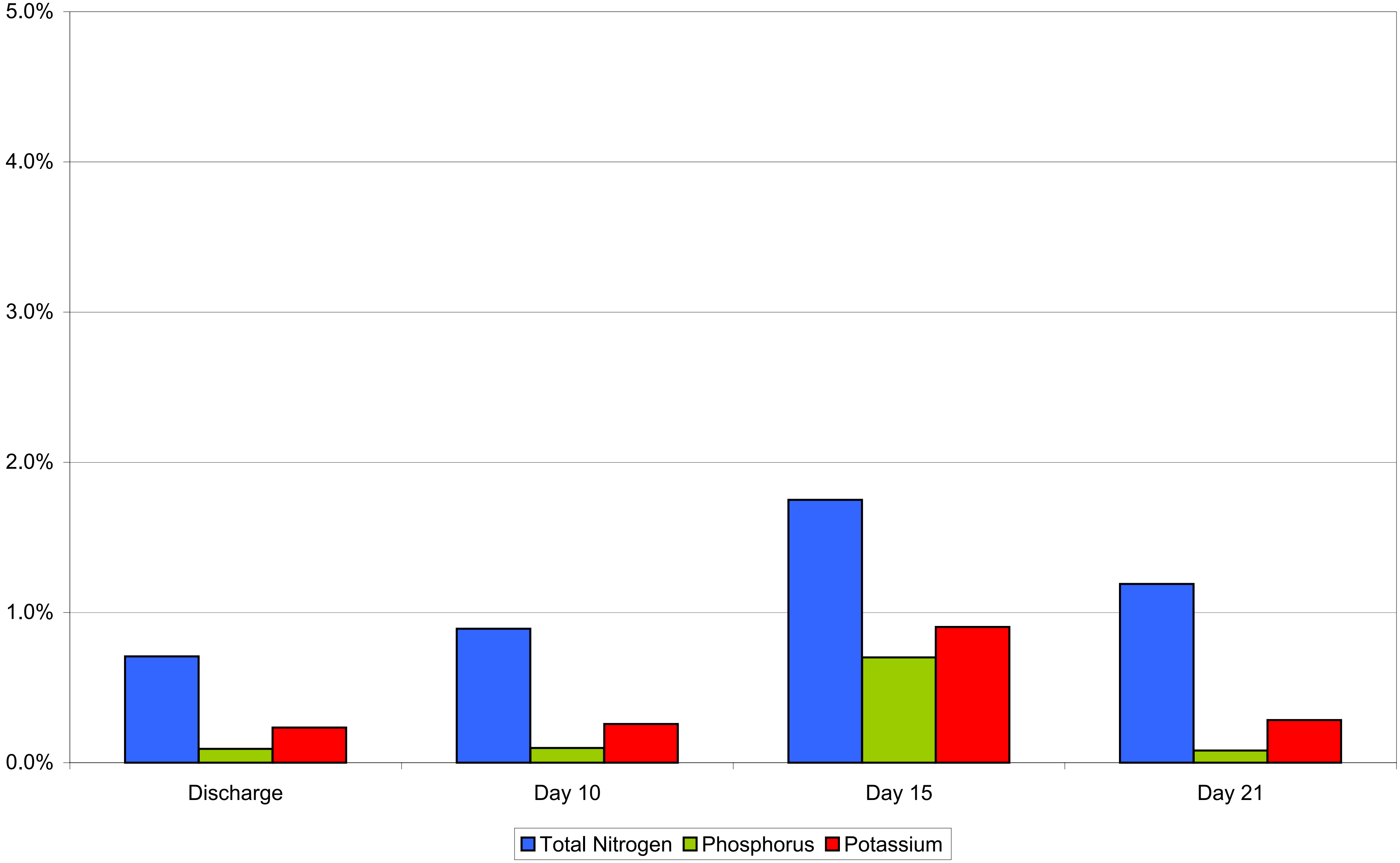
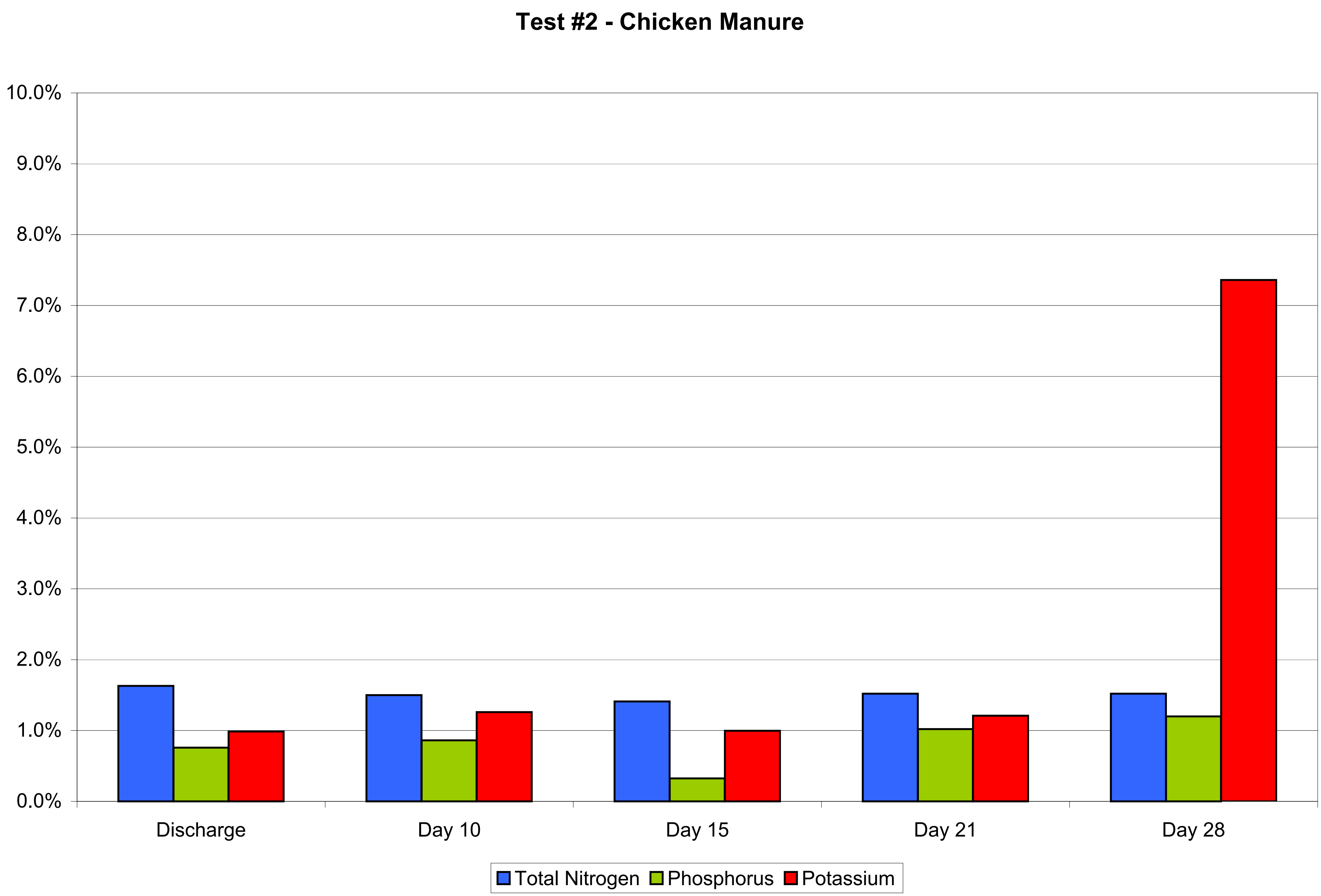
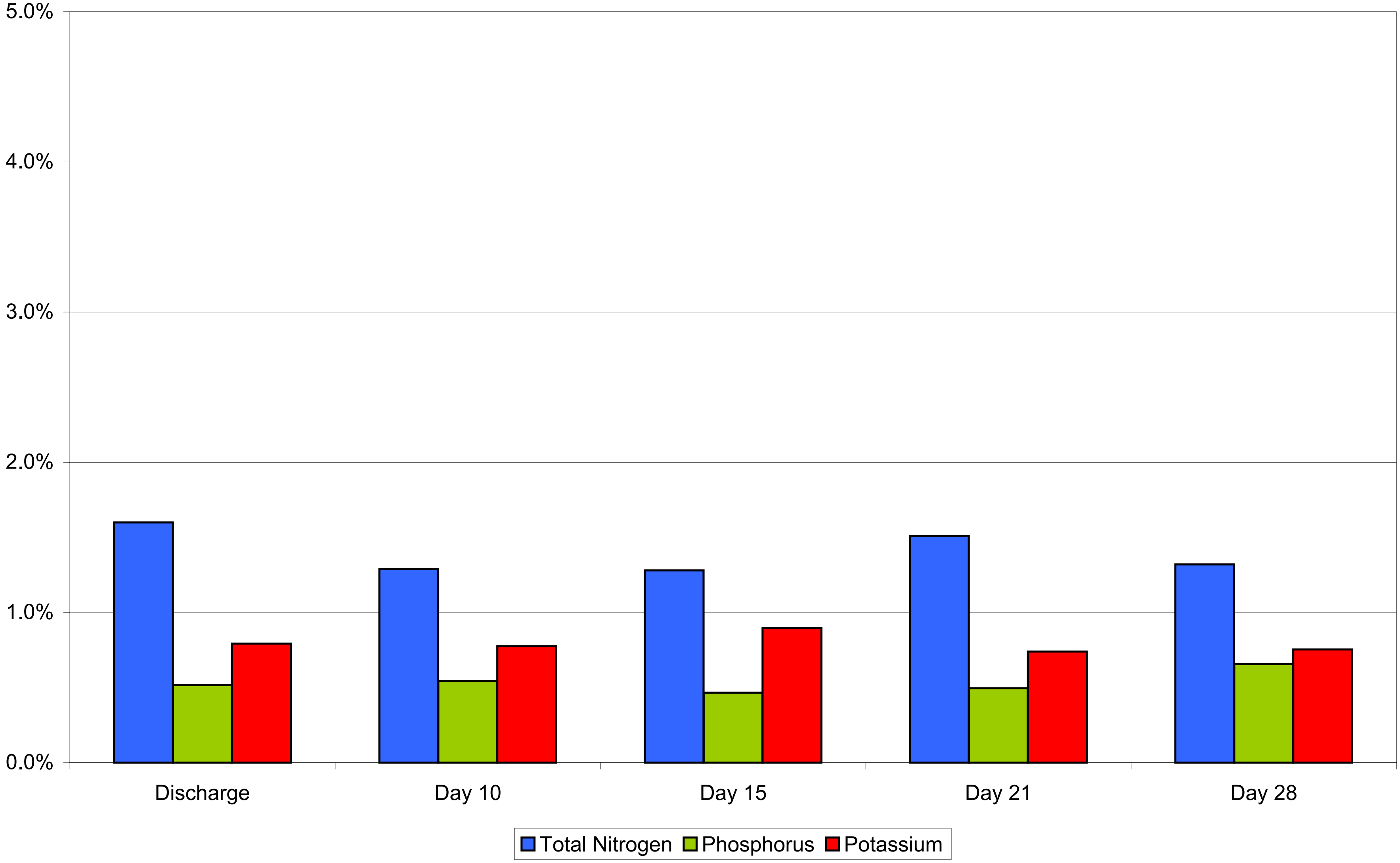


Chart 1


Test #2 - Chicken Manure
10.0%
9.0%
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
Discharge
Day 10
Day 15
Day 21
Day 28
Total Nitrogen
Phosphorus
Potassium

Test #3 - Chicken Manure & Biosolids



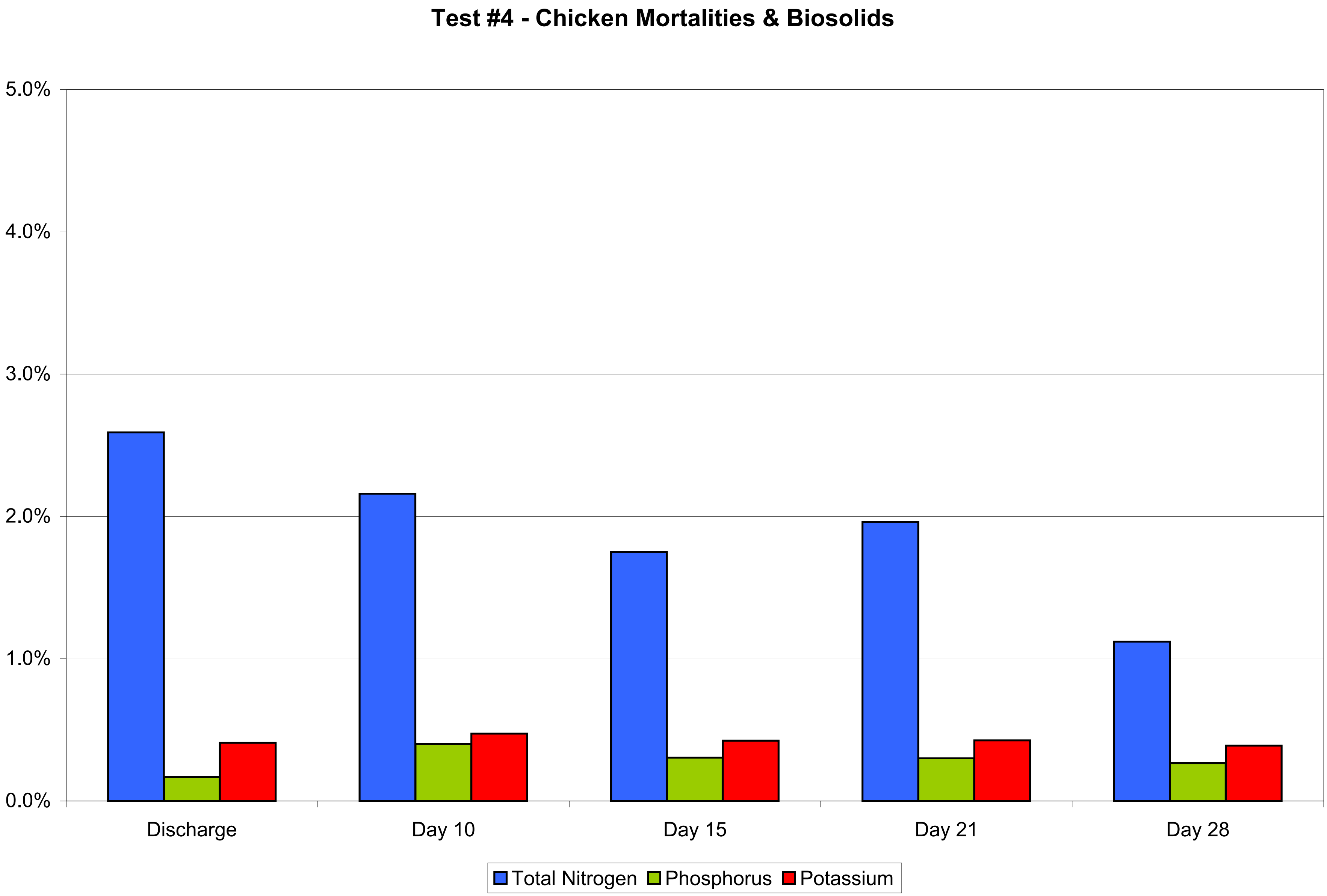

Test #4 - Chicken Mortalities & Biosolids
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
Discharge
Day 10
Day 15
Day 21
Day 28
Total Nitrogen
Phosphorus
Potassium

