Project MLMMI 03-01-06 Fluctuations in Manure Nutrient Concentration during Swine Storage Pump-outs

A detailed analysis of ammonia, total kjeldahl nitrogen, phosphorus, potassium, and moisture content profile every 5% increment throughout the pump-out of a circular, single-cell, and two-cell manure storage system.

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Introduction

This study was initiated to better understand the changing composition of manure samples within a storage and between different liquid swine manure storages used in Manitoba. In a recent study done by Fitzgerald and Racz, 2001, various storages across Manitoba were sampled and analyzed. This study found large variations between hog type (finisher, nursery, sow) and at different levels in the storage. (top, middle, or bottom) It is well known that stratification, settling of solids, occurs in all types of storages and when agitated the solids are mixed back into the liquids. This project will look at a single-cell, two-cell, and a circular storage system during a typical application and characterize the nutrient composition.

Description of Study

1. All applications were done via the same drag-hose applicator.
2. Sampling at the single-cell, and two-cell storages were done via a composite sampling method over 3-5 minutes at the specified sample time (drawing a mixed sub-sample from the pail) Sampling of the circular storage was taken as a static sample at the specified sample time. All samples were drawn from a small hose coming off the pump. All samples placed into a cooler until the end of the pumpout when they were taken directly to the lab.
3. Applications represented a full pumpout. The circular storage has 350 days storage while the single-cell and two-cell systems are designed for 400 days storage. The two-cell system had 2-3 feet left in the secondary cell.
4. Normal agitation practices were performed during the pumpout.
   Circular storage: 2 large propellers are lowered into the storage. Running off a portable power source, the propellers turn the contents of the storage in a circular motion.
   Single-cell storage: A Houle agitator, with propeller and gun was moved to 5 different locations during the pumpout. See figure 1 for diagram and description. (all figures in appendix at back of report)
   Two-cell storage: A Houle agitator is placed in one position in the primary cell for the entire pumpout. See figure 2 for diagram and agitator description. (Note this pump-out and agitation stopped for Sunday.)
5. Samples were taken at every 5% increment of the pumpout.

6. The following analysis was performed on all the samples. Total Kjeldahl Nitrogen, Ammonium in liquid manure by distillation, mineral analysis of liquid manure phosphorus, mineral analysis of liquid manures potassium, and Moisture at 104C. Norwest Labs performed all analysis.
7. All samples were stored in sealed containers provided by the lab. The samples were then maintained in a cooler. No additional cooling was introduced to the cooler. The mean air temperatures for the 3 storage types were as follows (listing the days from the beginning of the pumpout till sample arrived at the lab-all samples given to the lab 1 day following the pumpout completion): circular storage 21, 18, 17, 19 degrees Celsius, two cell storage 8, 0, -1.5, 0, 0 degrees Celsius, and for the single cell storage 15, 18, 9 degrees Celsius. All temperature data taken from Environmental Canada website. http://climate.weatheroffice.ec.gc.ca

Results:

See Figure 3: Single Cell, Figure 4: Two Cell, and Figure 5: Circular Storage
The following statistics were produced in another statistical program. (Minitab Statistical Software)
(note: TrMean = trimmed mean which is has the smallest and largest 5% of values removed)
(note: all variables are given in kgs/1000 L. except for Moisture (%))

Circular Storage:

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Ammonia	21	1.9619	2.0000	1.9632	0.0498	0.0109
Phosphor	21	0.6257	0.4900	0.5663	0.4027	0.0879
Potassium	21	1.0148	1.0100	1.0126	0.0191	0.0042
Moisture	21	98.552	99.000	98.721	1.054	0.230
TKN	21	2.3905	2.3000	2.3526	0.3097	0.0676

Single Cell Storage:

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Ammonia	23	1.7217	1.6000	1.6905	0.2194	0.0458
Phosphor	23	1.079	0.870	0.995	0.831	0.173
Potassiu	23	1.4052	1.3800	1.3857	0.1213	0.0253
Moisture	23	96.287	97.400	96.695	3.201	0.668
TKN	23	2.778	2.500	2.681	0.887	0.185

Two-Cell Storage:

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Ammonia	20	2.9100	2.8500	2.9111	0.2789	0.0624
Phosphor	20	1.099	0.635	1.037	1.049	0.235
Potassiu	20	1.5175	1.5150	1.5172	0.0436	0.0098

Moisture	20	95.885	97.200	95.994	3.026	0.677
TKN	20	4.155	3.650	4.111	1.271	0.284

Discussion of Results

Comments on each storage system:

1. Single Cell Storage: The single cell system had two time periods of the pumpout, which were not stable or predictable. These occurred at the beginning of the pumpout when the agitator and pump were first turned on and at the end when the liquids were almost all gone. Phosphorus concentrations increased throughout the pumpout. Highly soluble components such as potassium and ammonium-N remain stable and do not fluctuate. The overall nitrogen to phosphorus ratio is 2.6:1. Depending on the thoroughness of the agitation job from year to year, one year can have a higher solids content if the previous pumpout did not remove the year's accumulation of solids. This issue is very important for phosphorus since the amount of phosphorus increases with solids content. This nitrogen to phosphorus ratio (N:P) is expected to increase in this manure storage since phytase and a reduction in phosphorus in the feed has been implemented in the past 10 months.
   The phosphorus concentration increases notably at 500,000 gallons, which can be correlated with the movement of the agitator. After the initial increase in phosphorus it tails off till 760,000-gallon mark where the agitator is moved again.

