Overview of MASSTC Testing

Two Pirana biological incubators were inserted into existing mature septic tanks at the Massachusetts Alternative Septic Systems Test Center (MASSTC) in May 2002. Ponded septic trenches received the effluent. Daily loading of 330 gallons a day follow an ETV protocol with all operations and sampling managed by full time test facility staff. Laboratory analysis by a certified lab followed NSF/EPA QA/QC requirements.

Hydraulic acceptance rates increased dramatically as ponding dropped, eventually leading to flux rates (Q/wetted area) of 3 to almost 8 gallons per day per square foot. In the winter of 2003 these levels dropped slightly. Pathogen reduction was significant as the biological mat created by the new ecology maintained unsaturated flow.

Weekly than biweekly samples revealed a progressive reduction in nitrogen as residual solids in the tank and the sand fill were converted to a new ecology by facultative aerobes generated in the tank and discharged into the sand soil by the Pirana technology. One system showed an average total nitrogen reduction of 60% with average concentration of 14.7 mg/l after the tank was pumped. A second former Title 5 system exhibited a low of 2.1 mg/l total nitrogen with concentrations in a 2 ft pan dropping to less than 20 mg/l in the fall. A mass balance analysis of the sump concentrations strongly suggests that the Pirana system enables the soil to reduce nitrogen levels to less than 10 mg/l. Cold temperatures does not appear to affect the reaction rates or loss of nitrogen even with the higher than normal loading rates

Test Procedure

Pirana filters were installed in two septic tanks containing 12 inches of solids. One soil system was previously installed to test alternative media. The lysimeter utilized a liner and sump below 12 inches of washed sand as shown in Figure 1. The second system upgraded an existing Title 5 control system (F2) that had a similar sludge level in the septic tank. After about two months of testing both Pirana tanks were pumped and restarted. The septic tank controls remained unpumped for the entire period.

The Test Center pumped sewage from a main line that served military housing. The sewage was mixed and then pumped to each test system. Under the ETV protocol each tank received 330 gallons a day from 20 dosing events with diurnal peak flow in the morning and late afternoon and no flow between midnight and 6:00 AM. All sample were pulled from the septic tank outlet T or d-box during peak loading periods in the morning and likely reflect average concentration discharged from these 1250 gallon tanks.

Evaluation of the transformation in the soil was through the collection effluent from pans placed 2 feet below the trenches or from sumps that drained the liners. A composite sample from three alterative media trenches (Tire chip) reflects treatment through 12 inches of sand. Two 2-foot pans and samples from the F sump characterized soil treatment at a 2 ft or 5 foot depth. Samples at the sump were taken only because of a lack of effluent in the 2 foot control pans. These samples reflect a blend of 67% Pirana effluent and 33% Title 5 trench effluent. A complete printout of the data is available from the test center.