Chart 4

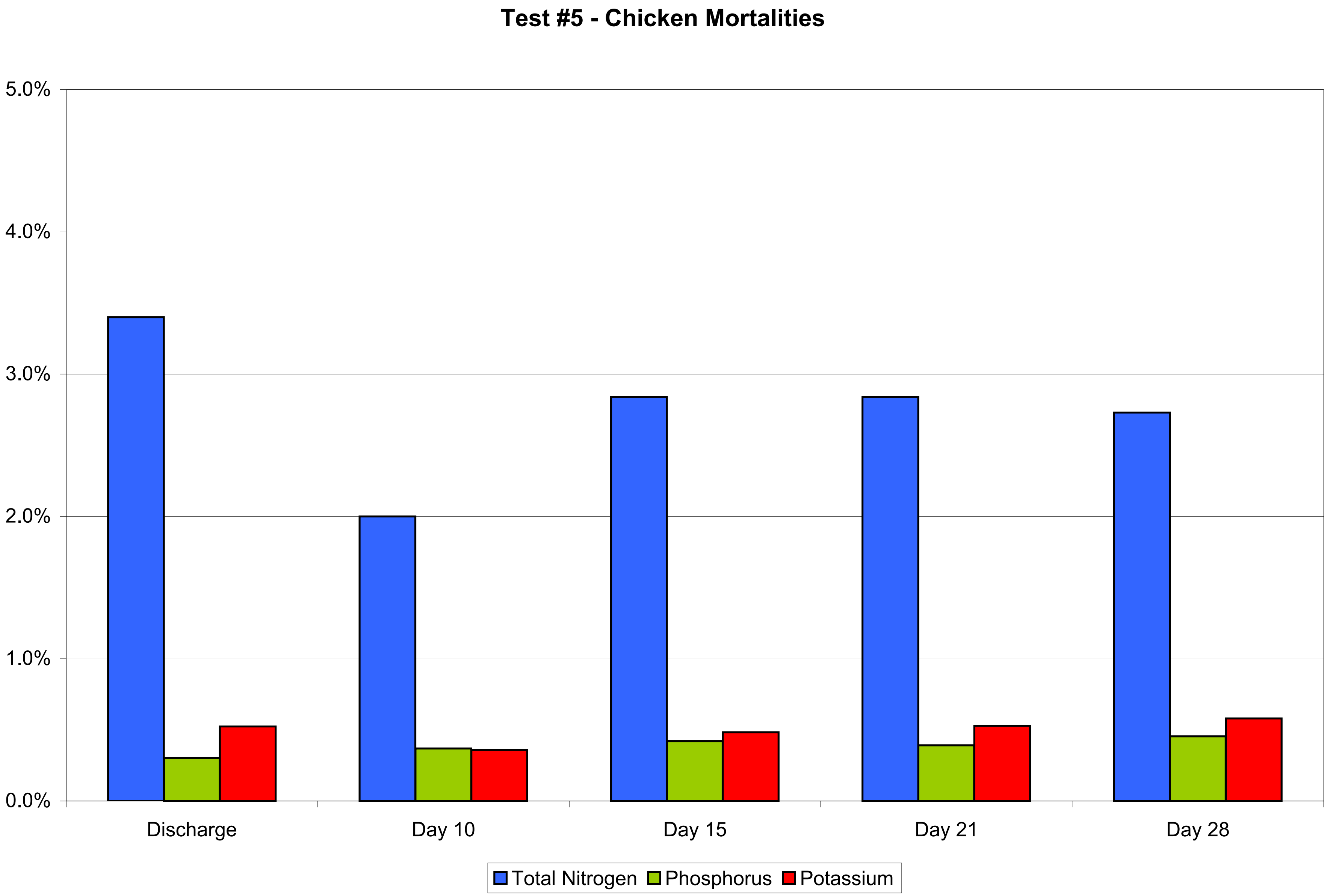
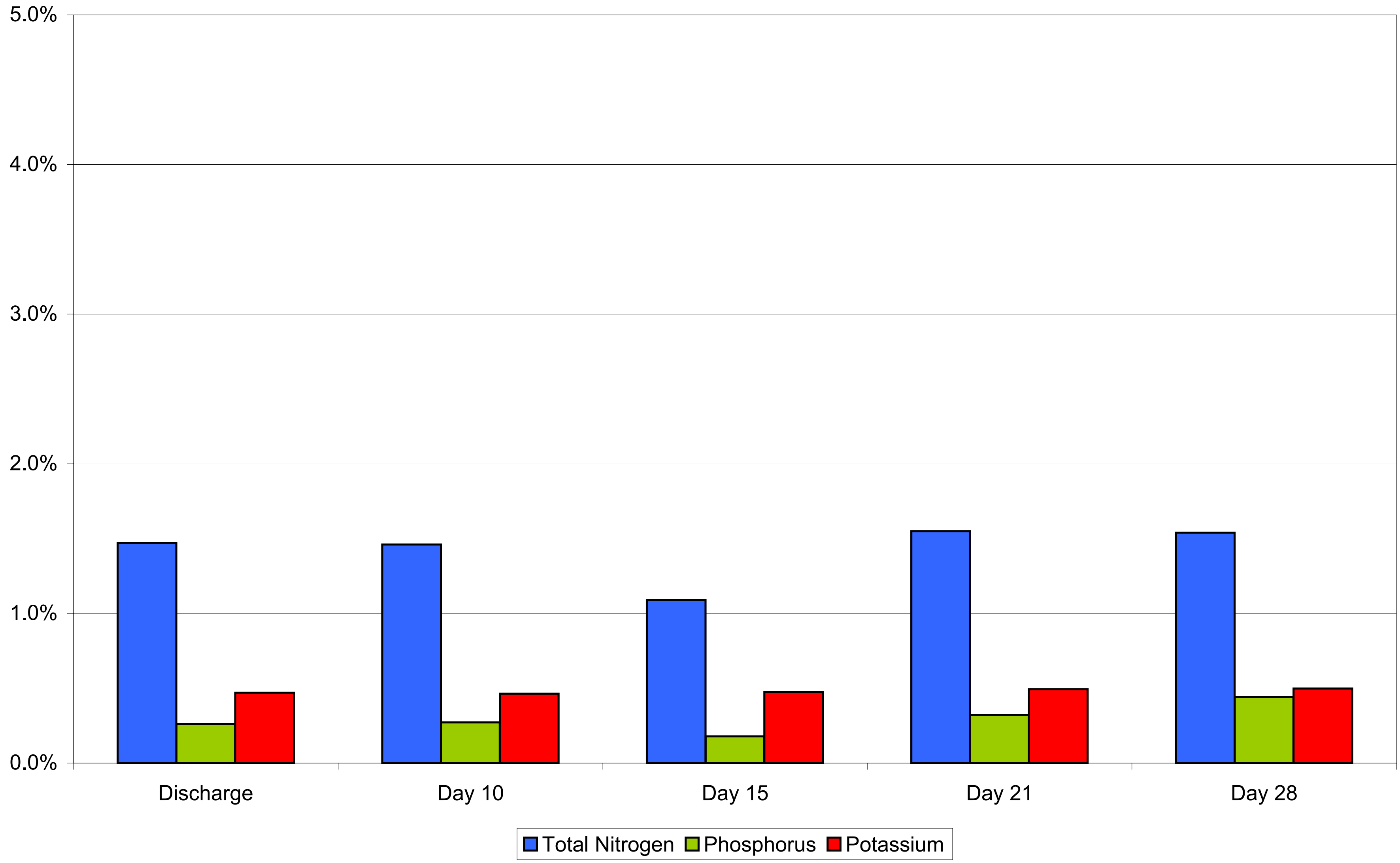
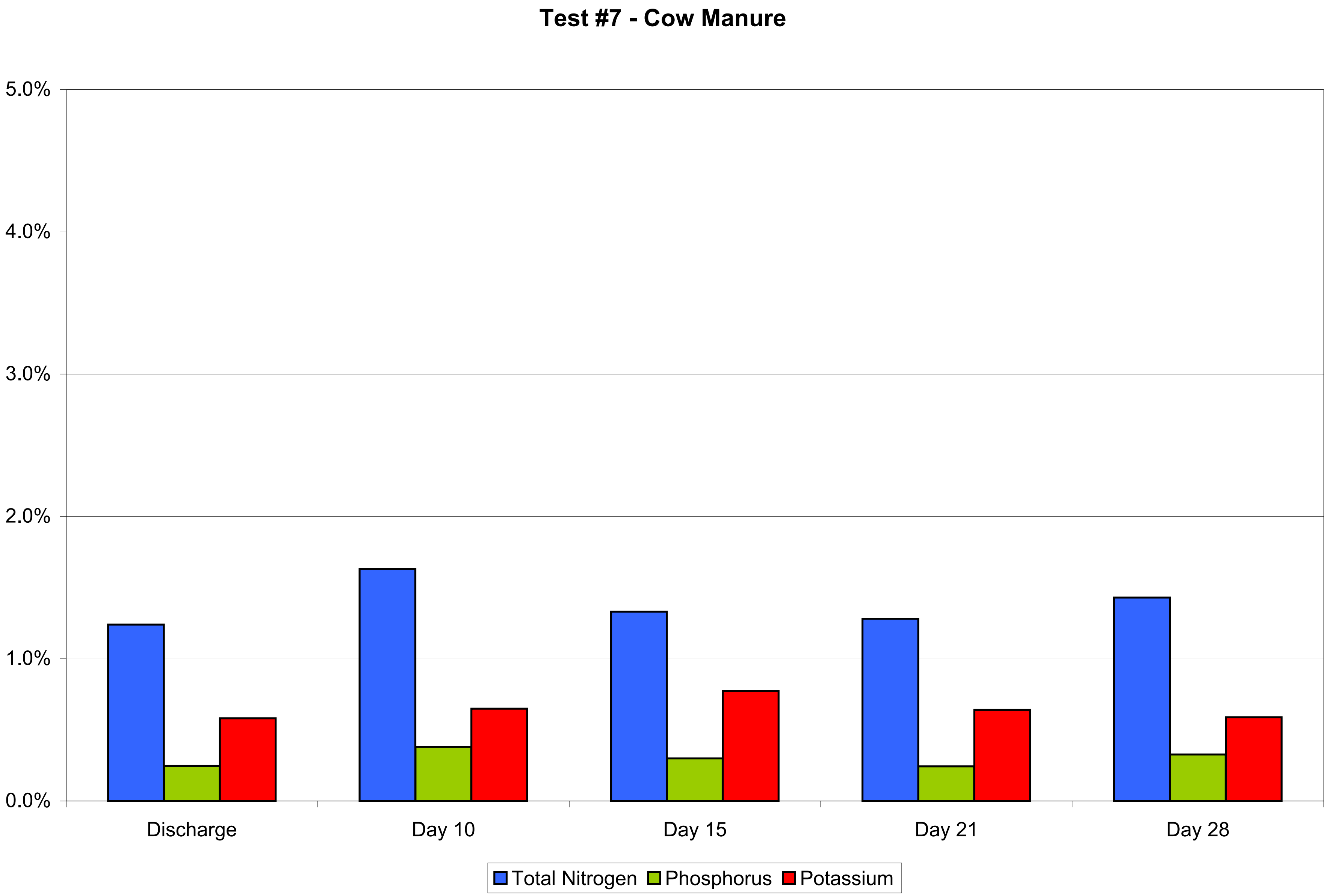

Test #5 - Chicken Mortalities
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
Discharge
Day 10
Day 15
Day 21
Day 28
Total Nitrogen
Phosphorus
Potassium