   Management Considerations:
   The product in this storage system is not segregated and therefore treatment options would have to treat the entire storage system. For the two time periods of higher phosphorus %'s this portion of manure should be placed on fields with lower phosphorus soil tests and further away from watercourses (based on Ontario's regulation, a higher soil phosphorus test close to a watercourse increases the phosphorus index rating). Additionally, if there was more agitation prior to starting the pumpout the initial high moisture content should be decreased.
   Since the ammonium-N does not change significantly after the first 5% of the pumpout, taking several NOVA meter tests at this point should provide sufficient data to set an application rate based on ammonium.
   For manure laboratory analysis it is important to take a composite sample which should average the entire storage into one sample (a composite sample minimum rather than a static sample). Since the phosphorus and dry matter trend up during the pumpout, obtaining a composite manure sample of the first 50% and second 50% would be preferred.

2. Two-Cell Storage: This storage system has stable potassium concentrations. The pumpout can be divided into 3 time periods: 1. Primary cell only (0 – 500,000 gallons) 2. Mixture of primary and secondary contents (500,000 – 800,000 gallons) 3.

Mostly secondary contents flowing through primary (800,000 – till the end) (note: gallon amounts will depend on size of the storage.) The ammonium-N concentration does appear to be statistically different between the primary and secondary cells. The N:P ratio was 3.8:1 from this finisher operation but is expected to increase in the future with the addition of phytase and reduction of phosphorus in the feed implemented in the last 10 months.

Management Considerations:
Based on treating this storage as 3 separate storages, the rate of application, based on ammonium-N, taken by the NOVA meter, would be adjusted for each portion of the pumpout. This would require separate NOVA meter readings for these three concentrations of ammonium-N. The relative differences in TKN should also be factored in from these 3 different storage analyses to adjust the nitrogen application rate. Therefore it is suggested to take three different manure samples throughout the pumpout from these 3 distinctive times.
Phosphorus should also be managed on the basis of 3 different nutrient compositions. Phosphorus deficient soils should receive the first manure where the N:P ratio is from a 2:1 to a 3:1. Application rates based on crop balance for the middle portion of the storage where the N:P ratio is 4:1 to 6:1 can be implemented using a phosphorus maintenance fertility program. The last portion of the pumpout can either go on fields with high soil phosphorus or to fields where additional phosphate fertilizer may be required. (based on N:P ratios of 9:1 to 35:1) The other option would be to use primary manure on one piece of land in a 3 to 4 year rotation and using the mixture and secondary manure in the other years.
The two-cell system has the unique opportunity to apply advanced treatment options to the primary cell of the storage. A portable separation device could be used to pre-separate the solids from the primary cell and place the liquid portion into the secondary cell. This would only require a treating of 25% to 30% of the annual manure. This may be a more economic solution than using separation on the entire storage volume. This would also ensure that the liquid portion of the manure would all have an N:P ratio 7.9:1 and higher. This ratio would allow for no long-term accumulation of phosphorus in both annual and perennial cropping systems.

3. Circular Storage: This storage has very stable ammonium and potassium concentrations. During the last 20% of the storage pumpout the N:P ratio, phosphorus, and moisture concentrations all fluctuated significantly and are consequently not stable or predictable. This is somewhat expected as this storage system has a buildup of solids in the bottom from current agitation practices (2 propeller drives which circulate the contents in a circular motion which leaves a cone of solids in the middle of the storage). The average N:P ratio was 3.8:1 but again will increase as the effect of phytase is realized over an entire pumpout's manure.

Management Considerations: There is a slow drop in the N:P ratio throughout the pumpout. Since the phosphorus slowly increases throughout the pumpout the fields which have the highest residual phosphorus should receive the first manure. If there were an opportunity for separation of a portion of the pumpout this would be performed during the last 20% of the pumpout. It is suggested that at least one composite manure sample be taken for laboratory analysis. The ammonium-N concentration does not change and therefore a series of NOVA meter tests any time during the pumpout should be sufficient.

Comments on all storages:

Figure 6 shows a matrix plot of all the parameters being plotted against each other in the x and y axis. This type of a plot shows regression relationships. The relationships which sticks is via the moisture to phosphorus relationship. Additionally there is a relationship between organic N vs. moisture. A regression analysis of moisture to phosphorus (Figure 7) shows 92.2% R-sq (adj.) between these two parameters. A hydrometer is one tool that can be used to determine specific gravity of a manure sample. As indicated on the Manitoba Agriculture web site "Estimates of total N and total P in manure can be determined using a hydrometer, an instrument which measures the specific gravity, or density, of a liquid. This method is based on two premises: that the density of manure varies with its dry matter, or solids, content; and that total N and total P concentrations vary with dry matter content." This data reinforces the notion that Total P varies with dry matter content. Since there has been significant discussions on phosphorus regulations in Manitoba, being able to determine phosphorus values at the time of application would be a valuable tool.