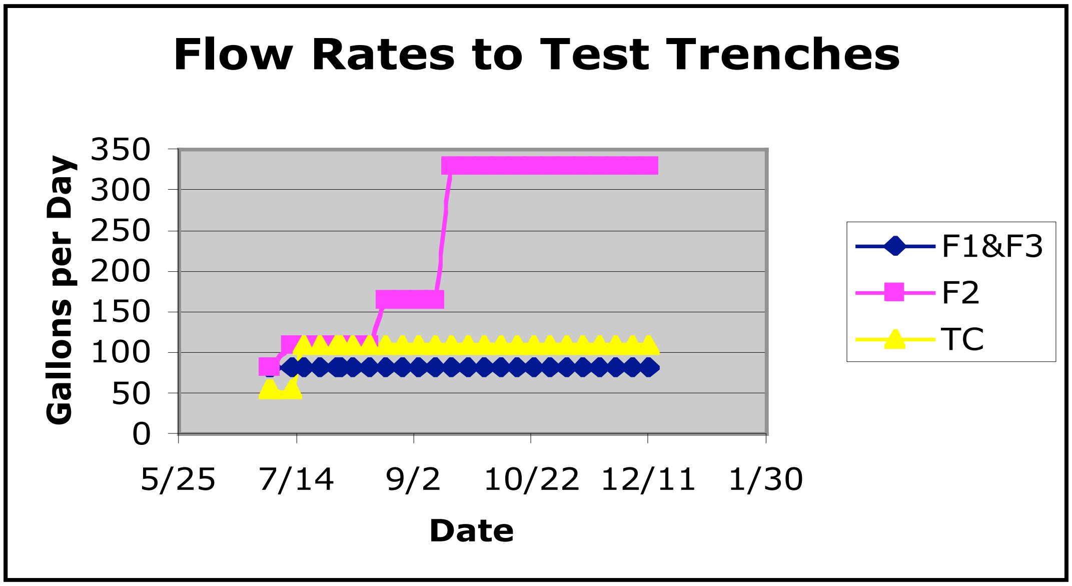
Loading Rate Adjustment

While each septic or Pirana tank receive the same flow the soil trenches receive a percentage of flow from these test tanks. Additional outlets in the d-box bypass a set percentage. For eample the Title five trench receive effluent from a dipper d-box with four outlets. Only one outlet is connected to the trench thus 75% is bypassed.

To maintain flow and ponding that seems to be essential to collecting pan effluent the loading was increased by closing the bypass outlet in the dipper box receiving Pirana effluent. As each bypass outlet was sealed the flows increased from 25% to 33% to 50% and finally 100% of the 330 gpd flow from the Pirana tank. Figure 3 shows the change in flow to the trenches over time. The three alternative media cells each received 1/6 the flow followed by an increase to 1/3 the flow with each replicate trench receiving 1/3 the flow. Continued ponding in these cells likely reflects the limited unsaturated soil prior to the capture of effluent by the liner.

Two Title Five systems, F1 and F3, were operated with the tank receiving the same flow as the Pirana tank. These control test trenches only receive 25% of the forward flow and follow the design loading rate for a 3 foot by 2 foot deep aggregate trench in sand.

SepticWatch 24/7 Monitor was added to both Pirana tanks. This allows a comparison of sludge levels, temperature and scum levels and the F3 Title Five control tank. Valuable insight into the changes in sludge during the summer months when temperature and biological activity increased is very useful from a solids management standpoint.



Results and Discussion

Hydraulic Analysis

After about one month of operation the MASSTC staff began recording ponding levels in the absorption trenches. Soon after this activity was initiated and it was evident that ponding levels were dropping bypass outlets in the d-boxes were systematically closed and loading rates increased as shown below in Table 1. Only one adjustment was made to the d-box for the Pirana/TC Tank while three outlets were successively closed in the F2 Pirana tank d-box. Loading of the Title 5 control trenches remain constant. No further adjustments were made after September 18th as all effluent was loaded from the test tanks was finally directed into the absorption trenches.

Table 1 Trench Loading Rates in 2002

Date	Loading Rates (gpd)		
	F1&F3	F2	TC
7/2	82.5	82.5	55
7/3	82.5	82.5	55
7/12	82.5	110	55
7/17	82.5	110	110
7/24	82.5	110	110
7/31	82.5	110	110
8/2	82.5	110	110
8/7	82.5	110	110
8/14	82.5	110	110
8/21/200	82.5	165	110
8/28	82.5	165	110
9/4	82.5	165	110
9/11	82.5	165	110
9/18	82.5	330	110

In general its clear that as the temperature of the effluent and soil increased ponding levels dropped in all trenches. In the late fall when moisture increased and temperatures decreased we see the reverse. This is consistent with analysis of absorption trenches reported by Tyler. Lower temperatures increase soil water viscosity, reduces reaction rates and increases in soil moisture reduce oxygen transfer. The combined affect is an increase in biological resistance to water flow and thus an increase in ponding. It should be noted that the ponding levels were measure some time during the morning during peak loading and thus the variation may reflect when the measurements were made. Therefore a general trend and range of values is appropriate not a comparison of values on a given day. While some dramatic changes were observed between various readings the biomat and level of ponding was relatively stable and did not reflect dramatic breakthroughs that have been discussed in the literature.