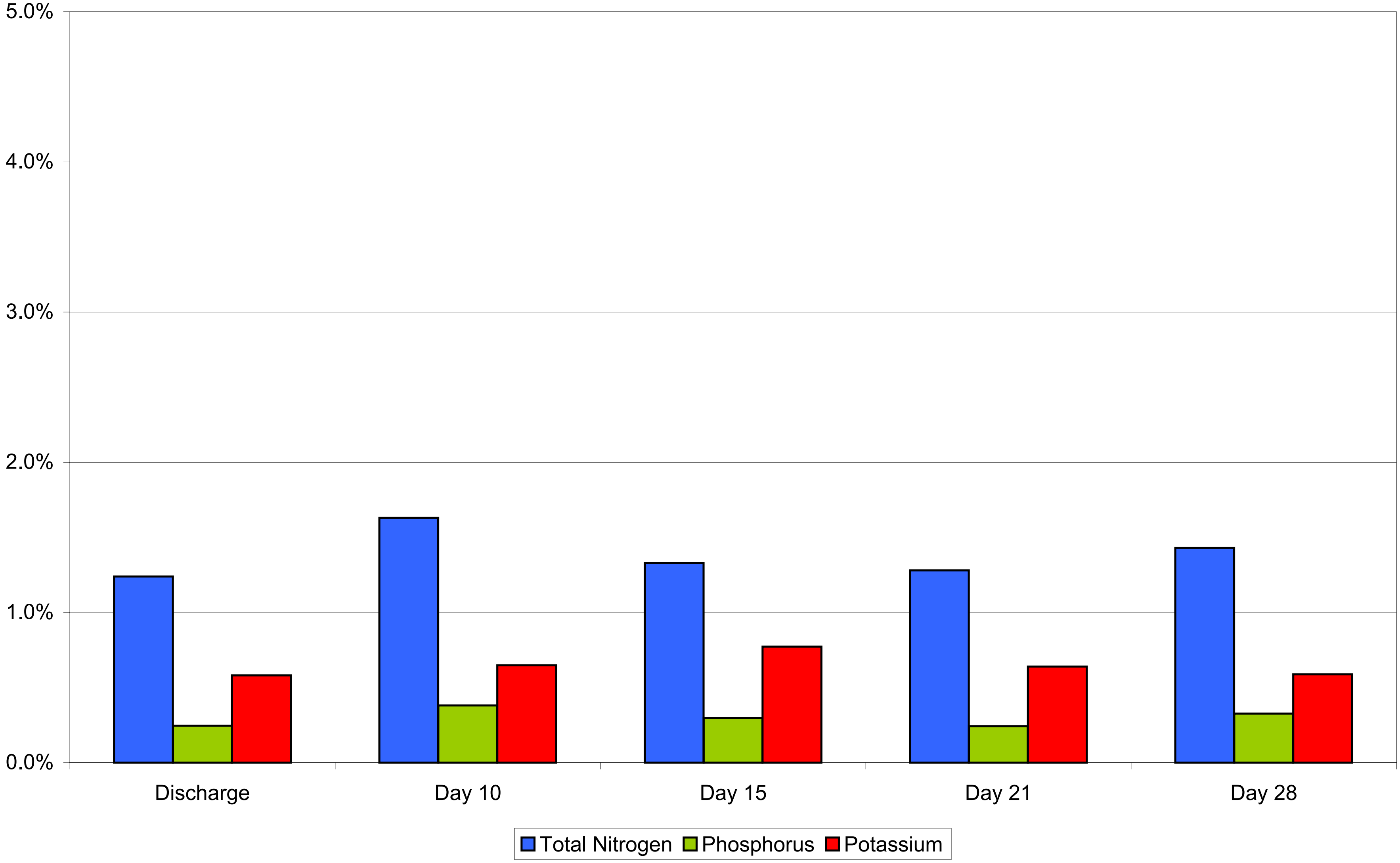
Chart 5

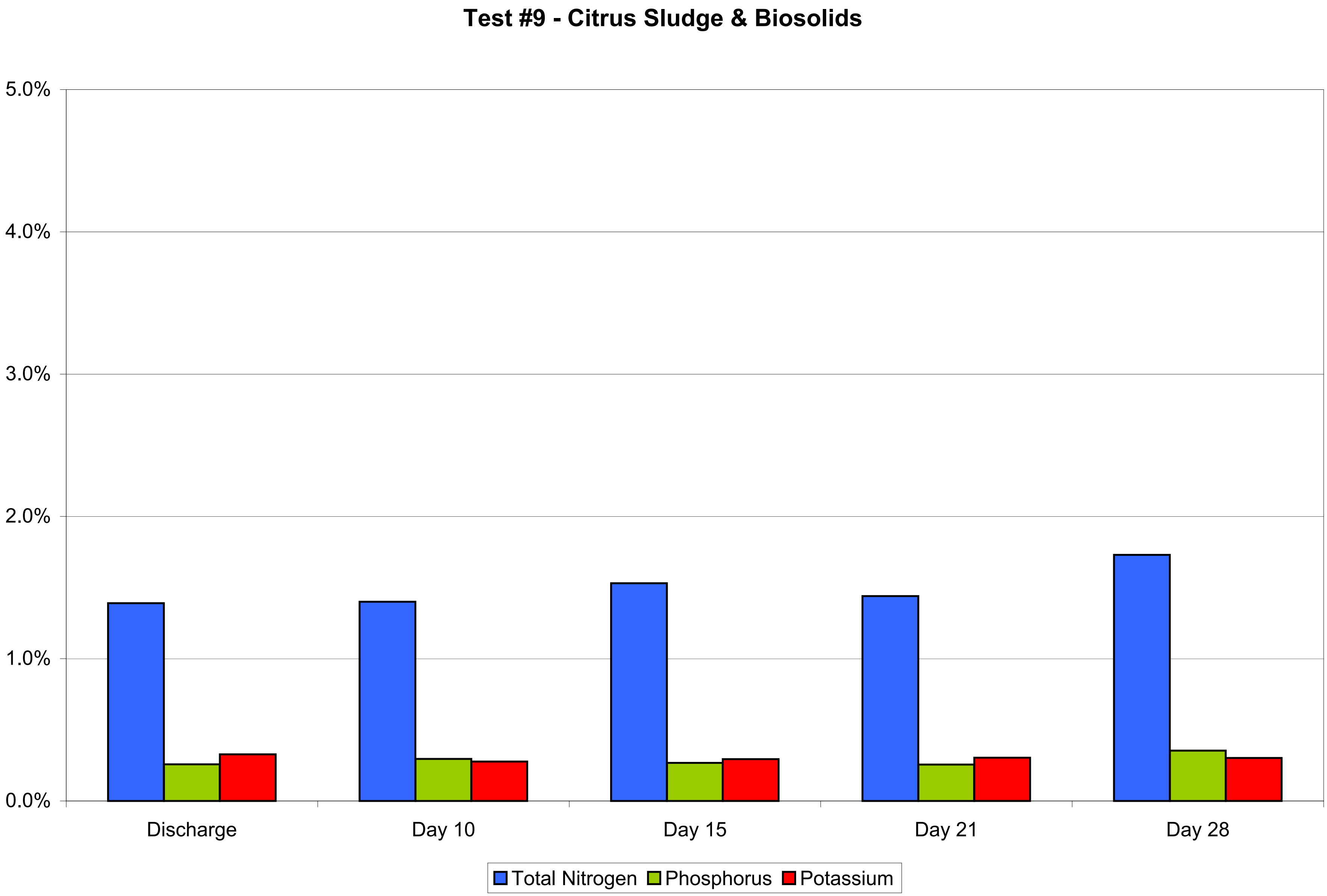
Test #6 - Cow Manure & Biosolids



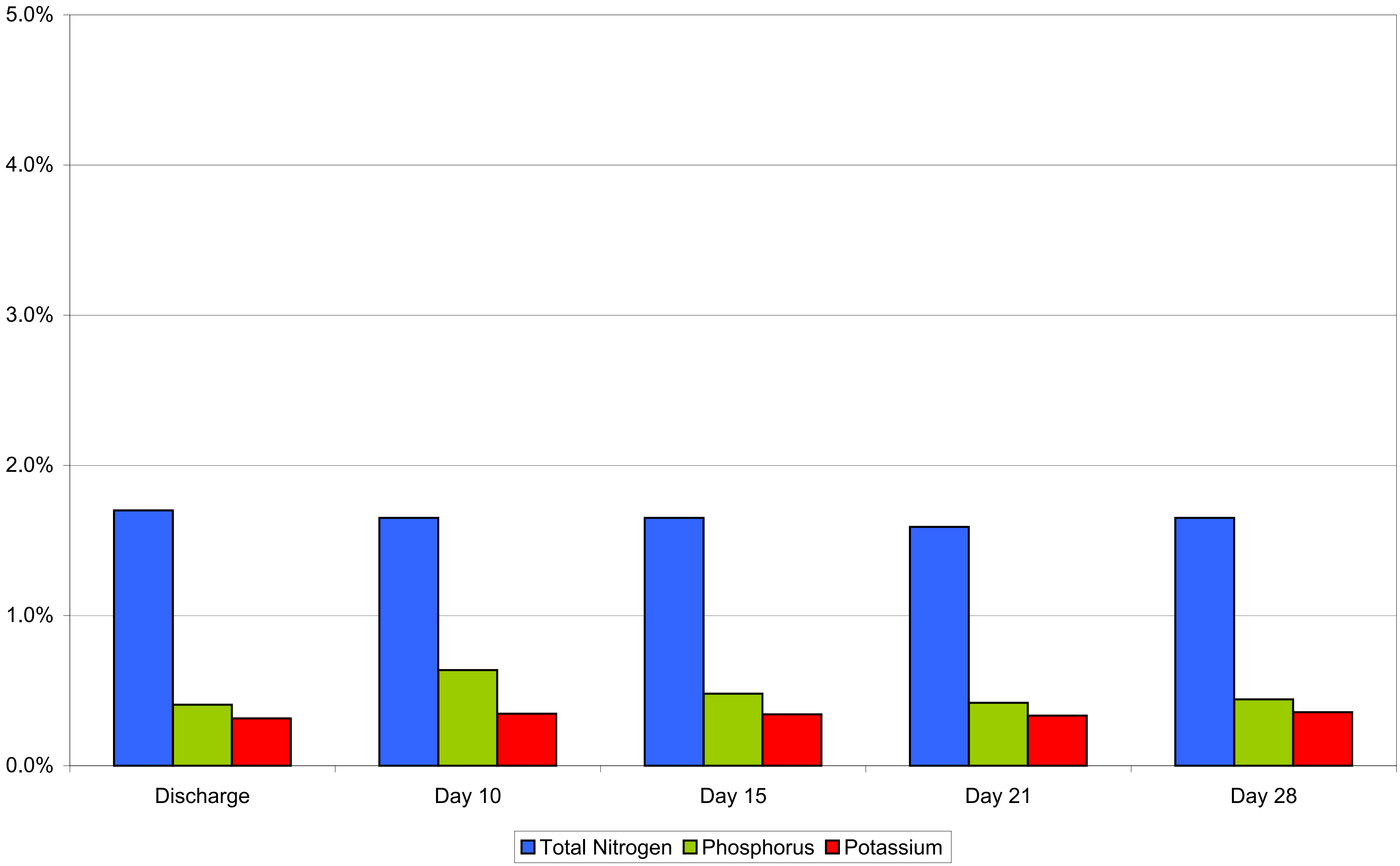

Test #7 - Cow Manure
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
Discharge
Day 10
Day 15
Day 21
Day 28
Total Nitrogen
Phosphorus
Potassium

Test #8 - Citrus Sludge

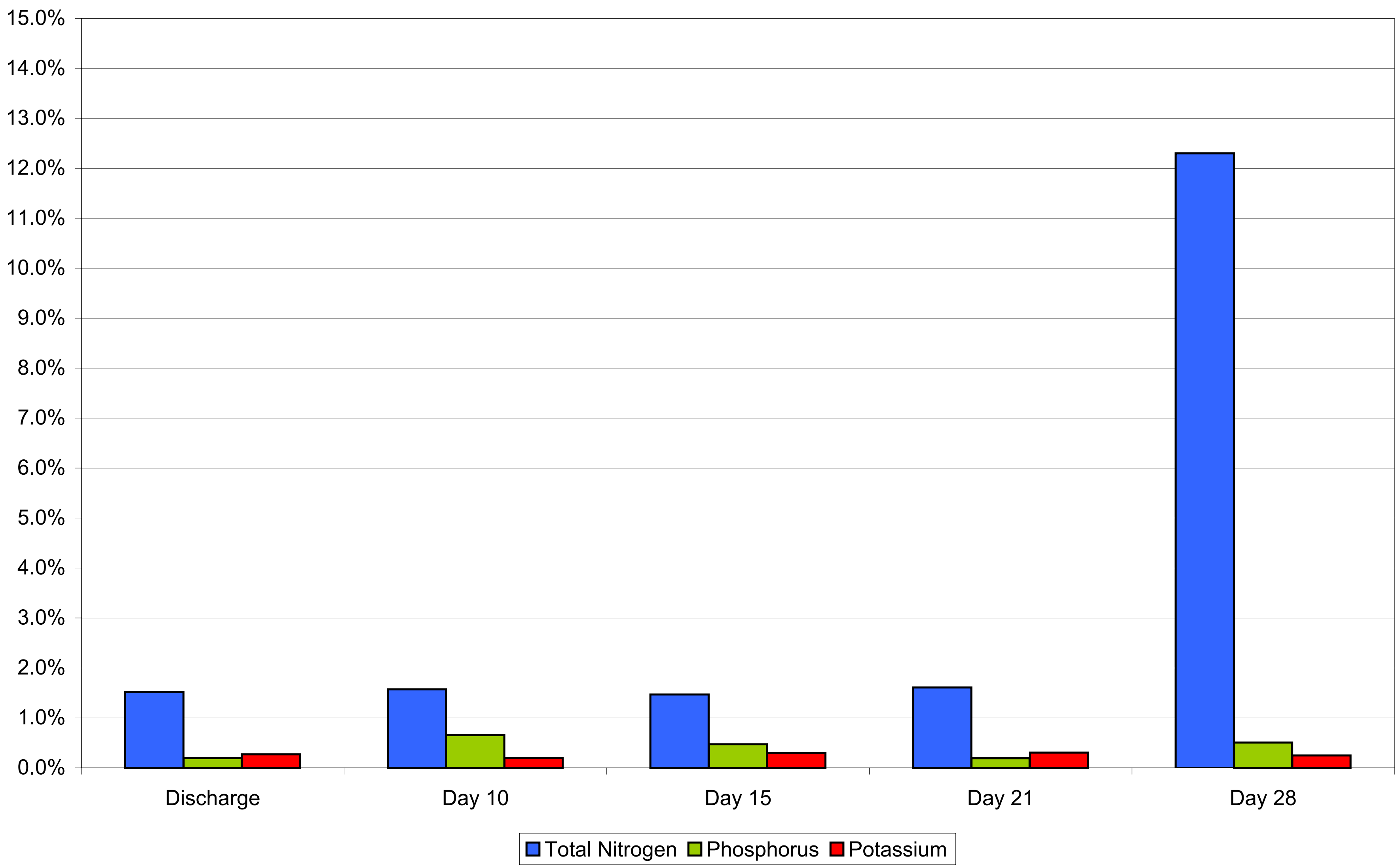



Test #9 - Citrus Sludge & Biosolids
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
Discharge
Day 10
Day 15
Day 21
Day 28
Total Nitrogen
Phosphorus
Potassium

