Final Report
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Changes in On-site Wastewater Treatment and Evaluation: Influent Equalization

Joe C. Yelderman Jr*.
Department of Geology
Baylor University
*Principle Investigator

Introduction

Background

On-site sewage facilities (OSSFs) have long provided treatment to an important segment of our society. Significant improvements have been made in the physical siting, treatment designs and regulation of OSSFs; especially in the last 20 years. However, recent changes in lifestyles, home construction and appliance technology are necessitating further changes in on-site wastewater treatment methods. Problems resulting from underfed systems or surges in loading are becoming more common and pronounced.

One proposed change that addresses these issues and needs to be studied is the idea of timed dosing and equalization of influent to improve treatment efficiency and accommodate variations in loading. Dr Bruce Lesikar spoke at the 2010 Texas On-Site Wastewater Treatment Research Council Conference on the ability of "Flow Equalization" to improve performance in an OSSF treatment train. Pre-treatment and post-treatment tanks already exist in the on-site wastewater industry and can be readily used or easily converted to control dosing/loading and dispersal alternatives.

However, these changes have not been studied in direct comparison to traditional dosing such as Standard 40 design loading. These proposed new treatment methods require new methods of evaluation in order to properly implement any proposed changes.

Questions

Questions such as;

"How significantly does relatively constant dosing (influent equalization) affect effluent quality for CBOD and TSS?",

"Does influent equalization allow for better effluent quality when treatment resumes after dosing has been stopped for a while?",

and

"If treatment efficiency is improved significantly can the same size treatment system handle more influent?"

If these questions can be answered, then both the industry and the regulatory agencies can make better decisions regarding on site wastewater. Since aerobic treatment units (ATUs) can be easily modified with timers and pumps to incorporate influent equalization and since the Baylor Wastewater Research Program (BWRP) site has 4 ATU systems available for research application, the BWRP proposes to try and answer the questions above.

The Baylor Wastewater Research Program (BWRP) as a part of the Department of Environmental Science at Baylor University and Dr Joe C. Yelderman Jr., Director of the BWRP, and professor in the Department of Geology design were well qualified to design and implement a research experiment to answer the previous questions.

Facilities and Setup

The BWRP compared several ATU units designed exactly alike and dosed with the exact same influent but which were each dosed differently One unit was dosed under the ANSI/NSF Standard 40 design dosing (35%, 25% and 40%) at 480 gallons per day (GPD) and compared directly to 3 other units dosed with influent equalization (IE) at 480, 600, and 720 GPD for approximately 3 months. The above increases are each 120 GPD (125% and 150% of the original volume) and designed to represent additional bedroom capacity according to recent Texas Commission on Environmental Quality (TCEQ) rules.

Figure 1. Graduate student, Amy Price, setting up control panels for the aerobic systems.

Figure 2. The enlarged new configuration showing the 4 aerobic systems with standard control panels and blowers in the foreground and the new, larger-capacity dosing buckets re-plumbed at the dosing shed in the background.

Each aerobic system was comprised of a 1500-gallon 3-chambered tank with a settling tank, clarifier and effluent tank. The aerobic systems were also equipped with SJE Rhombus control panels (model # 1018500 with dual indictors) and HP 80 model blowers with pressure ports from HIBLOW USA, Inc.

Methods

The design loading occurred for 2 months (September and October, 2001) followed by 48 hours of no power (Nov. 11 – Nov. 13, 2011) similar to the Power Outage Stress applied in Standard 40 testing, then one month of design loading (Nov. 21-Dec.-21, 2011followed by 10 days of no influent additions similar to the Vacation Stress in Standard 40 (because of the influent equalization dosing scheme, the Working Parent and Wash Day stresses in Standard 40 were not expected to offer enough beneficial information to justify the extra costs and effort), followed by 4 months (January –April, 2012) of design loading. The extended designed loading provided a more robust statistical evaluation and incorporated the seasonal temperature changes from winter to spring. After the extended design loading period, Unit #4 was taken out of service, dosing schemes for units #1 and #3 were switched so that Unit #1 received IE and Unit#3 received Standard 40 design loading. At this time Unit #2 was increased in loading with a target of 840 GPD using IE.