The data suggests that there could be more intensive look at data modeling using a Nova meter and hydrometer to provide a more prescriptive application rate determination in the field.

Since it is apparent that phosphorus, TKN, and N:P ratios vary significantly with moisture content, agitation practices play a key role in achieving a homogeneous concentration of these nutrients. The other type of storage system, which needs to be examined, is the deep pit barn.

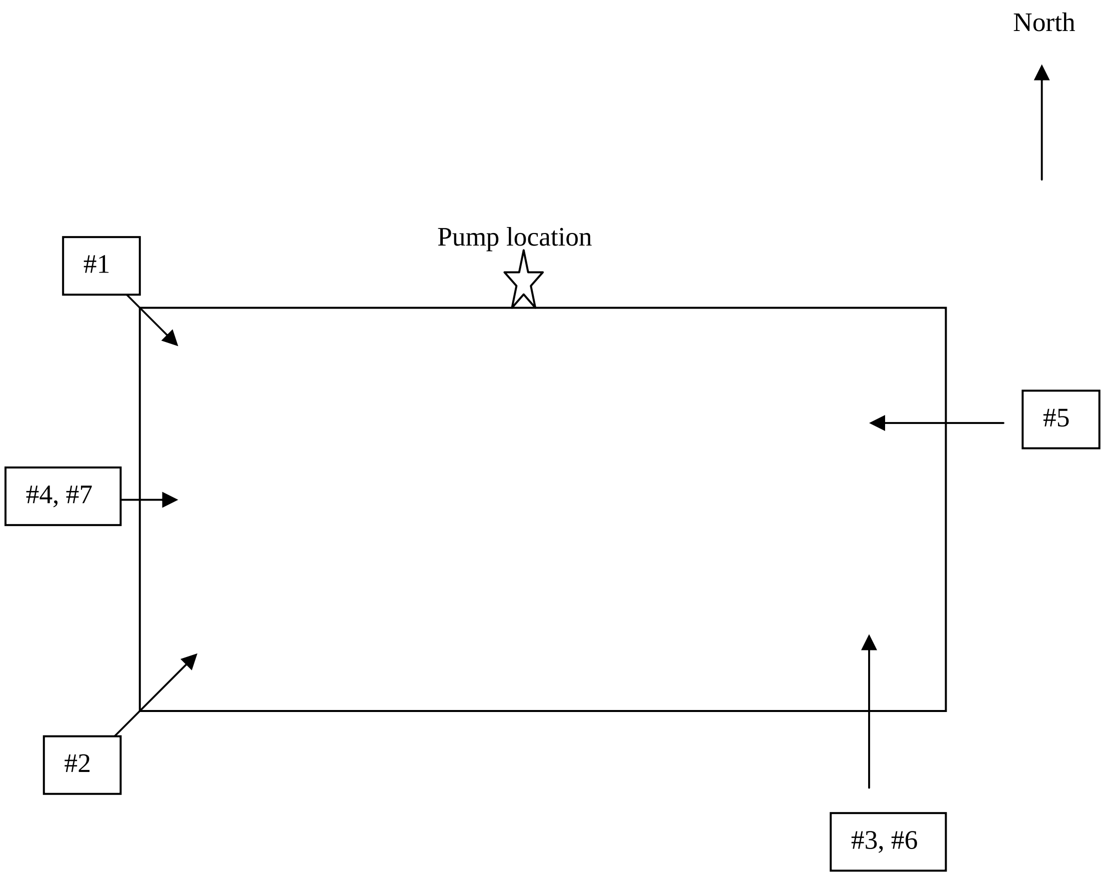
Only by understanding the nature of the liquid nutrients can we establish more prescriptive instructions to the applicators and a more uniform application for the cash cropper.

References

Fitzgerald and Racz, Long-term effects of hog manure on soil quality and productivity Volume 1: Properties and composition of hog manure samples. MLMMI, 2001.

Manitoba Agriculture Website.
http://www.gov.mb.ca/agriculture/livestock/poultry/bba01s24.html

Figure 1: Agitator description for single-cell storage
(arrows represent position and direction of agitator)



Agitator times:
#1: Day 1: 11:15am –6:45pm (0 - 345,000 gal)
#2: Day 1: 6:45pm-11:00pm (345,000 – 500,000 gal)
#3: Day 1: 11:00pm-5:30am (500,000 – 760,000 gal)
#4: Day 2: 5:30am-7:36am (760,000 – 873,000 gal)
#5: Day 2: 10:40am – 12:55pm (873,000 – 984,000 gal)
#6: Day 2: 12:55pm-1:12pm (984,000 – 1,000,000 gal)
#7: Day 2: 1:12pm-2:45pm (1,000,000 – 1,100,000 gal)

Agitator down time: (moving of agitator, re-fueling process, and or hose movement)
Day 1: 3:10pm-3:55pm, 9:20pm-10:45pm
Day 2: 3:00am-4:40am, 7:20am-7:30am, 7:36am-10:40am, 2:45pm-3:35pm

Figure 2: Agitator Description of Two-Cell storage agitation
(arrows represent position and direction of agitator)

Pumpout started: Oct 24 1:30pm
Pumpout finished: Oct 27 8:30pm
Pumpout stopped Oct 25 from midnight till midnight