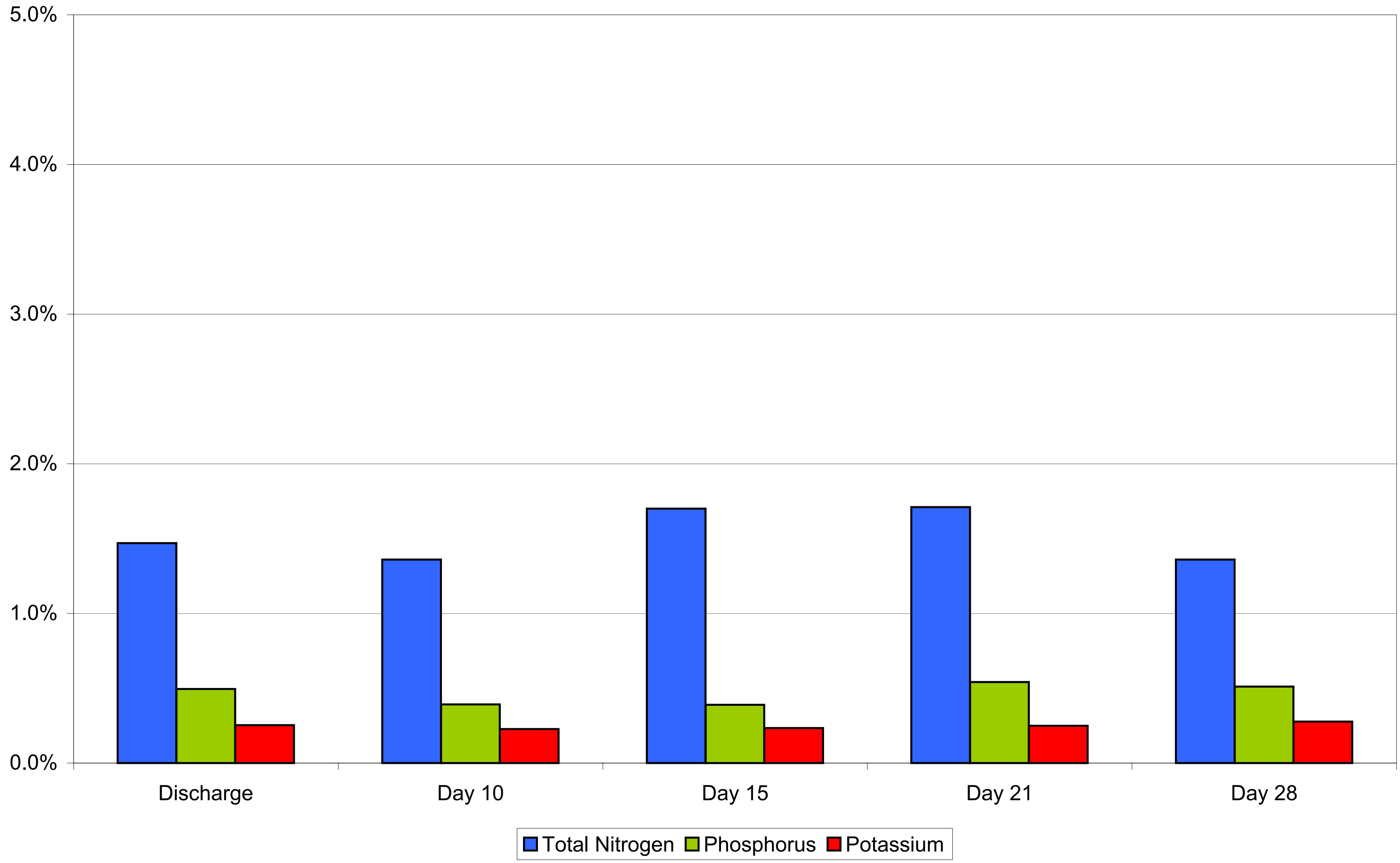
Test #10 - Biosolids



Test #11 - Biosolids & No Inoculant



Test #12 - Biosolids & No Inoculant w/ Dygest506



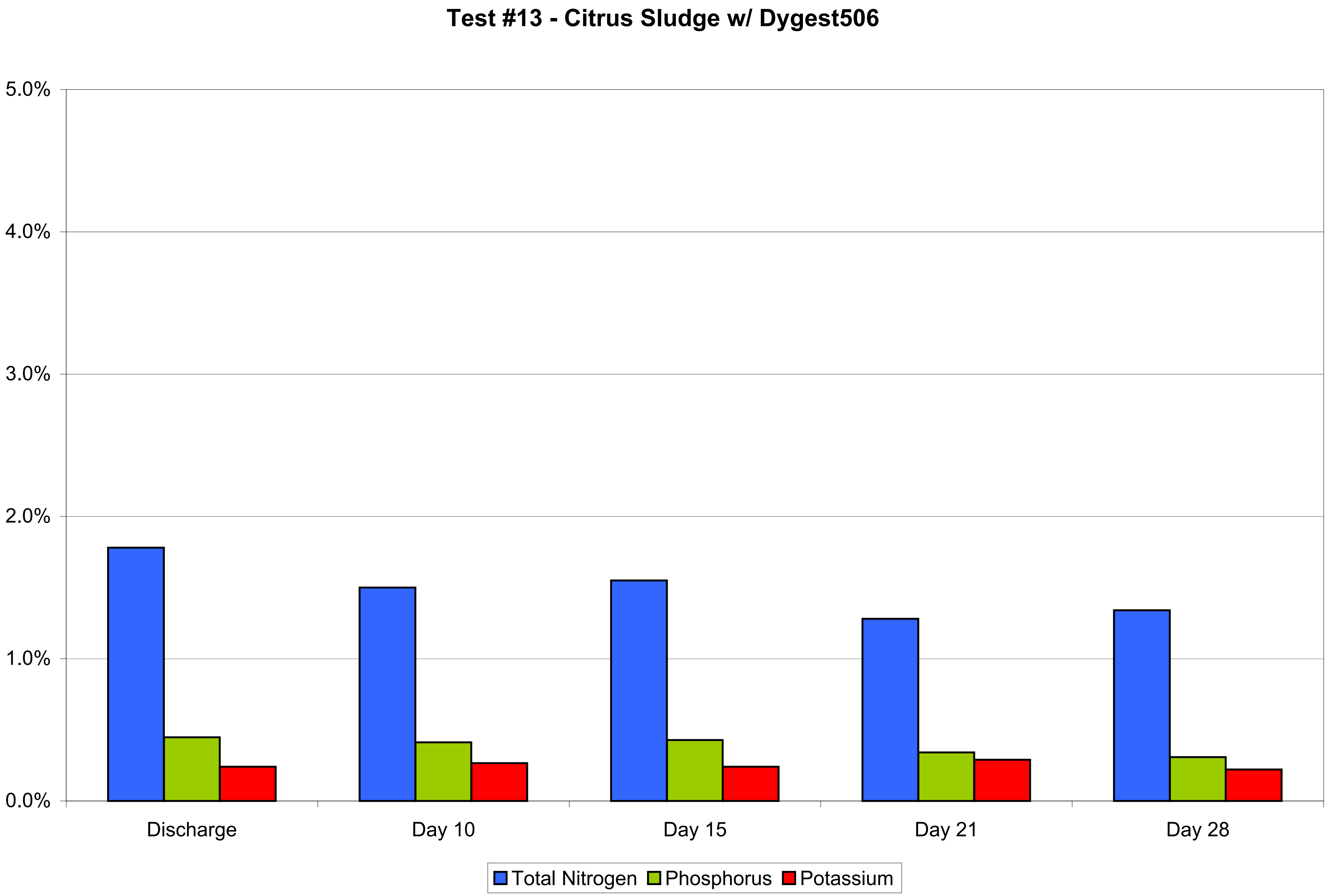
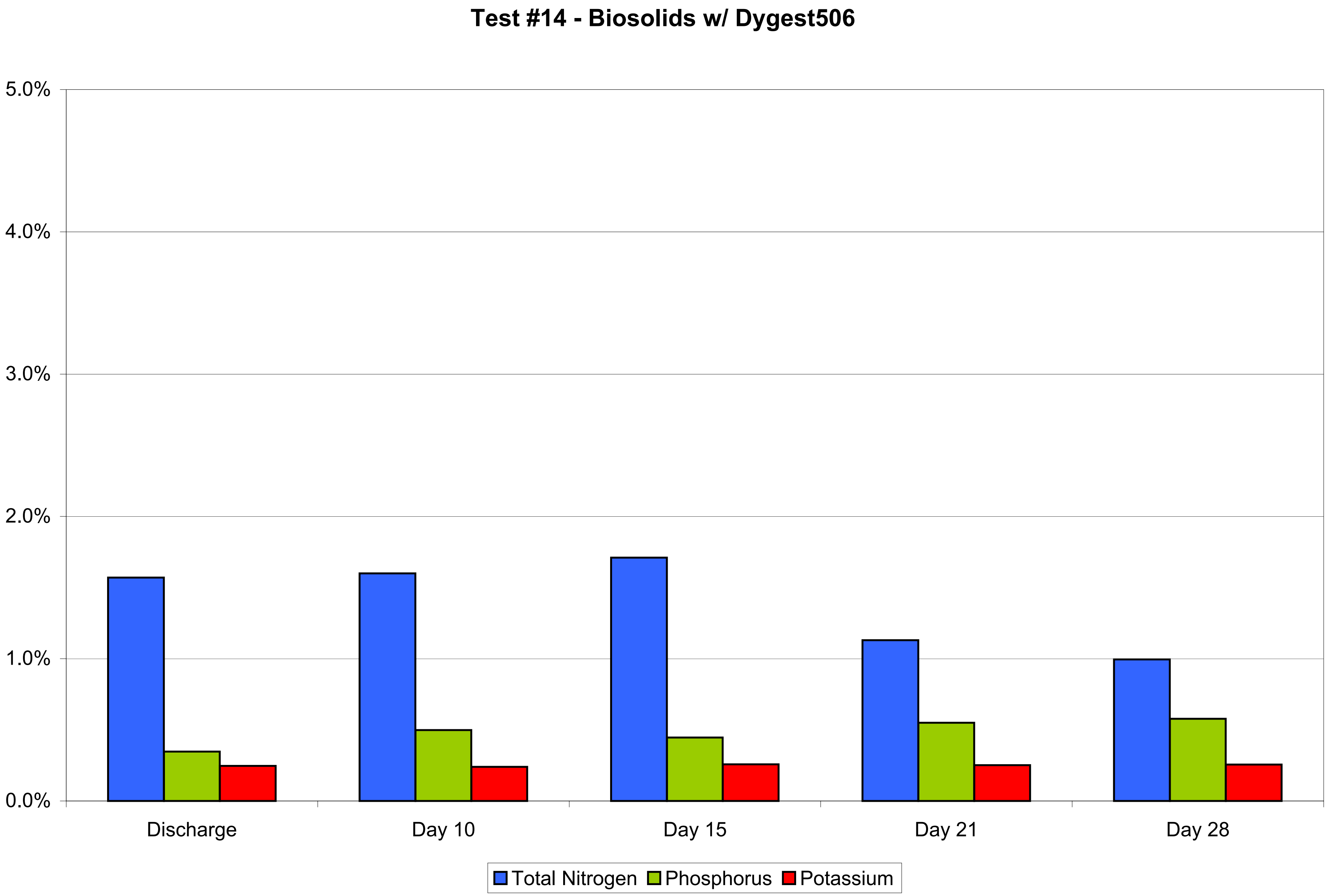
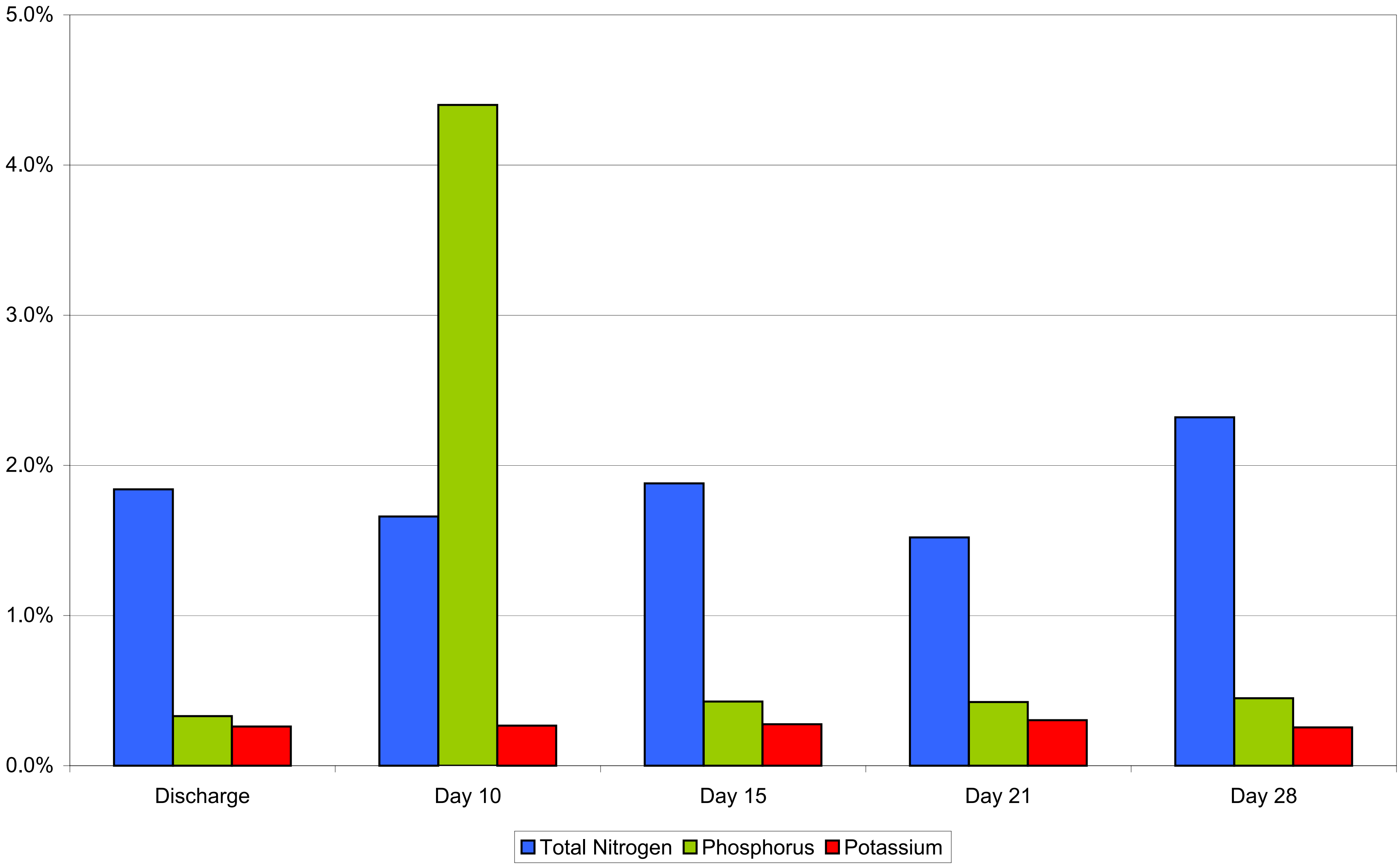

Test #13 - Citrus Sludge w/ Dygest506
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
Discharge
Day 10
Day 15
Day 21
Day 28
Total Nitrogen
Phosphorus
Potassium

Chart 13


Test #14 - Biosolids w/ Dygest506
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
Discharge
Day 10
Day 15
Day 21
Day 28
Total Nitrogen
Phosphorus
Potassium

Test #15 - Biosolids w/ Ortec



Test #16 - Citrus Sludge w/ Ortec

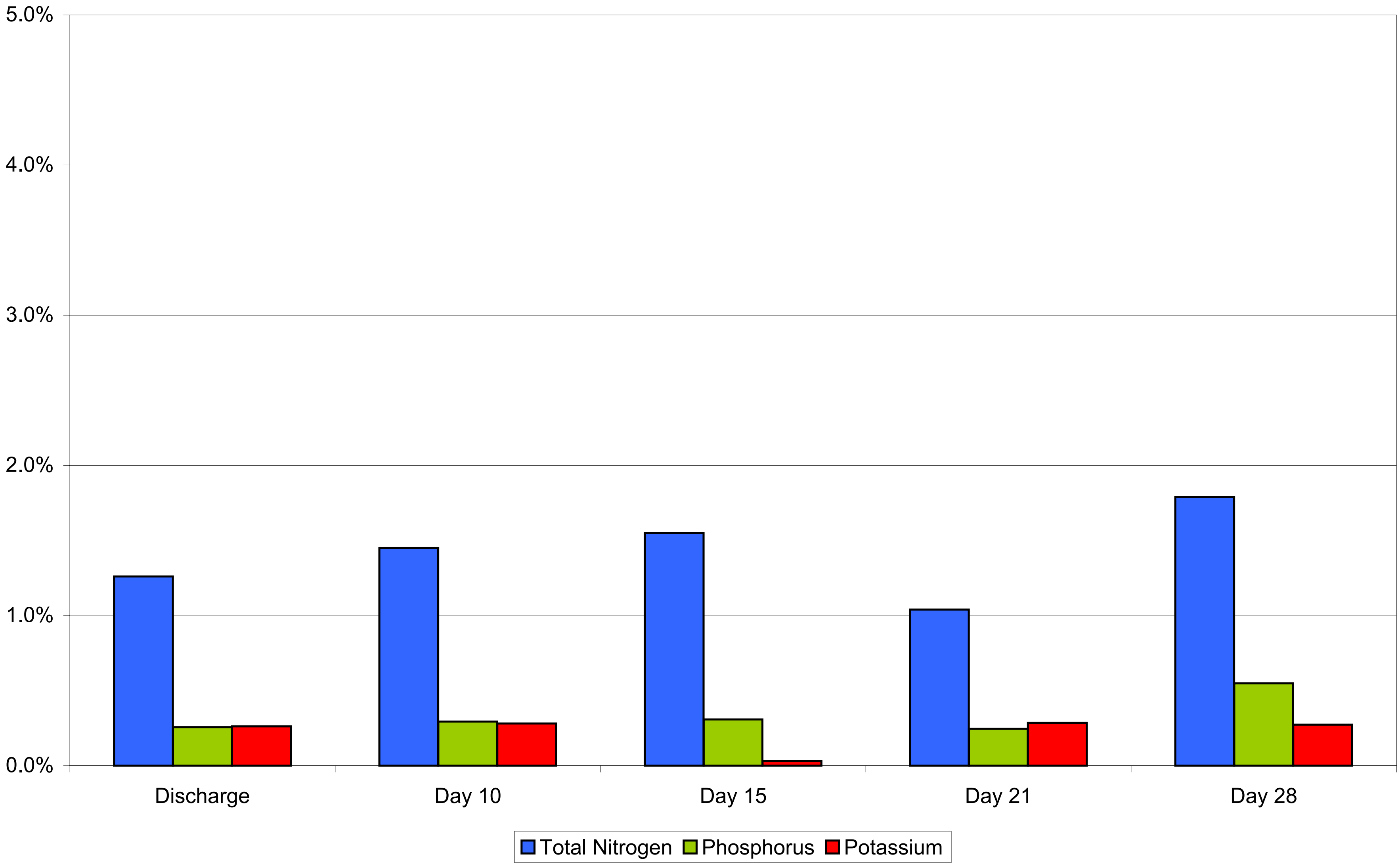
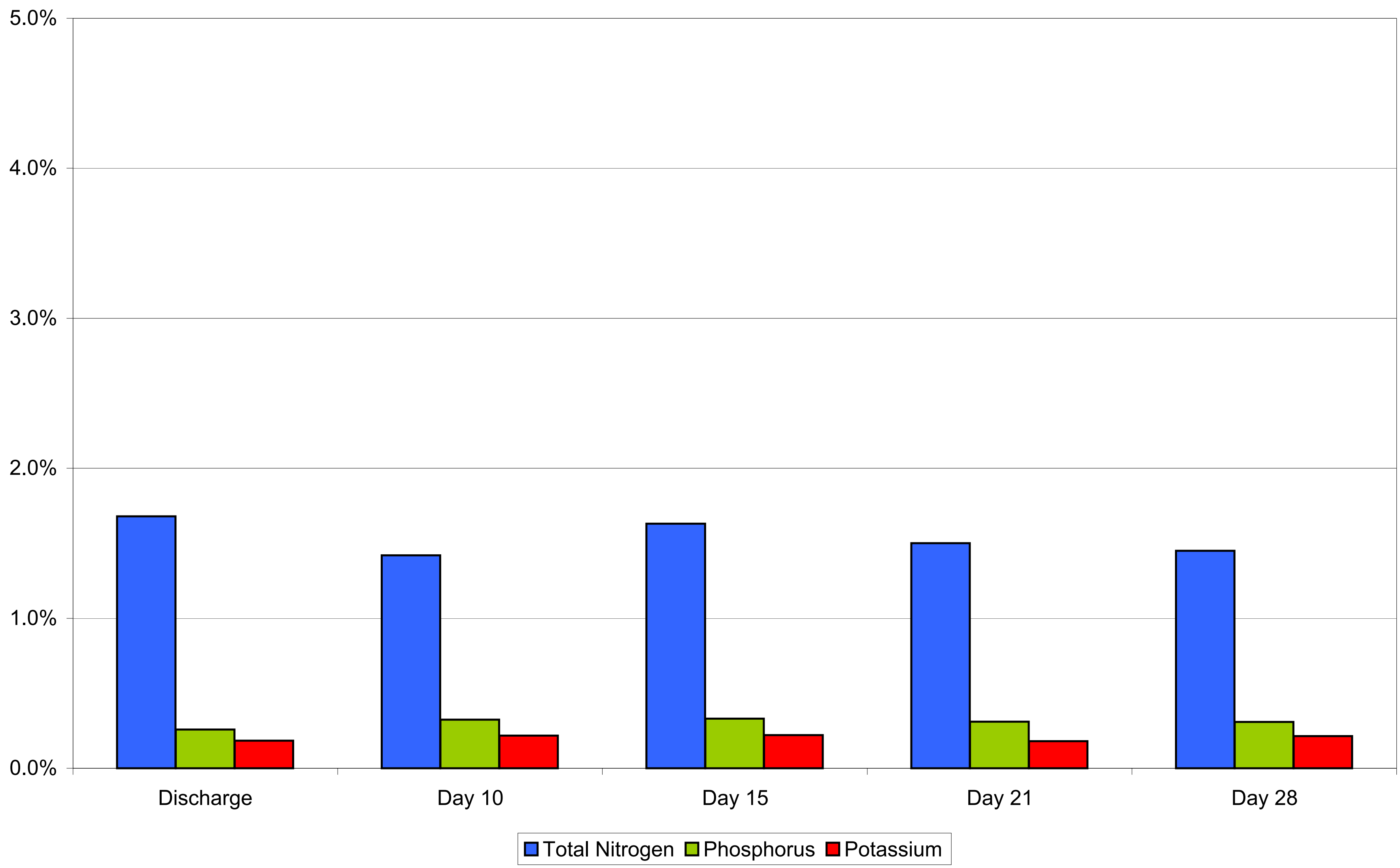