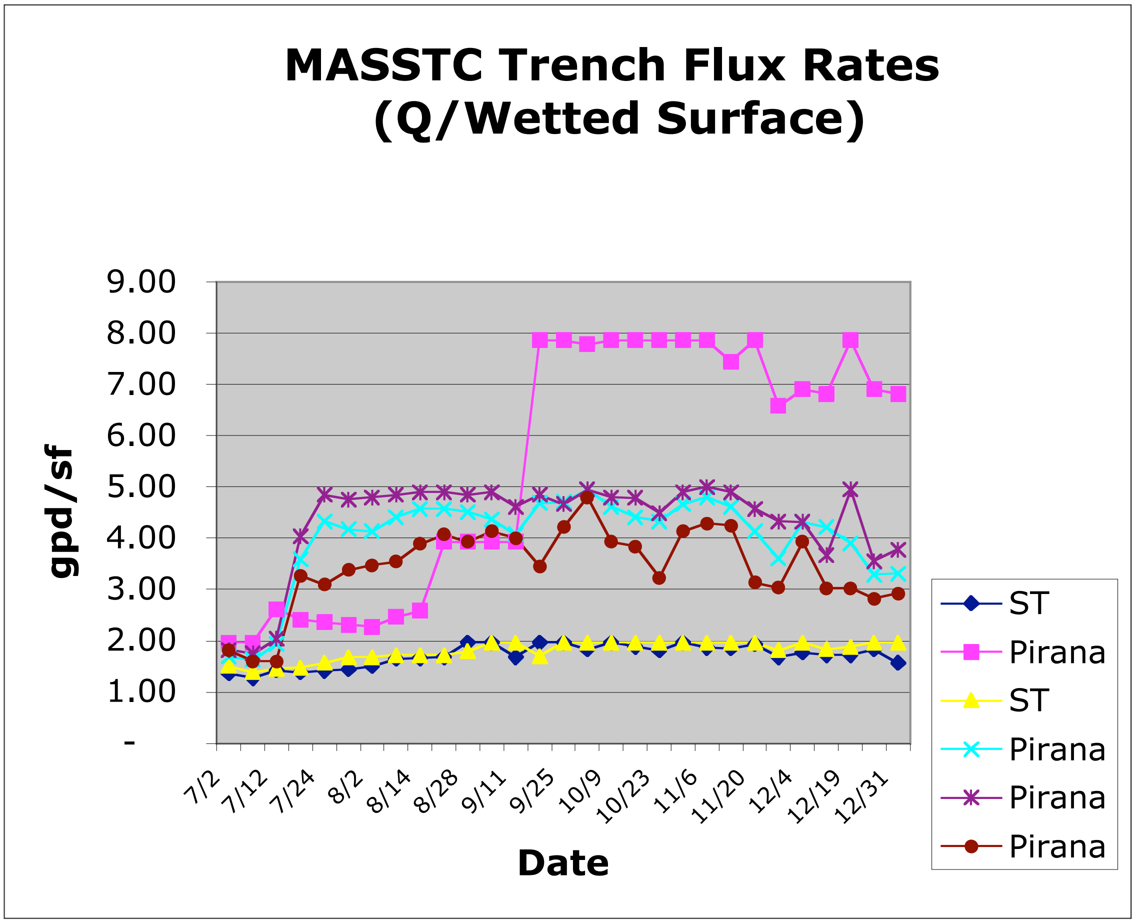
Table 2 Ponding levels in absorption trenches