Agitator off
Day 1: 6:00pm – 6:15pm (approx. 150,000 gal)
Day 2: 7:50am – 8:05am (approx. 550,000 gal)
Day 3: off all day
Day 4: 12:15pm (approx. 1,050,000 gal) – end (once all solids gone from primary then agitator was stopped)

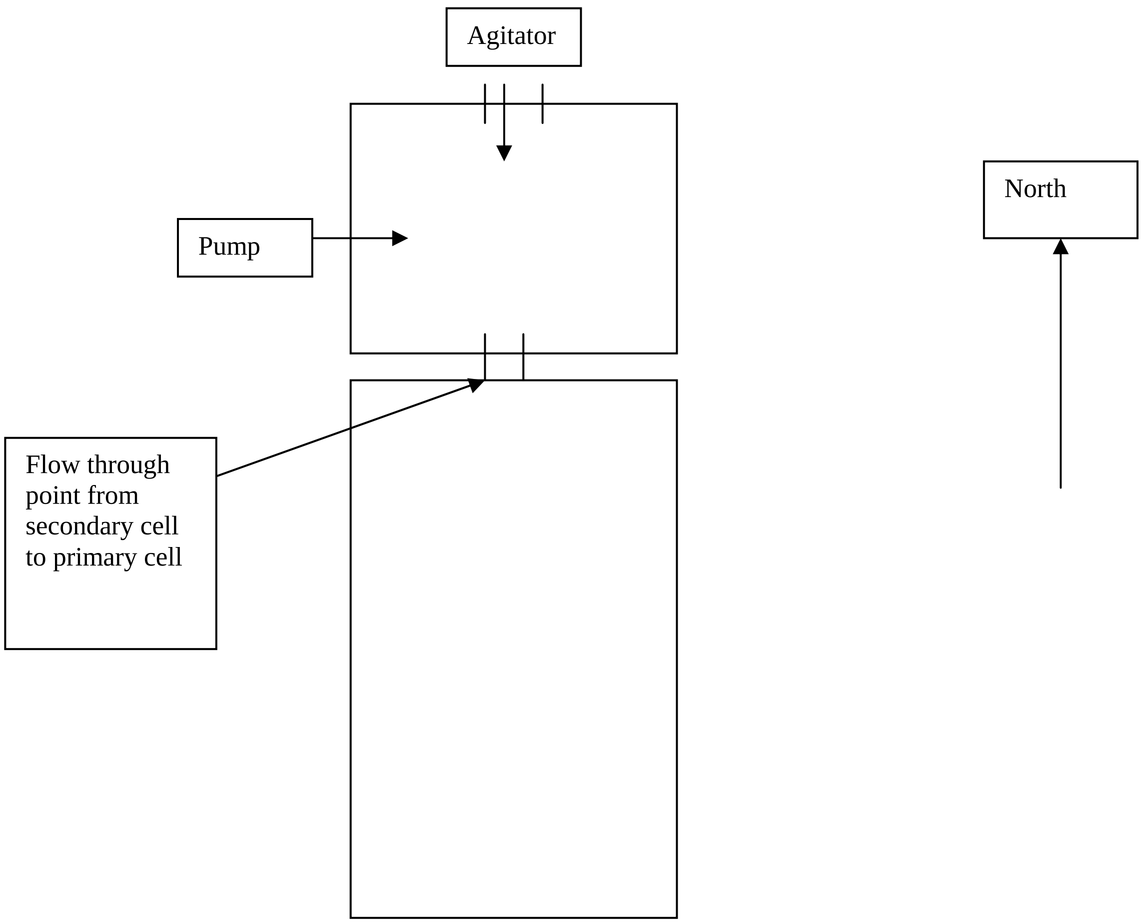


Figure 6: Matrix Plot of all storage systems pooled.