The following description is the targeted dosing for the design loading and the influent equalization dosing during Phase 1 of this project. The standard unit received 100 doses per day at 4.8 gallons per dose with 35 doses between 6 - 9am, 25 doses between 11am - 2pm and 40 doses between 5 - 8pm. The equalization units received 5, 6.25, and 7.5 gallons per dose every 15 minutes respectively for a total of 96 doses per day and 480, 600 and 720 gallons per day respectively.

Parameters sampled focussed on $CBOD_5$ and TSS with in situ measurements of Temperature, pH, and DO. Samples were collected 3 times a week with slight modifications during the two stress periods. There was one sample collected for the influent and 4 effluent samples for each sample day. Samples were analyzed at the Waco Metropolitan Area Regional Sewerage System (WMARSS) lab at the site. The close proximity of the lab saved costs and improved analytical results due to short travel times.

Results and Discussion

Design Loading

Although dosing began on 8-17-11, the system was not consistently functioning for a few weeks and the data collection for analysis started in September, 2011. These results are reported below and discussed in context with the above research questions. These first two months indicated the ATU units with Influent Equalization (IE) dosing were equal to the Standard 40 dosing scheme even at higher daily dosing volumes (Table 1).

All ATU units were dosed within 10% of the targeted dosing rate in gallons per day (GPD). Units #1 and #3 which were both targeted at 480 GPD were within 5% of each other. These data suggest comparisons are appropriate with regard to the dosing volumes. The sample sizes for the parameter analyses were similar for units 1-3 but somewhat smaller for unit #4. This was related to the difficulty of operating the larger dosing rate for Unit #4 in the beginning. The lab reported results that were below the acceptable reporting limits and all those results were rounded up to the lowest acceptable reporting limit of 4 mg/l for TSS and 2 mg/l for $CBOD_5$ before the means and the medians were calculated.

The results for the first two (2) months (table#1) showed that all the units performed very well. The lowest mean effluent value for TSS (4.40 mg/l) was unit #3 which was the IE-480 gpd unit. The highest mean effluent value for (5.18 mg/l) was unit #4 which was the IE-720 gpd unit receiving the largest dose per day (actually an average of 665 gpd). With respect to $CBOD_5$ the best performing unit was the IE-600 gpd unit (#2) which had a mean effluent concentration value of value of 2.24 mg/l . Unit #2 was also the most consistent unit with its highest value being only 4.10 mg/l of $CBOD_5$. The Standard 40 unit received the least influent and had the highest maximum, mean and median effluent values for $CBOD_5$. When the reduction efficiency was evaluated using mass rather than concentration, the percent removal values were the same except for the IE-720 unit which received 665 GPD. The mass reduction efficiency for $CBOD_5$ in this unit (#2) was 96.5% while the concentration efficiency was only 96.3%. Because there was such a small difference between concentrations and mass, all further analyses used only concentrations.

Table 1. Effluent results for the first two (2) months of designed loading (9-2-11 to 10-28-11)

Parameter	TSS	TSS	TSS	TSS	TSS	$CBOD_5$	$CBOD_5$	$CBOD_5$	$CBOD_5$	BOD
Concentration	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
ATU #	1	2	3	4	Raw	1	2	3	4	Raw
Dosing method	Std 40	IE-600	IE-480	IE-720	na	Std 40	IE-600	IE-480	IE-720	na
High value	9.90	22.30	11.00	12.80	575	8.16	4.10	4.42	4.86	351
Mean value	**4.79**	**5.15**	**4.40**	**5.18**	**139**	**3.24**	**2.24**	**2.42**	**2.74**	**179**
Low value	4.00	4.00	4.00	4.00	60	2.00	2.00	2.00	2.00	115
Median value	4.00	4.00	4.00	4.00	114	2.79	2.00	2.00	2.12	178
n (sample size)	23	21	22	12	22	23	21	22	12	22
GPD dosed	453	537	480	665	na	453	537	480	665	na
GPD targeted	480	600	480	720	na	480	600	480	720	na
% of targeted dosing	95%	90%	100%	92%	na	95%	90%	100%	92%	na
Mean % removal	97%	96%	97%	96%	na	98%	99%	99%	99%	na
Median % removal	97%	97%	97%	97%	na	98%	99%	99%	99%	na