Date	F1	F2	F3	TC 1A	TC 1B	TC 2A	TC 2B	TC 3A	TC 3B
7/2	8	0	5.5	3.5	4.75	4.25	7.3	4	5.2
7/3	9.8	0	7.5	4.25	5.25	5	7.8	6	7.5
7/12	6.8	0	6.3	3.6	3.4	2	5.0	6	7.5
7/17	7.5	1.5	6	3.5	2.5	3.25	6.3	5.5	7.25
7/24	7	2	4.5	0	0.25	0.5	3.3	6.5	8.25
7/31	6.5	2.38	3	1.5	0.5	0.75	4.0	4.75	6.75
8/2	5.5	2.75	3	3.5	0	1	4.0	4.25	6.33
8/7	3.5	1.13	2.5	0.25	0.38	0.38	2.9	4.25	5.63
8/14	3.3	0.25	2.5	0.13	0.25	0.25	2.0	2.75	4.13
8/21	3	0	2.5	0.25	0.25	0.25	2.0	1.75	3.75
8/28	0	0	1.8	0.5	0.5	0.25	2.4	2.75	3.75
9/4	0	0	0	0.25	0	0.5	3.0	0	5
9/11	3	0	0	0.5	1	1	4.5	0.5	5.5
9/18	0	0	2.8	1.5	0.75	0	1.6	4.75	6
9/25	0	0	0	2.5	1.75	0	1.5	2.5	2
10/2	1.3	0.18	0	0	0.25	0	0.3	0.5	0.5
10/9	0	0	0	0	0.5	0.5	1.5	2.5	4
10/16	0.8	0	0	0	0.35	0.75	2.5	2.5	4.75
10/23	1.5	0	0	2.75	2.5	0.25	3.5	5.38	7.75
10/30	0	0	0	0	0	0.5	1.3	3	2
11/6	1	0	0	0	0	0	1.0	1	3
11/13	1.1	1	0	0	0.25	0.25	1.8	1.75	2.5
11/20	0.3	0	0	0	1.5	0.75	4.3	6.75	7.5
11/27	3	3.5	1.5	1	1.25	2.5	6.8	7	8.5
12/4	2	2.5	0			3.8			6.5
12/11	2.5	2.75	1.3	2.5	4.25	4.5		6.75	9
12/19	2.5	0	0.8			0.25	6.5	8.25	7.5
12/24	1.3	2.5	0	3.75	4.25	5.5	7.0	9.25	9.25
12/31	4.5	2.75	0	2.25	3	4.75	7.5	8	9

Flux Analysis

A better understanding of the absorption rate results from an analysis of the rate of effluent movement or flux across the soil interface. Using the continuity equation we can solve for v to get a general estimate of the flow across this interface where the area equals twice the average depth in the trench added to the basal area. Plugging in the ponding depths we can solve for the flux rate for each ponding measurement and thus drive the flow rate into the soil. Figure 2 shows these rates over time.

Figure 2 Trench Flux Rates



The estimated flux rate is a function of ponding under a constant daily loading from the pretreatment tank as the ponding increases the surface area increase the rate across this boundary must decrease. More even distribution of effluent compared to the unponded bottom area is also very likely, as the ponded effluent must be pulled from the biomat. The wetted rim of the trench may also discharge more effluent up and way from trench given the greater tension gradient at this location. It should be noted that the sand at the test sight is relatively uniform and washed with a Ksat near the upper limits (1000 cm/day) reported by EPA. Therefore the flux rates are likely well below 4% of the soils capacity to move water.

Removal of pathogens reflects this unsaturated flow with the most dramatic reduction reflected in samples taken from the sump that receive effluent after 5 feet of sand from both Title 5 and Pirana trenches. We need to keep in mind that the effluent is a composite from three trenches, one discharging 330 gallons (67%) following the Pirana and two discharging 165 gallon each after a Title 5 t septic tank.

The septic tank effluent shows concentrations of 10^7 while after 1 foot of sand with Pirana effluent we area in the range of 10^3 and after 2 feet of sand and septic effluent 10^2

With the composite sample and 4 feet of sand dropping another log. Figure 3 presents this data graphically.