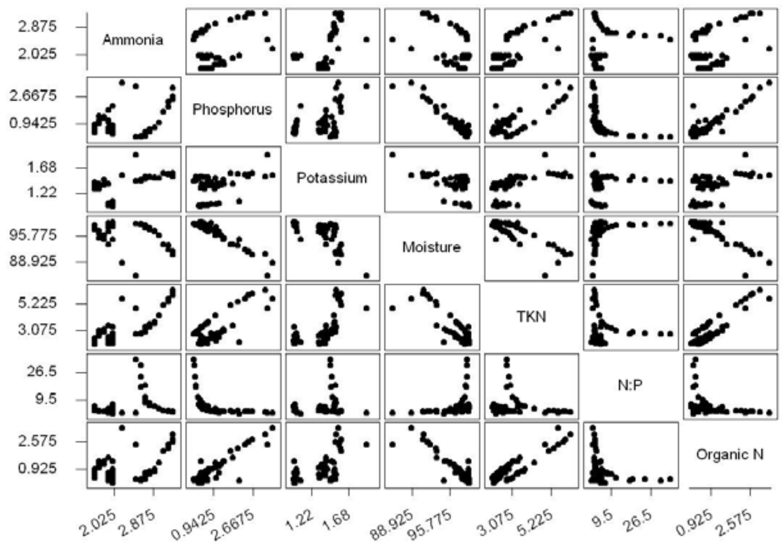


Figure 7: Regression analysis of Moisture versus Phosphorus

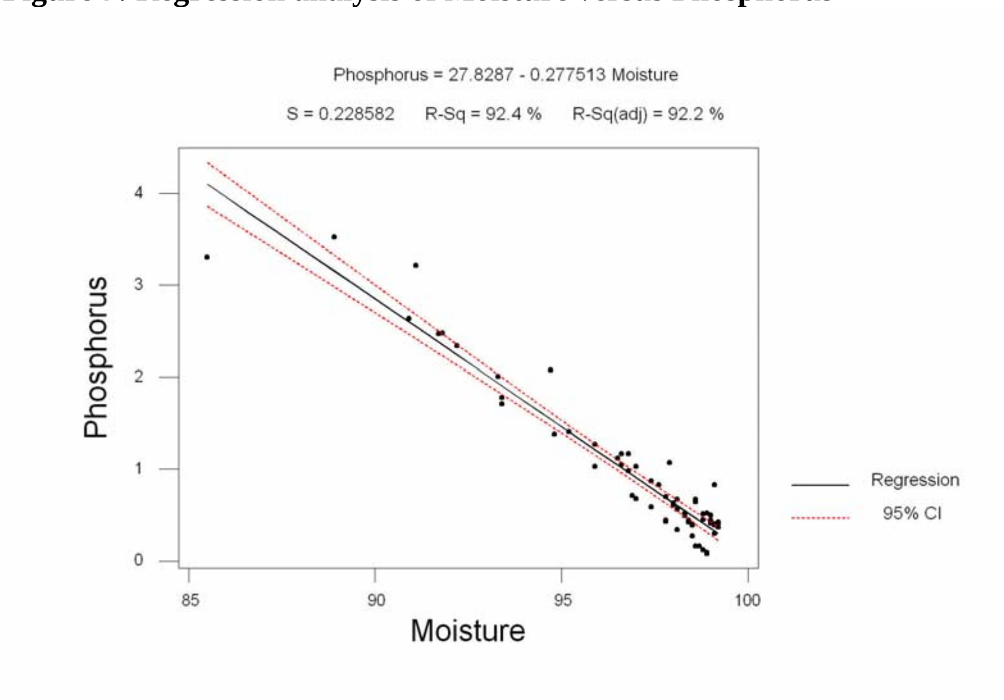


Figure 3: Single Cell Storage Pumpout

Sample Number	US Gallons	Time	Ammonium - N kg/1000L	Phosphorus kg/1000L	Potassium kg/1000L	Moisture %	Total Nitrogen kg/1000L	N:P Ratio	Organic N kg/1000L
1	2000	11:15AM (Day 1)	2.2	3.53	1.55	88.9	5.6	1.6	3.4
2	53000	12:35PM	1.6	0.83	1.42	97.6	2.5	3.0	0.9
3	103000	1:30PM	1.6	0.52	1.38	98.3	2.2	4.2	0.6
4	152000	2:30PM	1.6	0.61	1.39	98	2.2	3.6	0.6
5	202000	4:00PM	1.6	0.39	1.33	98.5	2.1	5.4	0.5
6	252000	4:58PM	1.6	0.56	1.31	98.1	2.2	3.9	0.6
7	307000	5:59PM	1.6	0.4	1.32	98.5	2	5.0	0.4
8	352000	6:52PM	1.6	0.42	1.37	98.4	2.1	5.0	0.5
9	405000	7:50PM	1.6	0.42	1.39	98.4	2.1	5.0	0.5
10	452000	8:42PM	1.6	0.44	1.37	98.4	2.1	4.8	0.5
11	508000	11:02PM	1.6	0.63	1.39	98	2.3	3.7	0.7
12	552000	11:57PM	1.7	1.12	1.35	96.5	2.9	2.6	1.2
13	612000	1:06AM (Day 2)	1.7	1.17	1.39	96.6	2.8	2.4	1.1
14	652000	1:52AM	1.7	1.03	1.36	97	2.7	2.6	1
15	702000	2:47AM	1.6	0.87	1.37	97.4	2.5	2.9	0.9
16	752000	5:18AM	1.6	0.7	1.37	97.8	2.4	3.4	0.8
17	802000	6:13AM	1.7	0.98	1.31	96.8	2.7	2.8	1
18	852000	7:11AM	1.7	1.05	1.39	96.6	2.8	2.7	1.1
19	902000	11:19AM	1.8	1.27	1.38	95.9	3	2.4	1.2
20	952000	12:15PM	1.7	1.41	1.4	95.2	3.1	2.2	1.4
21	1002000	1:12PM	1.9	1.78	1.4	93.4	3.5	2.0	1.6
22	1052000	2:15PM	2.5	3.31	1.91	85.5	4.9	1.5	2.4
23	1103000	4:10PM	1.8	1.38	1.47	94.8	3.2	2.3	1.4
				24.82			63.9		