During this portion of the study the temperatures generally decreased from the lower 30s to the mid 20s in celsius degrees and averaged between 28-29 C (Table #2). There appears to a slight warming trend from units 1-4. Although Unit #4 is toward the west, all samples were taken in the morning approximately between 9-10am and the tanks are all buried in the ground and would be fairly well insulated from daily fluctuations. It is possible the amount of dosing may have affected temperatures but it is unclear how, or why, and the differences are not great.

The pH values were all within the range between 6 and 9 pH units and median values were in the mid 7s. The highest pH value recorded was 8 and the values were very consistent among units.

Table 2. Temperatures of effluent for the first two (2) months of design loading.

Parameter	T	T	T	T
	Deg C	Deg C	Deg C	Deg C
ATU #	1	2	3	4
Dosing method	Std 40	IE-600	IE-480	IE-720
High value	32.1	32.7	32.9	32.6
Mean value	**28.2**	**28.6**	**28.6**	**28.7**
Low value	24.8	25.4	25.3	25.6
Median value	28.7	28.9	29.0	29.5
n (sample size)	22	22	21	21

Table 3. Values of pH during the first two (2) months of design loading.

Parameter	pH	pH	pH	pH
ATU #	1	2	3	4
Dosing method	Std 40	IE-600	IE-480	IE-720
High value	7.91	7.61	8.00	7.90
Median value	**7.46**	**7.30**	**7.67**	**7.69**
Low value	6.79	6.91	7.25	7.26
n (sample size)	22	22	21	21

Table 4. Dissolved Oxygen values during the first two (2) months of design loading.

Parameter	DO	DO	DO	DO
	mg/l	mg/l	mg/l	mg/l
ATU #	1	2	3	4
Dosing method	Std 40	IE-600	IE-480	IE-720
High value	4.62	4.72	4.53	3.68
Mean value	**3.24**	**3.22**	**3.21**	**2.38**
Low value	2.20	0.47	1.83	0.18
Median value	3.36	3.43	3.16	2.68
n (sample size)	22	22	21	21

The dissolved oxygen data are consistent among units with regard to mean and median values for the corresponding TSS and $CBOD_5$ values except for unit #4 (IE-720) which has a lower mean and a lower median value (Table #4). The IE units tended to have more extreme low values of DO than the Standard 40 unit (#1)

Power Outage Stress

The system was dosed with 40% of its daily hydraulic capacity between 5:00 p.m. and 8:00 p.m. on the day the power/equipment failure stress was initiated (11-11-11). Power to the system was turned off at 9:00 p.m.and dosing was discontinued for 45 h. After 45 h, the power was restored at 5pm and the system was dosed over a 3-h period with 60% of its daily hydraulic capacity, which included 1 wash load (1 wash cycle and 2 rinse cycles).

Table 5. Comparison of effluent values the week before and after the power outage stress.

	week before power outage				week after power outage			
ATU #	1	2	3	4	1	2	3	4
	Std 40	IE-600	IE-480	IE-720	Std 40	IE-600	IE-480	IE-720
TSS - mg/l	7.50	4.00	6.00	4.00	10.50	4.00	4.00	5.28
$CBOD_5$ - mg/l	10.50	5.07	2.38	2.19	6.83	2.01	2.00	3.32
DO - mg/l	3.19	4.28	4.86	*3.55	2.71	4.41	4.89	3.55
T degrees Celsius	23.1	23.6	23.0	24.1	22.7	23.3	23.1	23.7
n (sample size)	3	3	3	3	5	5	5	5

* n=2 anomally 11-7

The weather remained fairly constant during the power outage stress assessment and the stress did not appear to change the effluent quality in any of the systems.