When reviewing this data we need to keep in mind that the difference in loading and sampling location. The pan installed in the soil does not receive effluent consistently while the sumps represent a composite sample for all effluent applied to the soil. The loading rates to the soil are also much greater following the Pirana. The combination of an unponded surface, higher loading rate and thus less consistent flow to the 2-foot pan may explain the higher variability in data. Effluent reaching the pan after the title 5 septic tank reflects effluent that reached this location under greater tension and likely reflects a greater degree of unsaturated flow as the effluent likely moved laterally to the pan.

Given challenge of collecting moisture held under tension in the soil the sump effluent likely serves as the best estimate of pathogen reduction. While 12 inches of sand is less than desired considering the loading rate the reduction in pathogens was remarkable. With 5 feet of sand the pathogens were well below expected. The Pirana's performance is likely somewhere between less than 10 and 1000 pfu per 100 ml, well below the limits of any treatment system where samples are collected directly below the system. Comparing this pathogen reduction to a slow sand drinking water filter an argument could be made that this soil based system receiving primarily Pirana effluent can generate effluent that meets drinking water standards≈

Table 3 Composite F Trench Sump Effluent Quality

Date	Notes	Temp	pH	Sp Cond(uS)	DO	Total Nitrogen	TKN	NH4(mg/l)	Nitrate	Nitrite	BOD5	CBOD	TSS (mg/l)	Alkalinity (mg/l)	Fecal Coliform
10/10		19.60	5.38	407		30	0	1.1	30.2	0.03		1.0	3.5	7	5
10/17		18.60	5.41	443		28	0	0.1	27.3	0.03		1.0	0.6	2	0
10/31		17.10	5.36	394		5	0	1.0	4.7	0.03		1.0	0.5	12	10
11/27		-	5.50	-		19	0	0.2	19.0	0.05		3.0	2.2	7	10

Review of the average total nitrogen concentration values is necessary to compare changes in nitrogen as is moves through the treatment process. Wastewater is mixed in the Septic or Pirana Tank and may take several days to move through the soil. Further delays are evident as reported by Dr. Robert Siegrist. Due these time lags a comparison of individual samples can not be made on a given date. Therefore a comparison of the averages and trend over time provides the most meaningful comparison. Figure 2, 3 and 4 show the total nitrogen over time passing through the Title 5 control system. (Appendix 1 shows the forms of nitrogen.)

The control cell shows no change in average concentration as it passes though the soil, contrary to earlier findings. An average of 39 mg/l enters the system and 40 mg/l leaves the lysimeter. High values were found leaving the septic tank that my reflect when and how the samples were taken or the fact that stored solids ware more volatile in the summer and more organics nitrogen was found leaving the tank compared to that entering.