Overall N:P ratio	2.57

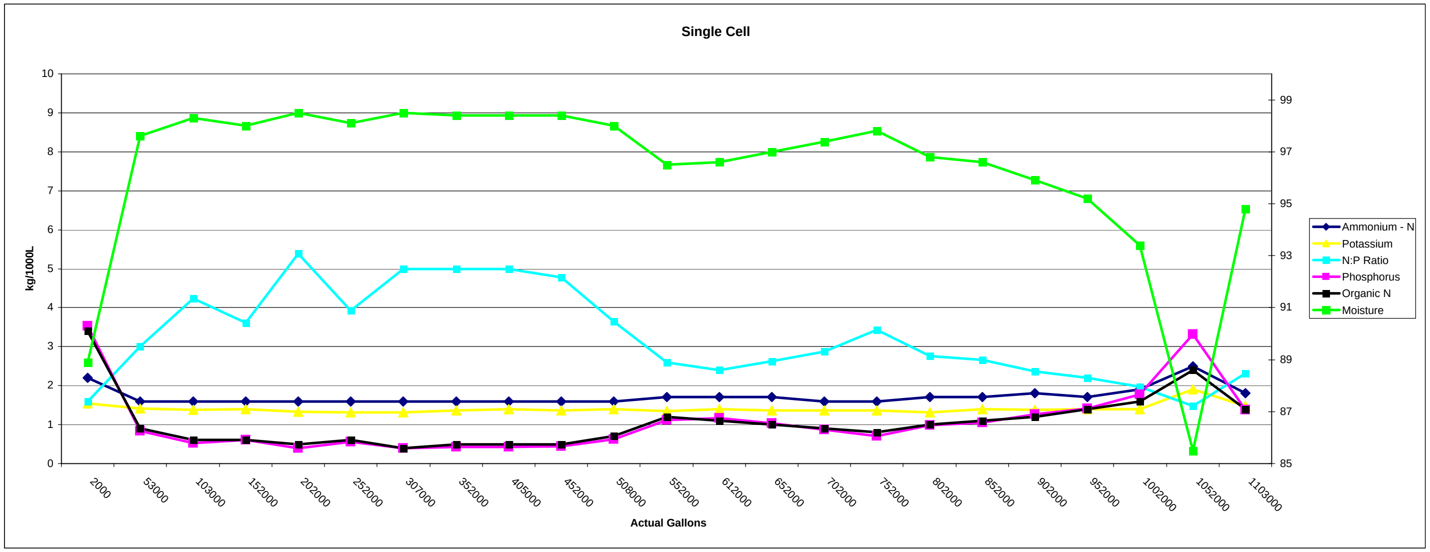


Figure 4: Two Cell Storage

Sample Number	US Gallons	Time	Ammonium - N kg/1000L	Phosphorus kg/1000L	Potassium kg/1000L	Moisture %	Total Nitrogen kg/1000L	N:P ratio	Organic N kg/1000L
1	0	TIME:1:30 pm Oct 24	3.3	3.22	1.53	91.1	6.3	2.0	3
2	103603	TIME:5:00 pm	3.2	2.01	1.58	93.3	5.4	2.7	2.2
3	200080	TIME:9:15 pm	3.2	2.34	1.56	92.2	5.6	2.4	2.4
4	295000	TIME:11:00 pm	3.3	2.48	1.57	91.8	5.9	2.4	2.6
5	400158	TIME:1:40 am Oct 25	3.3	2.47	1.52	91.7	5.9	2.4	2.6
6	498971	TIME:3:30 am	3.3	2.64	1.59	90.9	6	2.3	2.7
7	600395	TIME:9:16 am	3.1	1.71	1.59	93.4	5.1	3.0	2
8	699870	TIME:10:30 am	3	1.03	1.5	95.9	4.3	4.2	1.3
9	800000	TIME:12:40 pm	2.9	0.68	1.5	97	3.7	5.4	0.8
10	898000	TIME:2:00 pm	2.9	0.71	1.51	96.9	3.8	5.4	0.9
11	1001000	TIME:4:30 pm	2.8	0.59	1.51	97.4	3.6	6.1	0.8
12	1103370	TIME:1:56 am Oct 27	2.7	0.34	1.52	98.1	3.3	9.7	0.6
13	1204280	TIME:6:05 am	2.8	0.43	1.53	97.8	3.4	7.9	0.6
14	1298195	TIME:7:52 am	2.7	0.44	1.51	97.8	3.4	7.7	0.7
15	1400620	TIME:11:08 am	2.7	0.16	1.52	98.6	3	18.8	0.3
16	1500819	TIME:12:35 pm	2.7	0.27	1.48	98.5	3.1	11.5	0.4
17	1600508	TIME:3:30 pm	2.6	0.12	1.47	98.8	2.9	24.2	0.3
18	1700060	TIME:5:00 pm	2.6	0.09	1.45	98.9	2.8	31.1	0.2
19	1800100	TIME:7:00 pm	2.5	0.08	1.45	98.9	2.8	35.0	0.3
20	1901397	TIME:8:30 pm	2.6	0.16	1.46	98.7	2.8	17.5	0.2
				21.97			83.1		
						Total N:P	3.78		