Chart 16

Test #17 - Biosolids & No Inoculant w/ Ortec



APPENDIX D

COMPOST CHARACTERISTICS – MARKET PARAMETERS

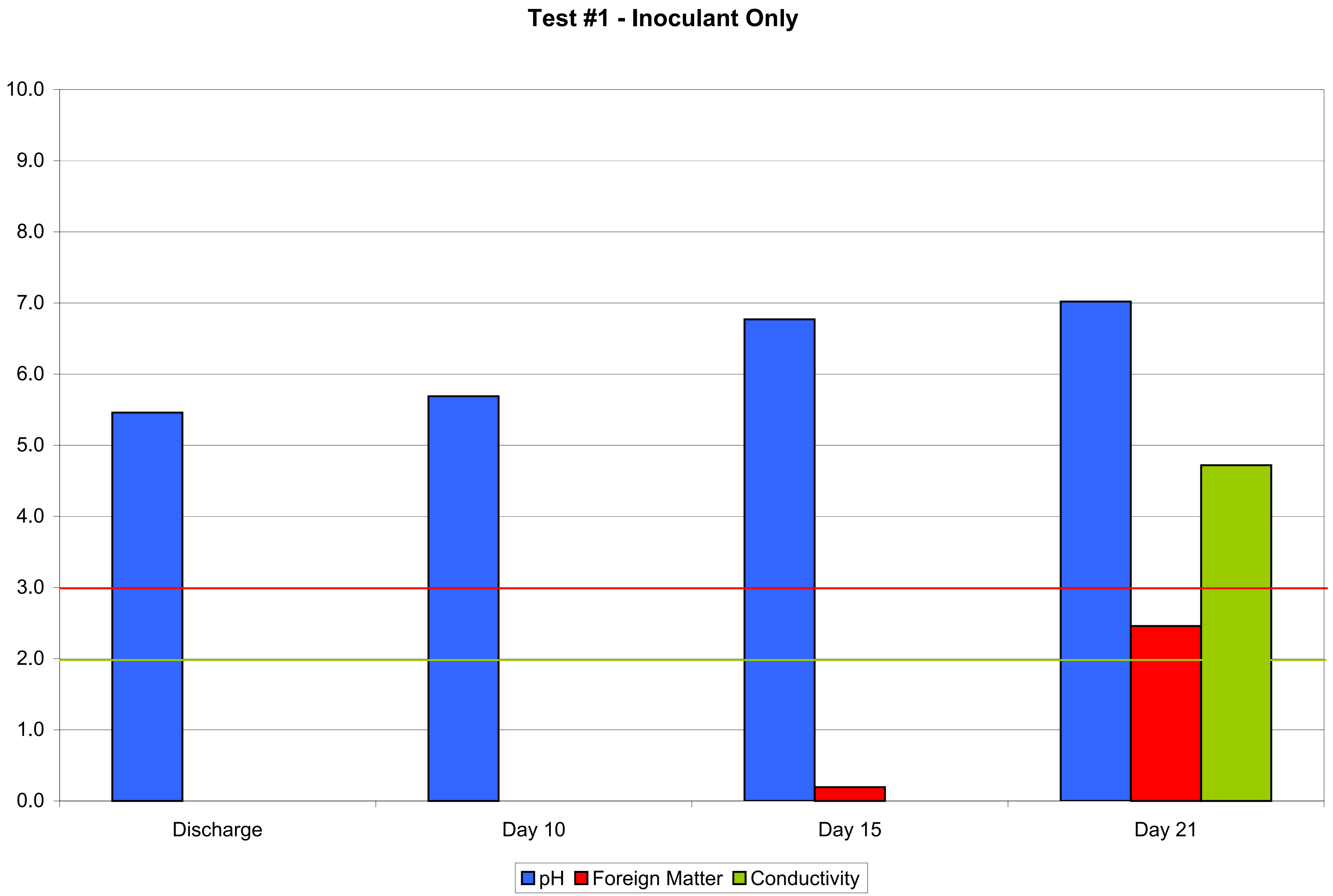
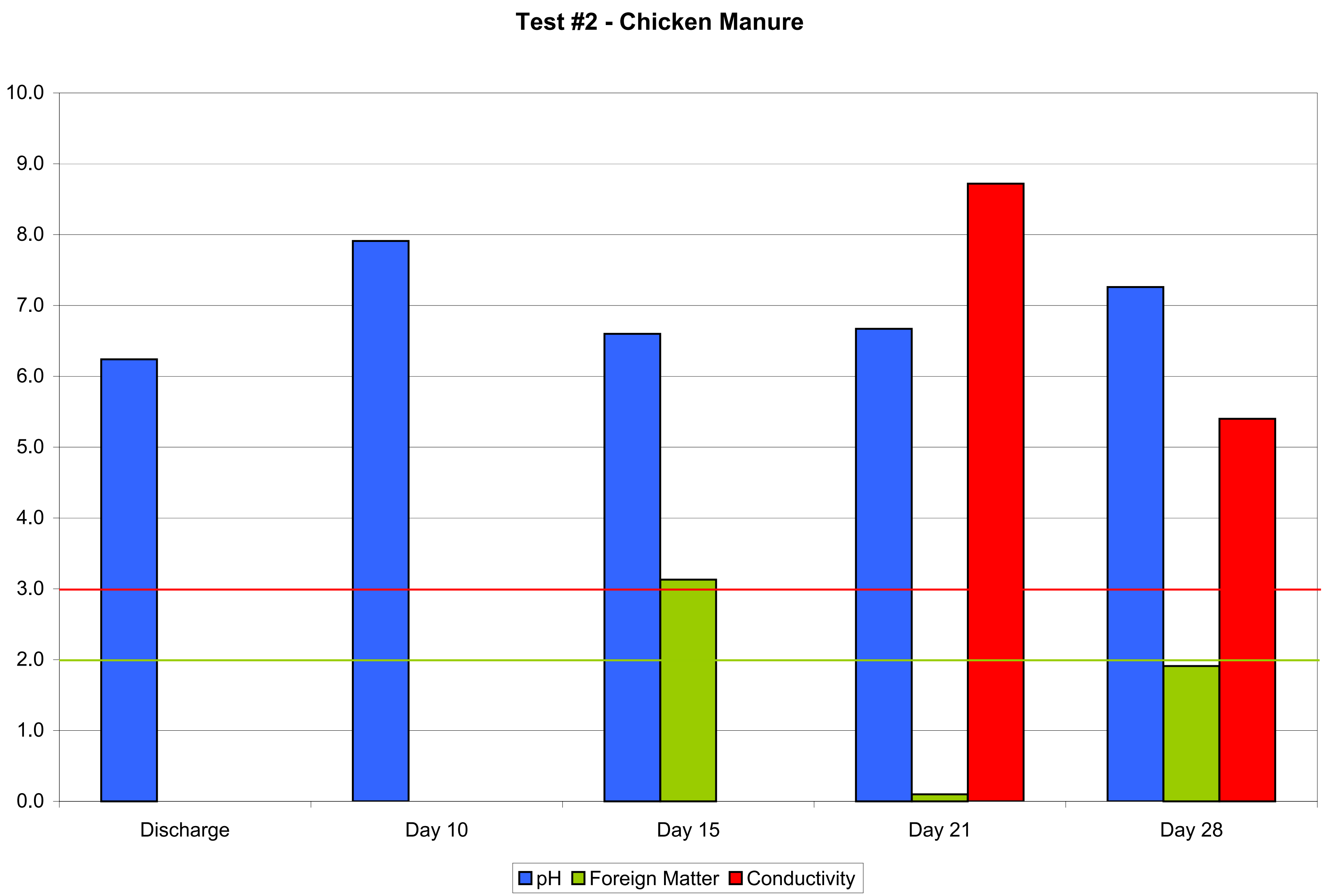
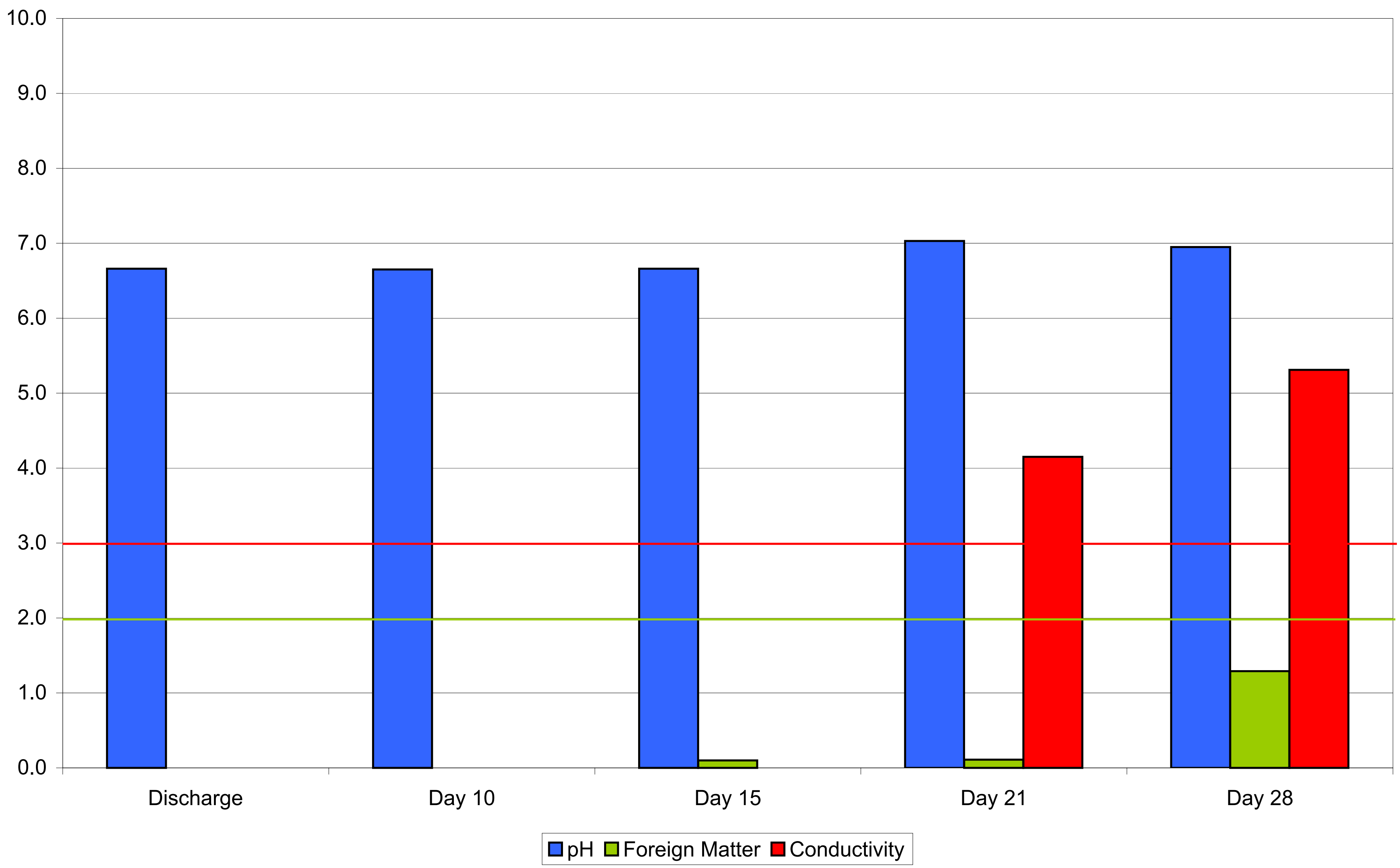

Test #1 - Inoculant Only
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Discharge
Day 10
Day 15
Day 21
pH
Foreign Matter
Conductivity

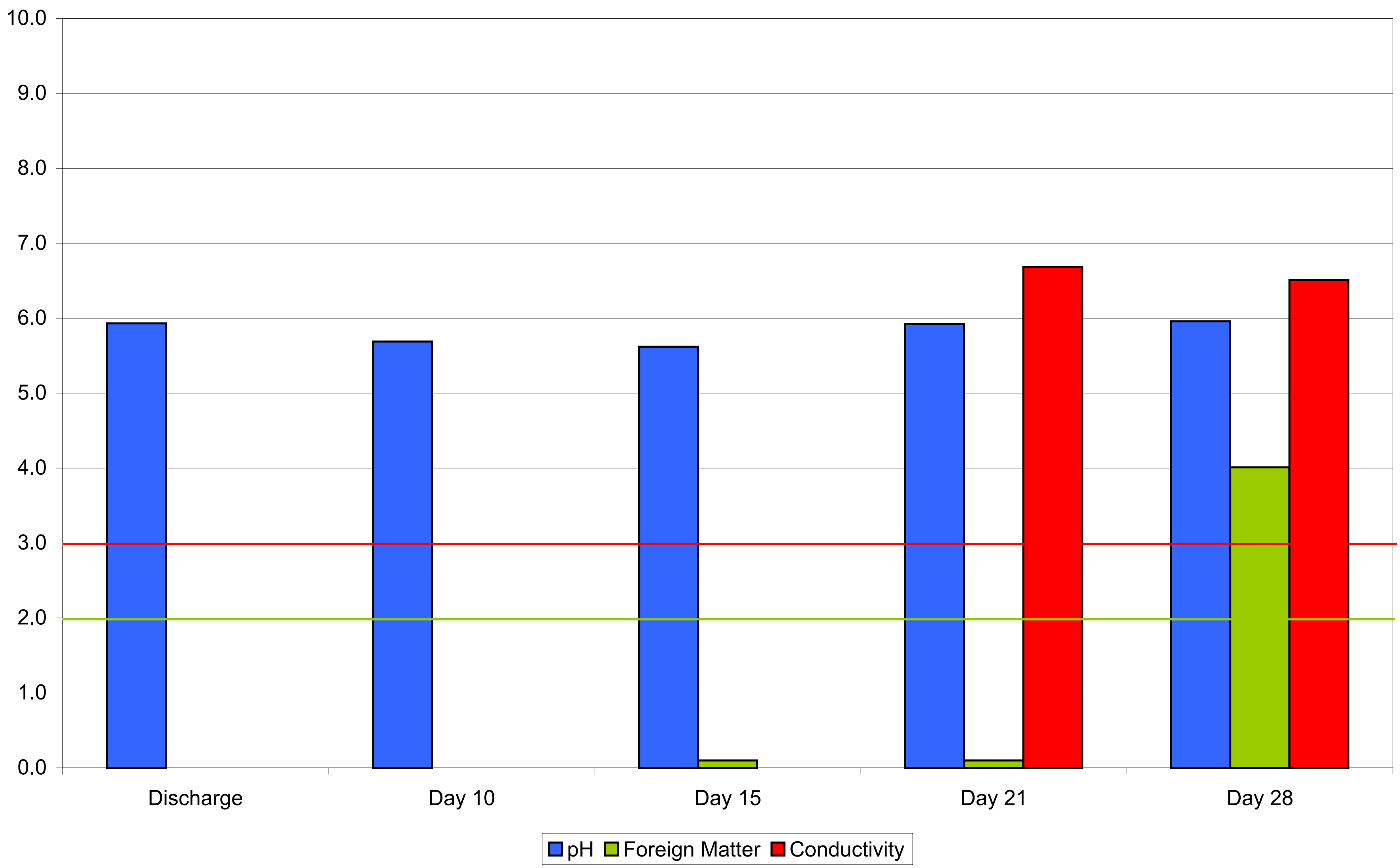
Chart 1


Test #2 - Chicken Manure
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Discharge
Day 10
Day 15
Day 21
Day 28
pH
Foreign Matter
Conductivity