Design loading after power Outage stress

Following the Power Outage Stress the units were dosed according to their design loading for one month to establish equilibrium before the next stress occurred. For the month after the power outage stress assessment (11-21-11 to 12-21-11) the design loading showed that all the IE units (#2-#4) continued to perform well and during this month the IE units performed better than the Standard 40 unit (#1) with regard to TSS and $CBOD_5$ (Table #6). the raw influent was slightly higher on average than the first two (2) months but did not vary as much see tables #1 and #6. There is a hint in the data that the IE-720 unit may be near its loading capacity for best efficiency and this unit received 99% of its targeted dosing during this time (713 GPD). The pH values were all well within the acceptable range but there were only a few data points due to some equipment failures (Table 7). However, there is nothing in the data to indicate there should be any variation in pH. The DO was the lowest in the Standard 40 dosing unit (#1) and in the IE-720 unit. These DO values coincide with what is being observed in the TSS and $CBOD_5$ data. In general, all units exhibited higher dissolved oxygen values than prior to the Power Outage Stress which may be related to the cooler temperatures (Table 8). During this portion of the study the temperatures had decreased to an average of 29-20 C (Table #9). There still appears to a slight warming trend based on the mean values from units 1-4.

Table #6. Design loading after the Power Outage Stress

Parameter	TSS	TSS	TSS	TSS	TSS	$CBOD_5$	$CBOD_5$	$CBOD_5$	$CBOD_5$	BOD
Concentration	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
ATU #	1	2	3	4	Raw	1	2	3	4	Raw
Dosing method	Std 40	IE-600	IE-480	IE-720	na	Std 40	IE-600	IE-480	IE-720	na
High value	32.40	22.30	11.00	12.80	212	8.16	4.10	4.42	4.86	289
Mean value	**17.20**	**5.15**	**4.40**	**5.18**	**145**	**3.24**	**2.24**	**2.42**	**2.74**	**185**
Low value	5.70	4.00	4.00	4.00	90	2.00	2.00	2.00	2.00	93
Median value	17.90	4.00	4.00	4.00	140	2.79	2.00	2.00	2.12	186
n (sample size)	14	14	14	14	14	14	14	14	14	14
GPD dosed	468	681	449	713	na	468	681	449	713	na
GPD targeted	480	600	480	720	na	480	600	480	720	na
% of targeted dosing	98%	114%	94%	99%	na	98%	114%	94%	99%	na
Mean % removal	88%	97%	97%	97%	na	94%	99%	99%	99%	na

Table 7. Values of pH during the month after the Power Outage Stress.

Parameter	pH	pH	pH	pH
ATU #	1	2	3	4
Dosing method	Std 40	IE-600	IE-480	IE-720
High value	7.50	7.61	8.00	7.90
Median value	**7.50**	**7.30**	**7.67**	**7.69**
Low value	7.40	6.91	7.25	7.26
n (sample size)	2	2	2	3

Table 8. Do values for the month following the Power Outage Stress

Parameter	DO	DO	DO	DO
	mg/l	mg/l	mg/l	mg/l
ATU #	1	2	3	4
Dosing method	Std 40	IE-600	IE-480	IE-720
High value	4.28	5.25	5.14	4.50
Mean value	**3.50**	**4.87**	**4.85**	**3.48**
Low value	2.44	4.41	4.53	2.54
Median value	3.43	4.90	4.86	3.64
n (sample size)	13	13	13	13

Table 9. Temperatures during the month after the Power Outage Stress.