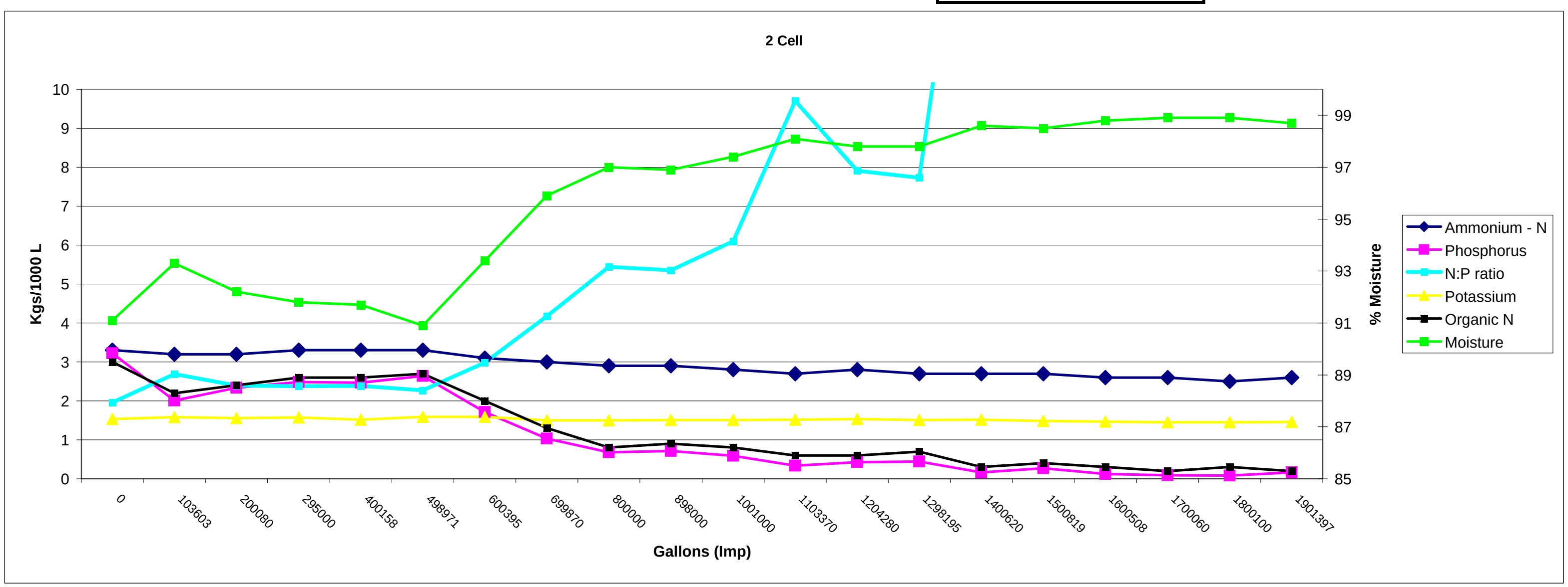


Figure 5: Circular Storage

Sample Number	US Gallons	Time	Ammonium - N kg/1000L	Phosphorus kg/1000L	Potassium kg/1000L	Moisture %	Total Nitrogen kg/1000L	N:P	Organic N kg/1000L
1	0	7/29/2003 2:26	2	0.45	1	98.8	2.2	4.4	0.2
2	99335	7/29/2003 3:46	2	0.41	1	99.2	2.1	4.9	0.1
3	199872	7/29/2003 5:11	2	0.37	0.99	99.2	2.3	5.4	0.3
4	300632	7/29/2003 6:29	2	0.42	1.01	99.2	2.2	4.8	0.2
5	400032	7/29/2003 8:23	2	0.4	1	99.1	3.4	5.0	1.4
6	500105	7/29/2003 9:42	2	0.41	1.01	99	2.4	4.9	0.4
7	609000	7/29/2003 13:30	2	0.39	1	99.1	2.7	5.1	0.7
8	701400	7/29/2003 14:32	2	0.4	1.01	99.1	2.5	5.0	0.5
9	800396	7/29/2003 16:36	2	0.83	1.03	99.1	2.9	2.4	0.9
10	904000	7/29/2003 17:55	1.9	0.5	1.01	99	2.5	3.8	0.6
11	1000083	7/29/2003 21:17	1.9	0.44	1.02	99	2.2	4.3	0.3
12	1100086	7/30/2003 12:51	1.9	0.52	1.01	98.9	2.3	3.7	0.4
13	1199890	7/30/2003 2:50	1.9	0.51	1.02	98.8	2.3	3.7	0.4
14	1310094	7/30/2003 5:00	2	0.64	1.01	98.6	2.2	3.1	0.2
15	1139991	7/30/2003 6:55	1.9	0.67	1	98.6	2.1	2.8	0.2
16	1499450	7/30/2003 8:52	1.9	0.49	1.01	98.3	2.4	3.9	0.5
17	1600027	7/30/2003 16:06	2	0.67	1.02	98.1	2.3	3.0	0.3
18	1700112	7/30/2003 18:06	1.9	1.17	1.04	96.8	2.6	1.6	0.7
19	1800853	7/30/2003 20:10	1.9	1.07	1.03	97.9	2.3	1.8	0.4
20	1900202	7/30/2003 22:08	2	0.3	1.01	99.1	2.1	6.7	0.1
21	2081238	7/31/2003 5:20	2	2.08	1.08	94.7	2.2	1.0	0.2
				13.14			50.2		