Figure 2 Raw Wastewater in Summer and Fall of 2002

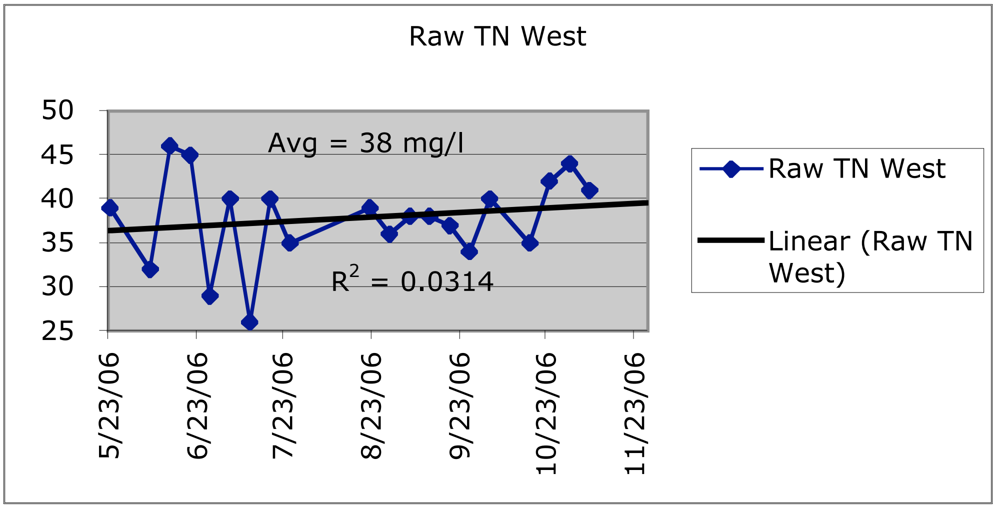
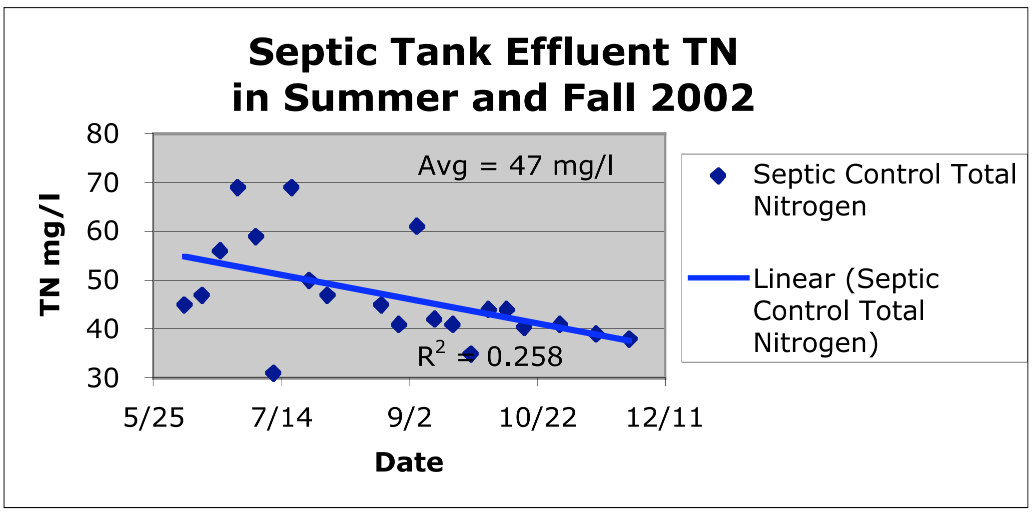


Figure 3 Total Nitrogen in T5 Septic Tank d-Box

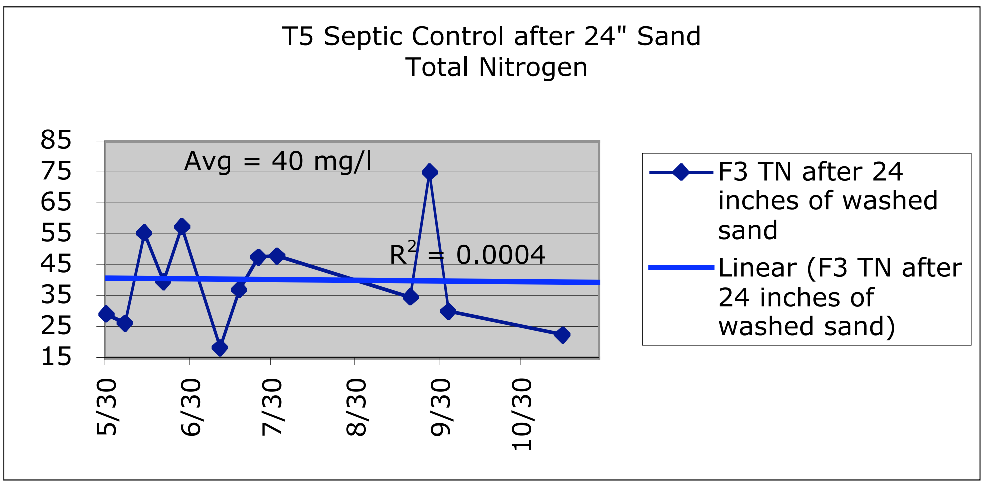


The above two figures suggests an increase in nitrogen during the summer in a standard septic tank. Sampling during the morning hours with some short circuiting of fresh effluent could have lead to the high level on a few occasions creating the impression of an increase. Release of solids stored in the tank over the winter may also explain this change during the summer. Fall readings are more in line with averages with the colder temperature reading suggesting a possible increase in solids.