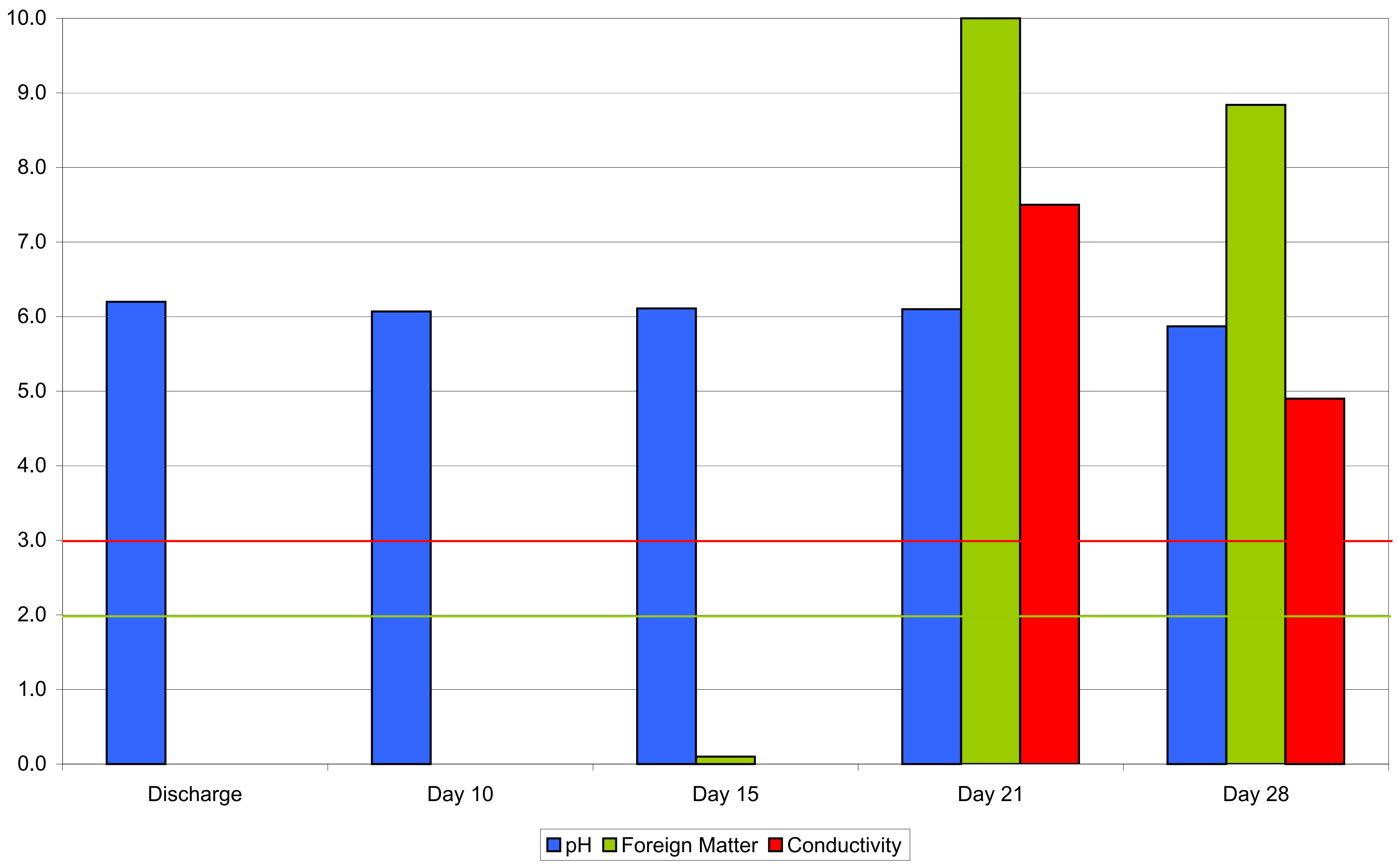
Test #3 - Chicken Manure & Biosolids

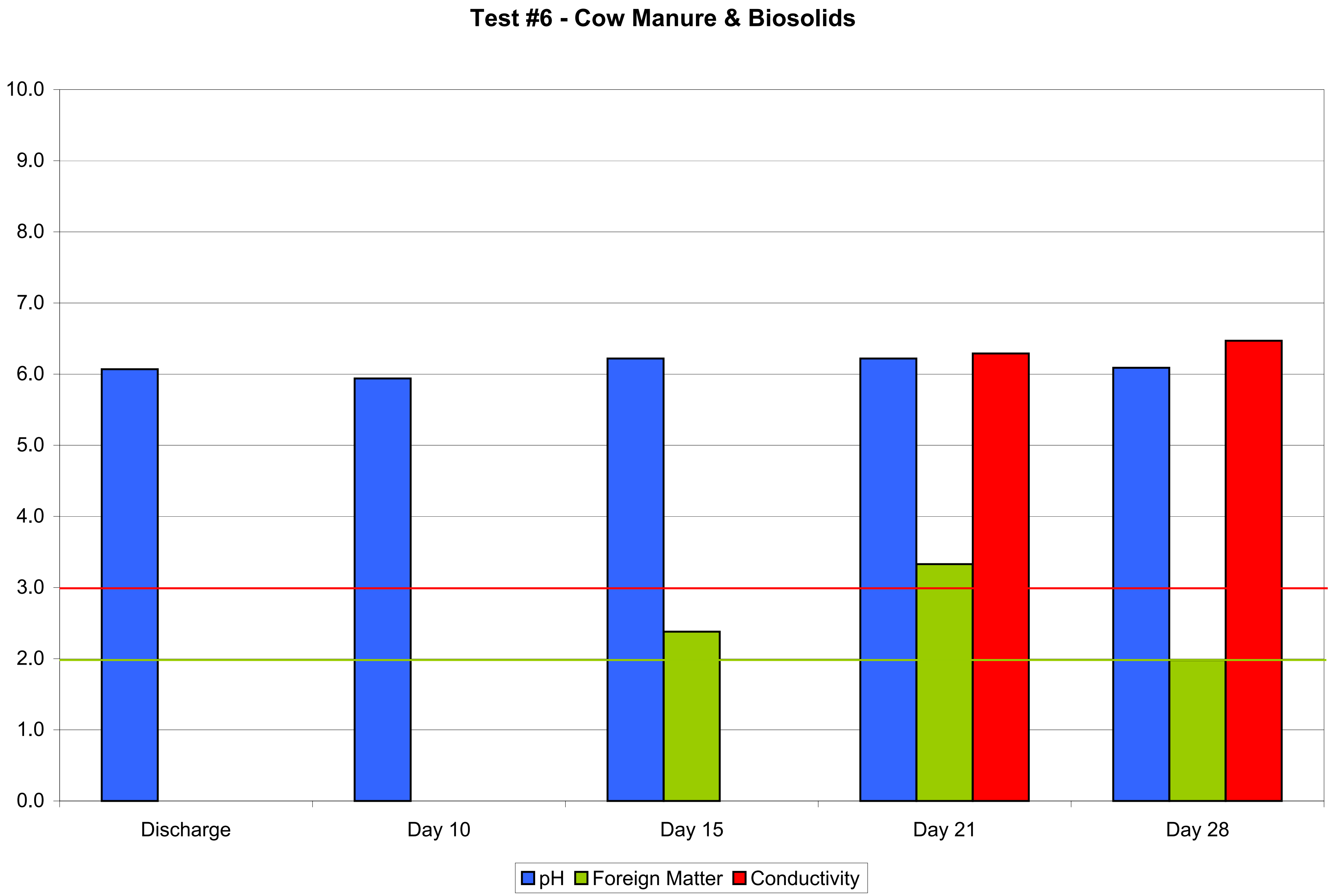


Test #4 - Chicken Mortalities & Biosolids

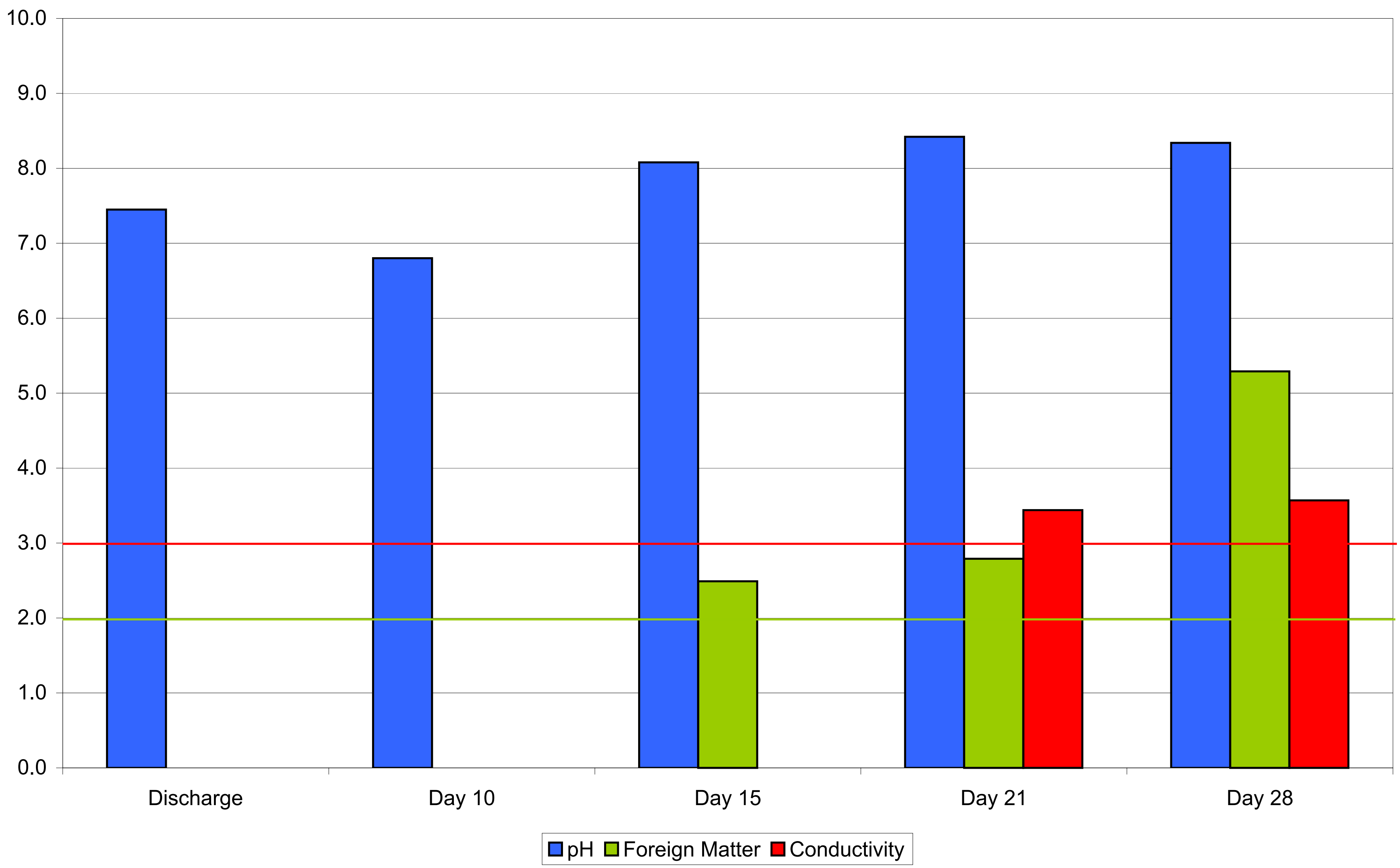


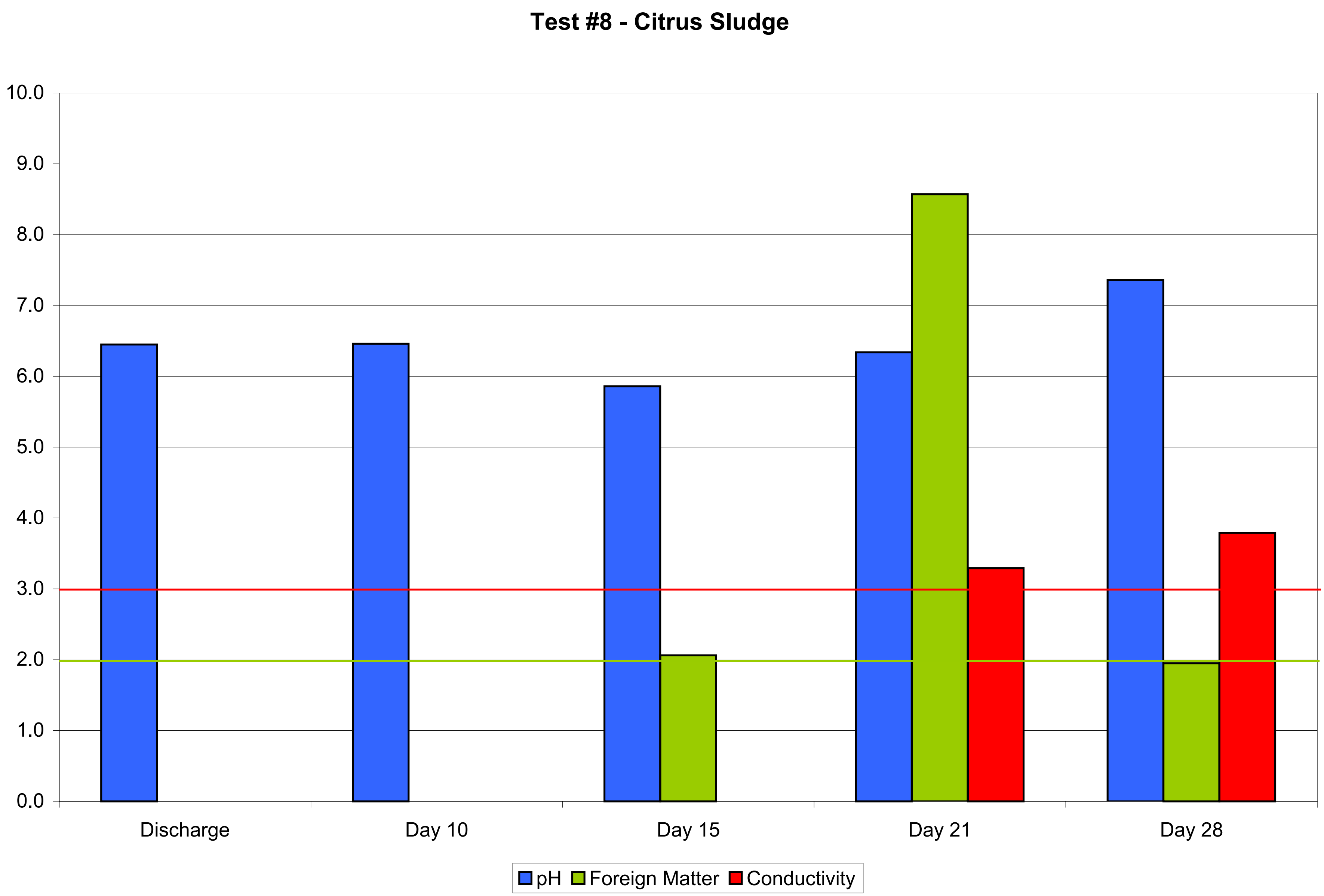
Test #5 - Chicken Mortalities



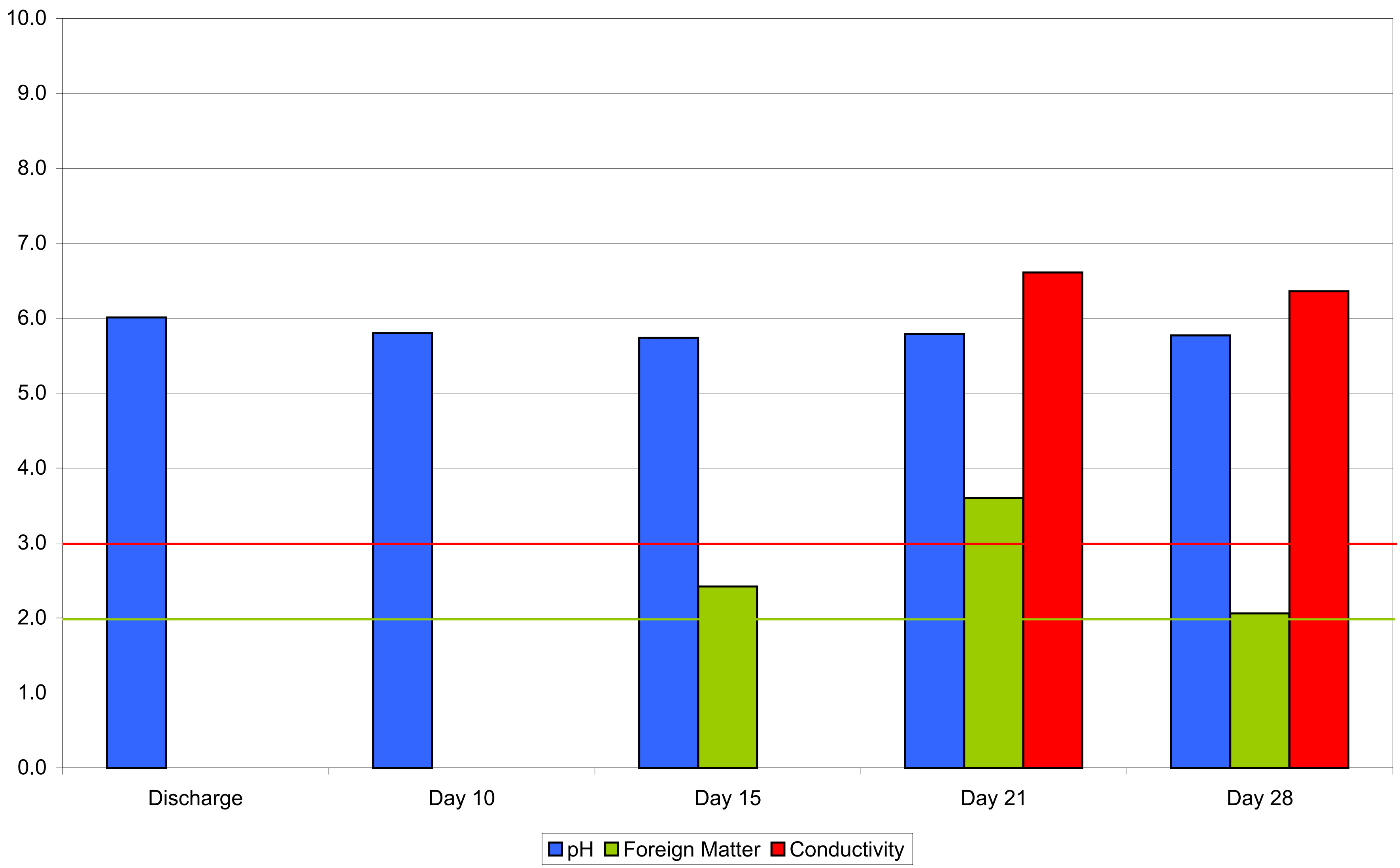

Test #6 - Cow Manure & Biosolids
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Discharge