N:P	3.82

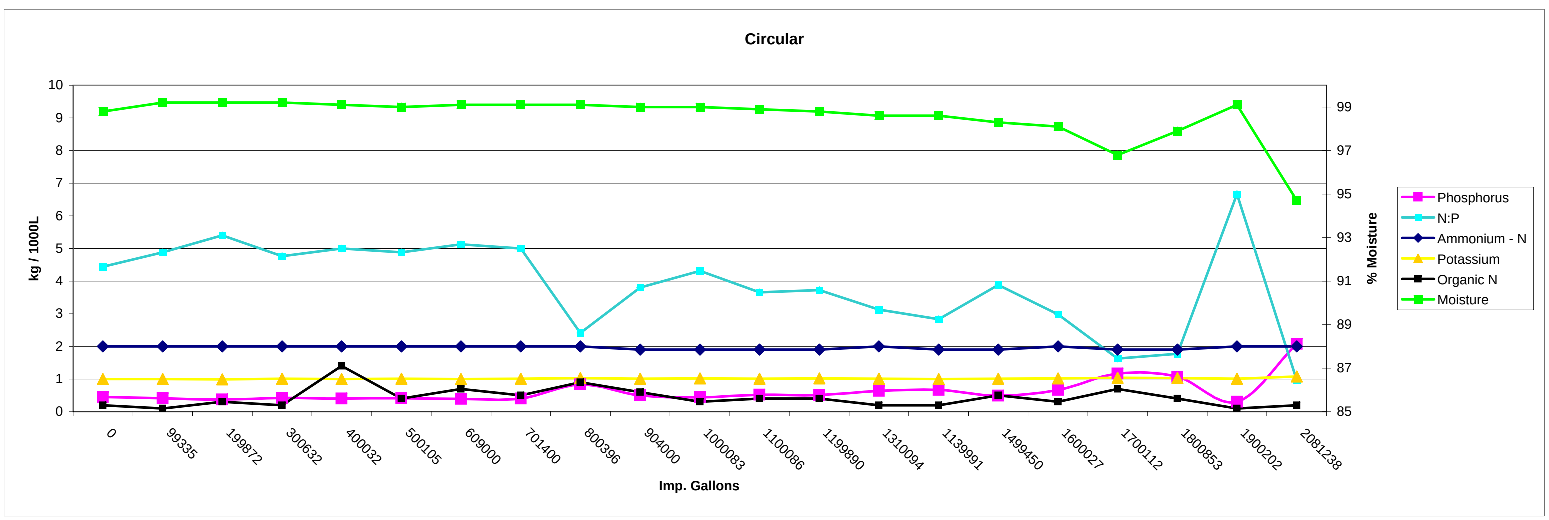


Figure 5: Circular Storage

Sample Number	US Gallons	Time	Ammonium - N kg/1000L	Phosphorus kg/1000L	Potassium kg/1000L	Moisture %	Total Nitrogen kg/1000L	N:P	Organic N kg/1000L
1	0	7/29/2003 2:26	2	0.45	1	98.8	2.2	4.4	0.2
2	99335	7/29/2003 3:46	2	0.41	1	99.2	2.1	4.9	0.1
3	199872	7/29/2003 5:11	2	0.37	0.99	99.2	2.3	5.4	0.3
4	300632	7/29/2003 6:29	2	0.42	1.01	99.2	2.2	4.8	0.2
5	400032	7/29/2003 8:23	2	0.4	1	99.1	3.4	5.0	1.4
6	500105	7/29/2003 9:42	2	0.41	1.01	99	2.4	4.9	0.4
7	609000	7/29/2003 13:30	2	0.39	1	99.1	2.7	5.1	0.7
8	701400	7/29/2003 14:32	2	0.4	1.01	99.1	2.5	5.0	0.5
9	800396	7/29/2003 16:36	2	0.83	1.03	99.1	2.9	2.4	0.9
10	904000	7/29/2003 17:55	1.9	0.5	1.01	99	2.5	3.8	0.6
11	1000083	7/29/2003 21:17	1.9	0.44	1.02	99	2.2	4.3	0.3
12	1100086	7/30/2003 12:51	1.9	0.52	1.01	98.9	2.3	3.7	0.4
13	1199890	7/30/2003 2:50	1.9	0.51	1.02	98.8	2.3	3.7	0.4
14	1310094	7/30/2003 5:00	2	0.64	1.01	98.6	2.2	3.1	0.2
15	1139991	7/30/2003 6:55	1.9	0.67	1	98.6	2.1	2.8	0.2
16	1499450	7/30/2003 8:52	1.9	0.49	1.01	98.3	2.4	3.9	0.5
17	1600027	7/30/2003 16:06	2	0.67	1.02	98.1	2.3	3.0	0.3
18	1700112	7/30/2003 18:06	1.9	1.17	1.04	96.8	2.6	1.6	0.7
19	1800853	7/30/2003 20:10	1.9	1.07	1.03	97.9	2.3	1.8	0.4
20	1900202	7/30/2003 22:08	2	0.3	1.01	99.1	2.1	6.7	0.1
21	2081238	7/31/2003 5:20	2	2.08	1.08	94.7	2.2	1.0	0.2
				13.14			50.2		
					N:P	3.82