As shown in Figure 4 below this conservation of nitrogen is evident in the effluent draining from the lysimeter with the average very similar to concentrations in the raw wastewater.

The greater variability in the soil also reflects the variation in drainage into the pan. On a number of occasions insufficient effluent was available suggesting that some Evapotranspiration may have affected concentration leaching from the soil. Unequal flow and possible release of solids stored organic in the soil may also have affected the concentrations reaching the two foot pan. Ponding levels dropped in the summer exposing the biomat to air and allowing aerobic digestion of the biomat to occur. The fact remains that the average concentration was 40 mg/l, which is equivalent to the concentration measured in the raw influent.

Figure 4 Total Nitrogen After ST Effluent Drains Through 24 Inches of Sand



Estimated Pirana Performance based on F Sump and F Pan

Estimated Pirana TN Concentration

Date	Composit F Sump TN	% Septic	Septic 2' Pan TN	% Pirana	Esimated Pirana TN
10/10	30.48	33%	40	67%	10.77
10/17	27.57	33%	40	67%	7.87
10/31	4.97	33%	40	67%	-
11/27	19.05	33%	40	67%	-

$$= \frac{\text{(composit concentration - (Avg Septic concentration * \% septic))}}{\text{\% Pirana Effluent}}$$

(Based on 2 foot Pan TN (40 mg/l) and % flow contributed by each system

Conclusion

Testing at the MASSTC demonstrates the increased efficiency and rapid recovery of trenches previously loaded with septic effluent. Actual acceptance rates primarily at the base of the trench in sandy are between 5 and 8 gpd/sf.

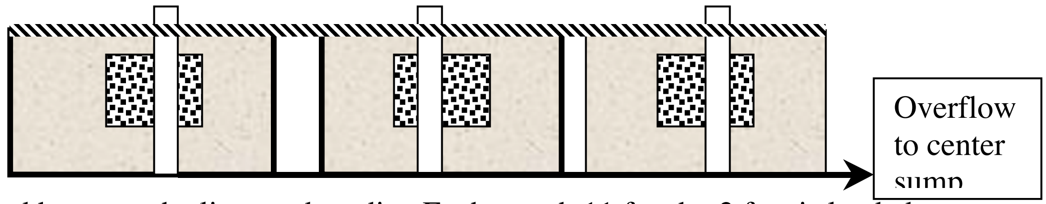
Pathogen reduction is also consistent with that found for septic effluent when more than 2 feet of unsaturated sand is provided. Even with as little as 12 inches of sand a 3 to 4 log reduction can be anticipated at the base of the trench. This is consistent with performance of single pass sand filters receiving septic effluent.

Total nitrogen concentrations are significantly lower that found for septic systems and is consistently less than 20 mg/l with less than 12 inches of sand if the tank is pumped of residual solids at startup. Digestion of these solids and conversion of nitrogen in these solids can lead to higher nitrogen concentrations.

Because the soil and effluent distribution likely varies over time in a trench, pan lysimeters likely reflect localized drainage and treatment of effluent near the pan. Comparison of these values with that in a sump that drains the entire system suggests that higher levels of treatment are very likely below 10 mg/l with fecal Coliform bacteria less than 10 pfu/100 ml after passing the effluent through 4 feet of sand.

Given the simple installation and operation of this system there is little question that the Pirana provides the most cost effective method for system remediation. Coupled with the 24/7 Monitor it can provide reliability second to none in the industry.

Figure 1 TC Trench Cross Section



12 inches of sand between the liner and media. Each trench 11 feet by 2 feet is loaded at 110 gpd from a Pirana Tank.

Figure 2 F Trenches Cross Section