Parameter	T	T	T	T
	Deg C	Deg C	Deg C	Deg C
ATU #	1	2	3	4
Dosing method	Std 40	IE-600	IE-480	IE-720
High value	21.9	21.9	22.9	21.9
Mean value	**18.8**	**19.3**	**19.4**	**19.8**
Low value	16.8	17.1	17.1	17.7
Median value	18.2	18.8	18.9	19.1
n (sample size)	13	13	13	13

Vacation Stress

On the day that the Vacation Stress was initiated, the Standard 40 system (Unit#1) was dosed at 35% of its daily hydraulic capacity between 6:00 a.m. and 9:00 a.m. and at 25% between 11:00 a.m. and 2:00 p.m. Dosing was discontinued at 2:15pm on 12-21-11 for 8 consecutive days (power was supplied to the system and blower units left on). All units were turned back on at 5:00 p.m. 12-29-11. The system was dosed with 60% of its daily hydraulic capacity, which included 3 wash loads (3 wash cycles and 6 rinse cycles) between 5pm and 8pm and then all units went back to their normal dosing schedules. .

Table 10. Effluent values for the week after the Vacation Stress

Parameter	TSS	TSS	TSS	TSS	TSS	$CBOD_5$	$CBOD_5$	$CBOD_5$	$CBOD_5$	BOD
Concentration	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
ATU #	1	2	3	4	Raw	1	2	3	4	Raw
Dosing method	Std 40	IE-600	IE-480	IE-720	na	Std 40	IE-600	IE-480	IE-720	na
High value	15.50	7.70	4.00	6.50	252	9.57	2.00	2.00	6.50	276
Mean value	**11.20**	**4.93**	**4.00**	**5.53**	**195**	**8.58**	**2.00**	**2.00**	**5.53**	**193**
Low value	8.40	4.00	4.00	4.00	128	6.96	2.00	2.00	4.00	140
Median value	10.50	4.00	4.00	5.80	200	8.90	2.00	2.00	2.12	179
n (sample size)	4	4	4	4	4	4	4	4	4	4
GPD dosed	510	614	442	676	na	510	614	442	676	na
GPD targeted	480	600	480	720	na	480	600	480	720	na
% of targeted dosing	106%	102%	92%	94%	na	106%	102%	92%	94%	na
Mean % removal	94%	97%	98%	97%	na	95%	99%	99%	97%	na
Median % removal	95%	98%	98%	97%	na	95%	99%	99%	99%	na

Although the ANSI/NSF Standard 40 Vacation Stress requires 6 days of consecutive sampling after dosing is resumed we were only able to collect 4 consecutive days due to a failure of the supply pump which resulted in a lack of effluent after 4 days. The results are shown in Table 10. The performance was adequate for all systems and showed no observable problems with a Vacation Stress. The Standard 40 design loaded system (Unit #1) performed the poorest but it is not clear that it was affected by the Vacation Stress or just was performing poorer in general since it had performed poorer than the others during the last month of design loading between stress tests. When the mean effluent values for TSS and $CBOD_5$ are compared for the 5 consecutive samples after the Power Outage Stress and the 4 consecutive samples after the Vacation Stress, there is little observable difference and units #1 and #4 performed poorer than the other two systems in both cases. The mean effluent values for TSS and $CBOD_5$ after the Vacation Stress were a little higher than those after the Power Outage Stress. This may be in part because the raw influent strength was greater during the week following the Vacation Stress compared to the week following the Power Outage Stress (tables 6 and 10). The Temperatures were even cooler during the Vacation Stress than any time before and averaged between15.6 to 16.5 C. The warmest unit was Unit #4 which averaged 16.5 C and this slightly warmer temperature may be reflected in the slightly lower DO values

Table 11. Temperatures for the week following the Vacation Stress

Parameter	T	T	T	T
	Deg C	Deg C	Deg C	Deg C
ATU #	1	2	3	4
Dosing method	Std 40	IE-600	IE-480	IE-720
High value	16.1	16.3	16.2	17.0
Mean value	**15.6**	**15.8**	**15.8**	**16.5**
Low value	15.1	15.0	15.1	15.6
Median value	15.7	16.0	15.9	16.7
n (sample size)	4	4	4	4

Table 12. Values for pH during the week following the Vacation Stress.