Day 10
Day 15
Day 21
Day 28
pH
Foreign Matter
Conductivity

Test #7 - Cow Manure




Test #8 - Citrus Sludge
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Discharge
Day 10
Day 15
Day 21
Day 28
pH
Foreign Matter
Conductivity

Test #9 - Citrus Sludge & Biosolids



Test #10 - Biosolids

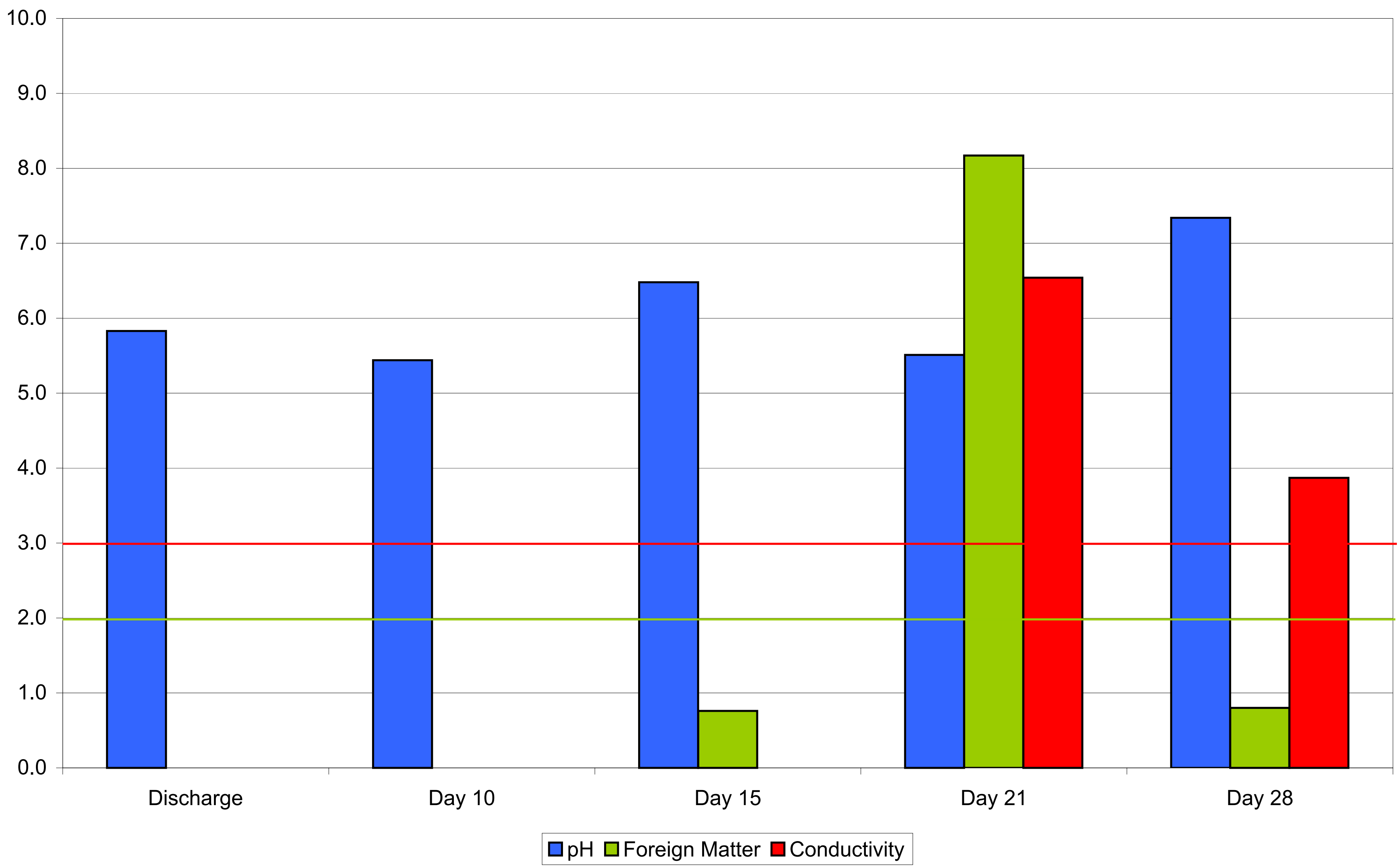
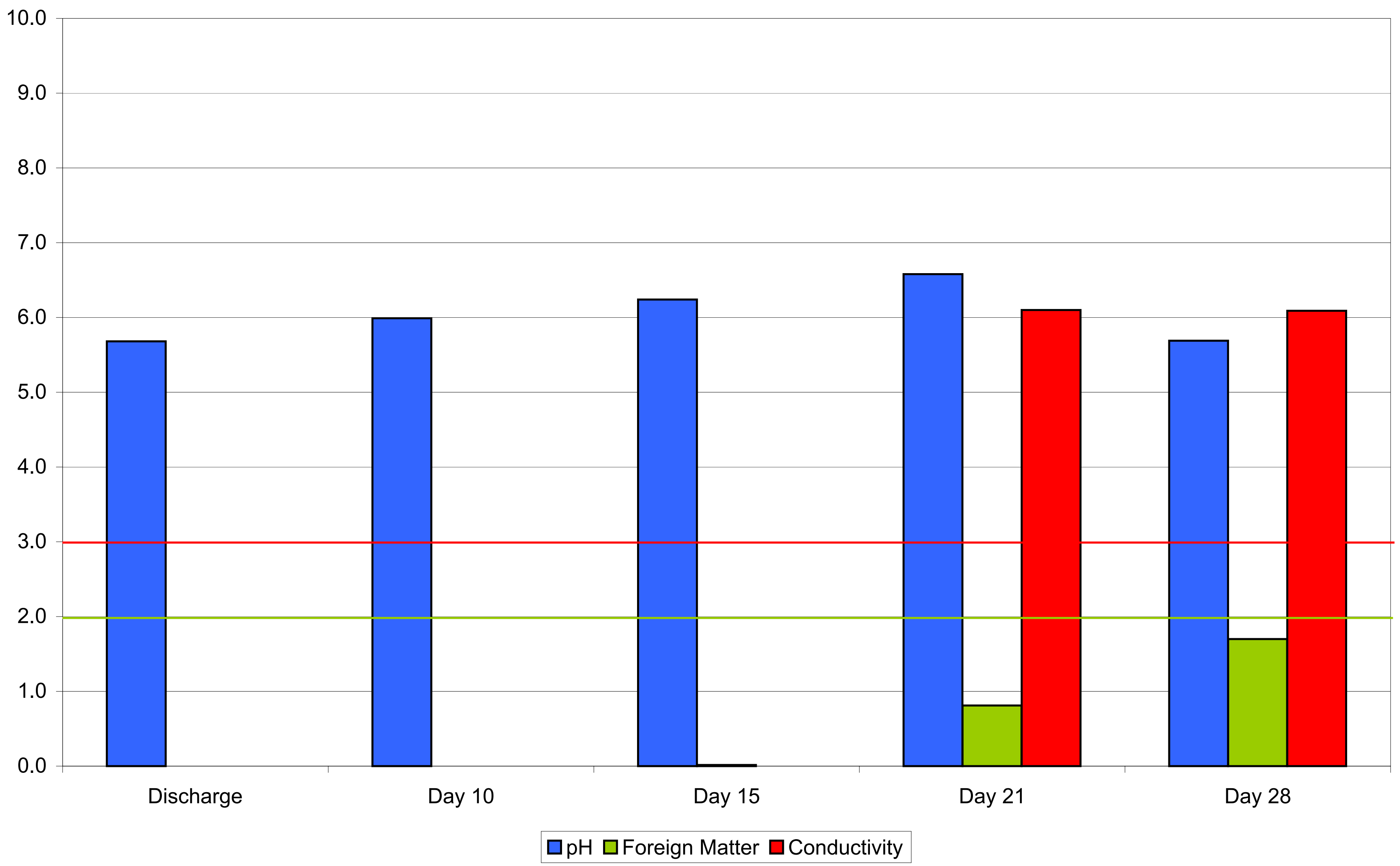
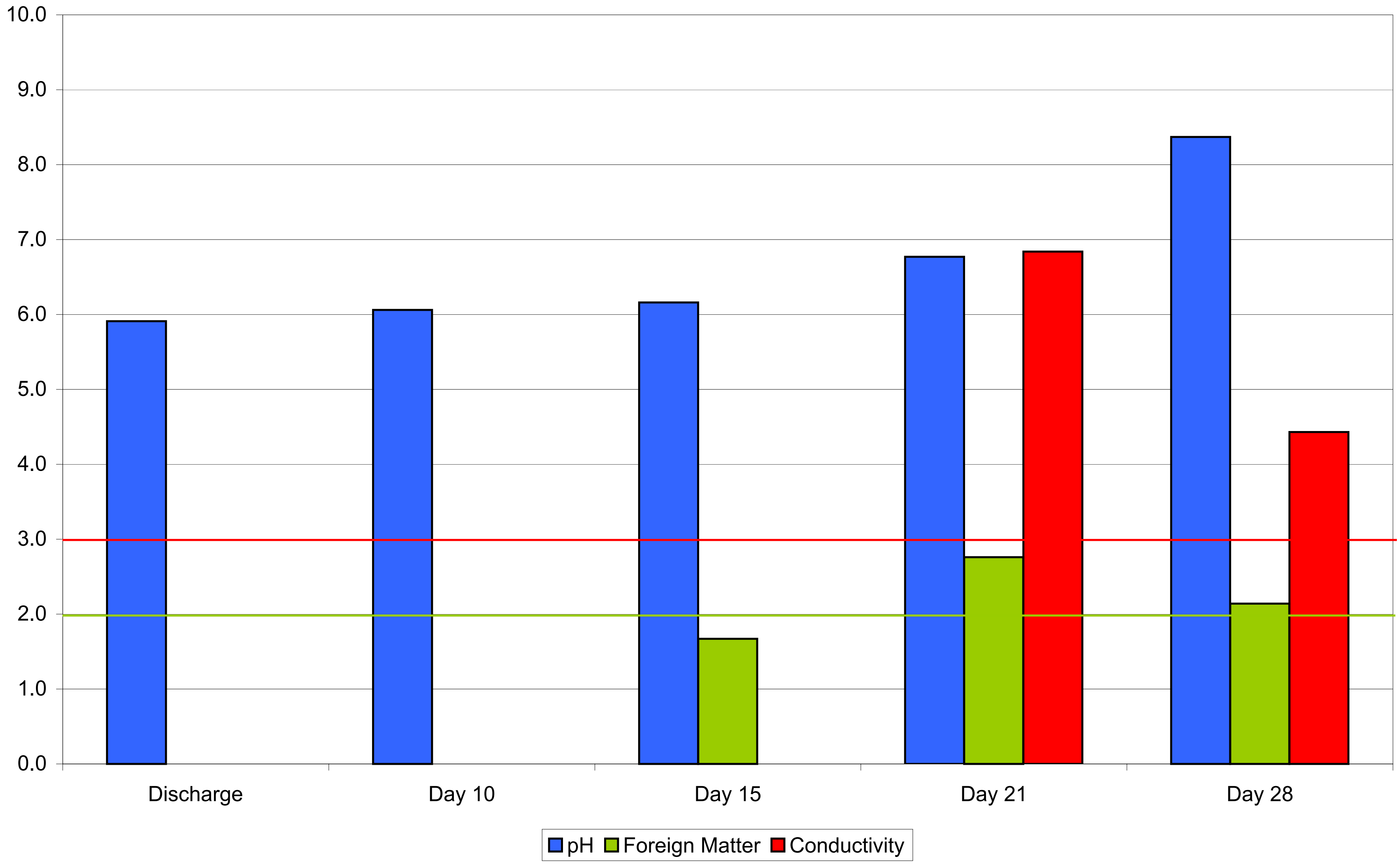


Chart 10

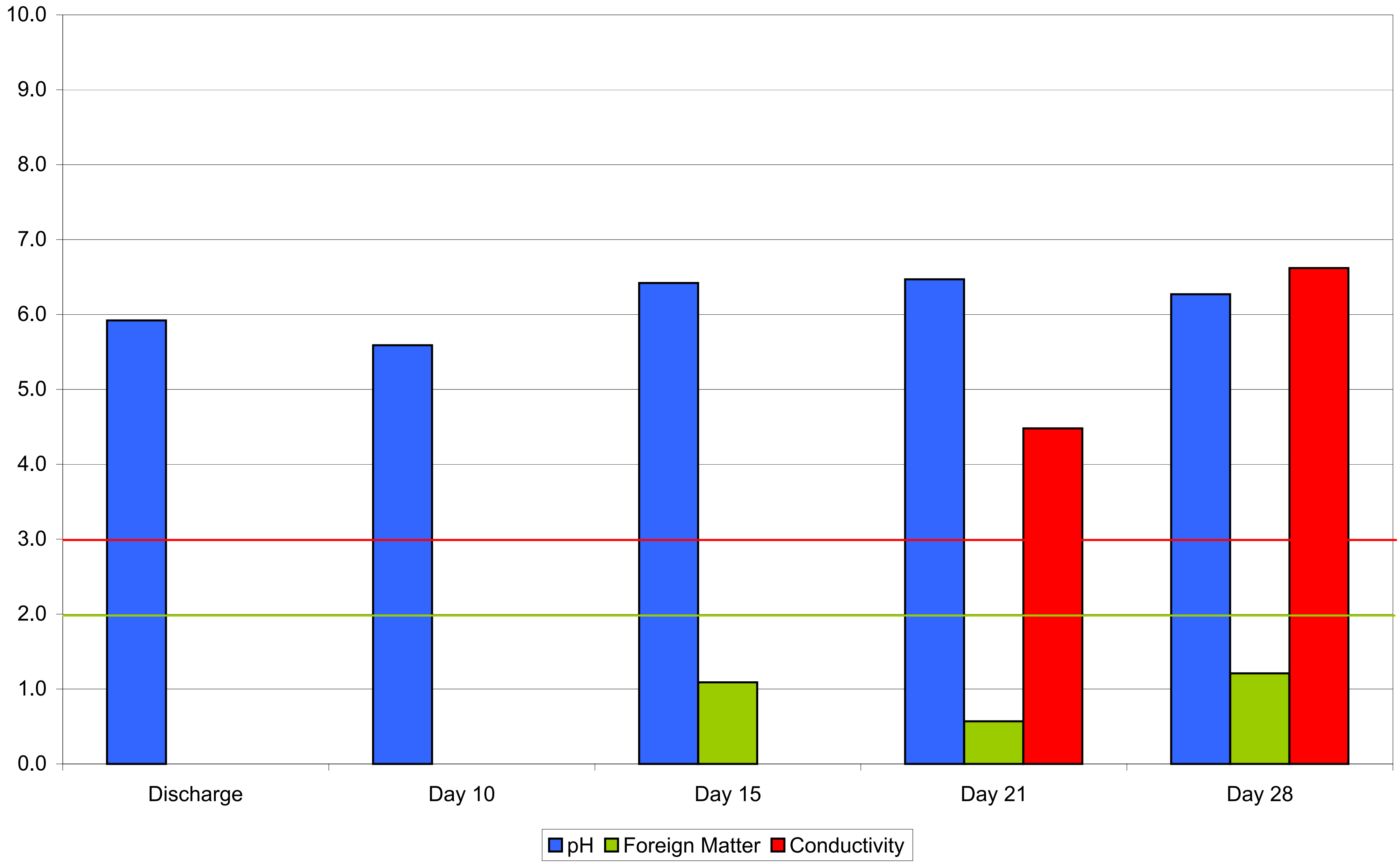
Test #11 - Biosolids & No Inoculant



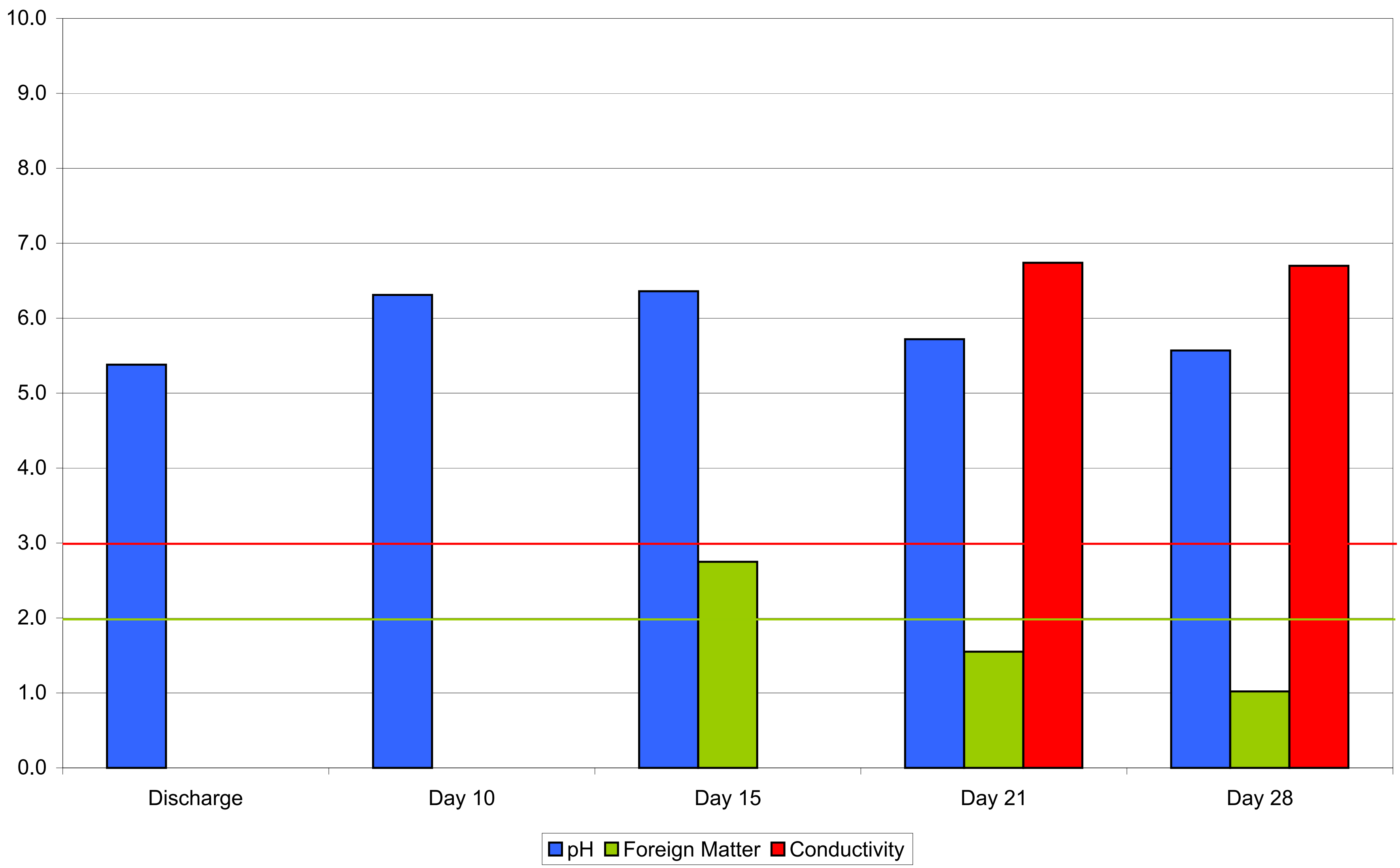
Test #12 - Biosolids & No Inoculant w/ Dygest506



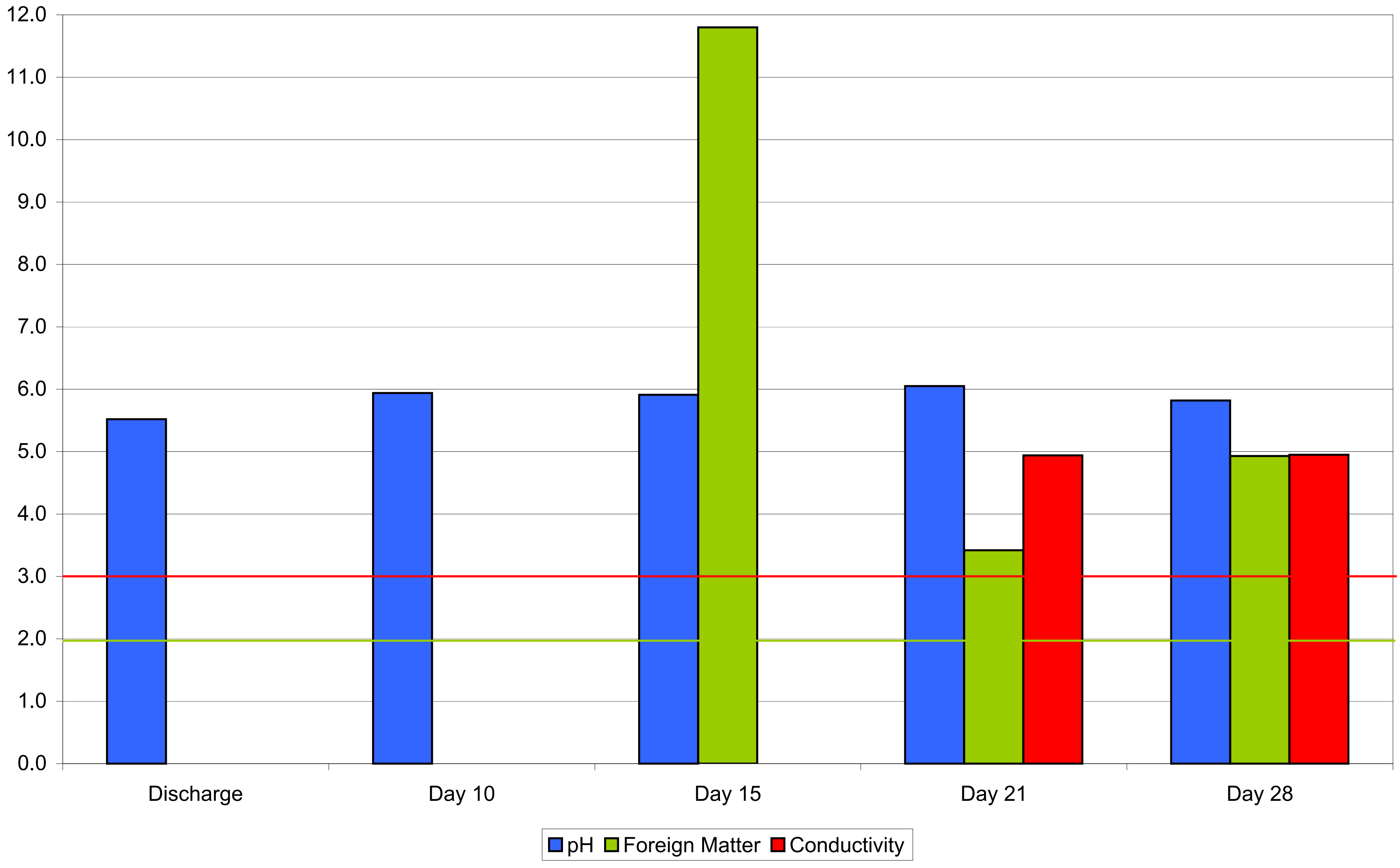
Test #13 - Citrus Sludge w/ Dygest506



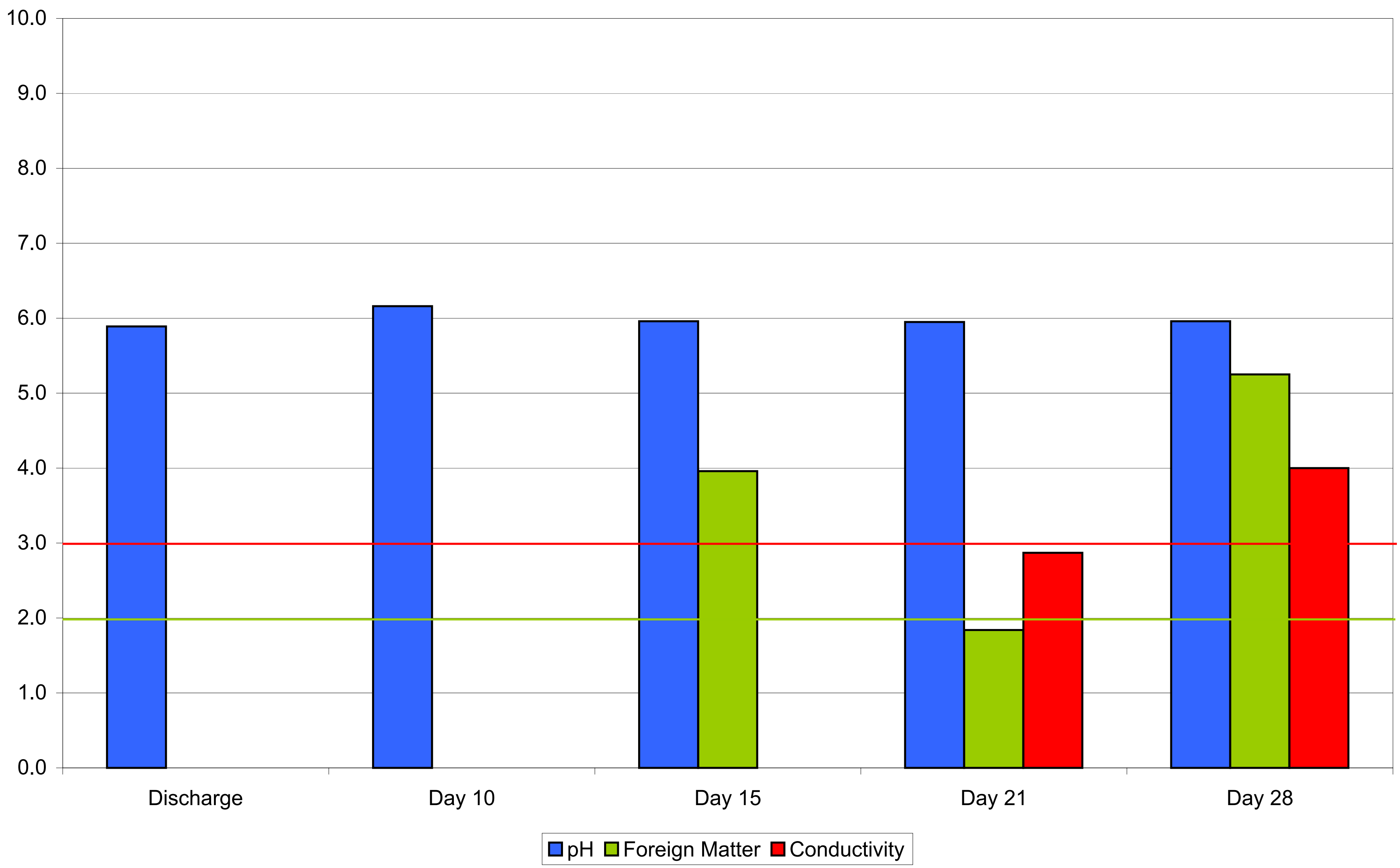
Test #14 - Biosolids w/ Dygest506



Test #15 - Biosolids w/ Ortec



Test #16 - Citrus Sludge w/ Ortec



Test #17 - Biosolids & No Inoculant w/ Ortec