Parameter	pH	pH	pH	pH
ATU #	1	2	3	4
Dosing method	Std 40	IE-600	IE-480	IE-720
High value	7.53	7.42	7.32	7.39
Median value	**7.40**	**7.30**	**7.20**	**7.30**
Low value	7.28	7.23	7.11	7.19
n (sample size)	4	4	4	4

Table 13. DO values for the week following the Vacation Stress

Parameter	DO	DO	DO	DO
	mg/l	mg/l	mg/l	mg/l
ATU #	1	2	3	4
Dosing method	Std 40	IE-600	IE-480	IE-720
High value	5.52	6.70	5.35	4.30
Mean value	**4.38**	**5.58**	**5.27**	**3.65**
Low value	3.78	5.43	5.18	2.15
Median value	4.10	5.60	5.30	4.10
n (sample size)	4	4	4	4

A number of repairs were made over a two week period before the system could be resumed with the designed dosing levels. This delay acted somewhat similar to a second Vacation Stress. When the systems were turned back on samples were collected in the normal periodicity of 3 times a week (MWF) and the first week of samples showed mean values that were similar to the 4 consecutive samples collected after the original Vacation Stress (there was no adjustment to dosing levels or added wash loads in the latter event). These results help support the results of the original Vacation Stress.

Table 14. Results of first week after delay due to repairs that was similar to a second Vacation Stress.

Parameter	TSS	TSS	TSS	TSS	TSS	$CBOD_5$	$CBOD_5$	$CBOD_5$	$CBOD_5$	BOD
Concentration	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
ATU #	1	2	3	4	Raw	1	2	3	4	Raw
Dosing method	Std 40	IE-600	IE-480	IE-720	na	Std 40	IE-600	IE-480	IE-720	na
Mean value	**9.60**	**4.10**	**4.00**	**5.60**	**101**	**9.40**	**2.89**	**3.60**	**4.20**	**153**
n (sample size)	3	3	3	3	3	3	3	3	3	3

Extended Design Loading

After the delay, the systems were operated for 3.5 months (January 16, 2012 to April 25, 2012) to confirm the earlier results and develop a more robust data set for design loading. During this period there were some wide fluctuations in the raw (influent) concentrations; especially on the high strength end. Although the mean values for the influent were within range, one sample recorded TSS at 1380 mg/l and $CBOD_5$ at 1286 mg/l. In addition, Unit #3 (IE 480) had a series of valve failures that reduced its loading such that the results during this period must be viewed with caution. It performed very well but did not get an acceptable load during much of this period (Table 15). However, because Unit #2 (IE 600) received more influent during this time than the Standard 40 unit (#1), there is still the ability to compare dosing schemes at similar loading The Standard 40 design loading unit (#1) received an average of 450 GPD while the influent equalization unit (#2) received 498 GPD. These dosing volumes are within 10% of each other and the IE unit which actually received more loading, performed better. Unit #4 received the most loading with an average of 537 GPD and it performed the poorest with regard to TSS but Unit #1 which was the Standard 40 unit received an average 450 GPD performed the poorest with respect to $CBOD_5$. The same general patterns were repeated during this more extensive portion of the study as were observed in the previous design loading periods in that Units #1 and #4 a performed poorer than units #2 and #3.

Table 15. Results of design loading after the Vacation Stress

Parameter	TSS	TSS	TSS	TSS	TSS	$CBOD_5$	$CBOD_5$	$CBOD_5$	$CBOD_5$	BOD
Concentration	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
ATU #	1	2	3	4	Raw	1	2	3	4	Raw
Dosing method	Std 40	IE-600	IE-480	IE-720	na	Std 40	IE-600	IE-480	IE-720	na
High value	80.00	29.50	25.00	364.00	1380	22.30	6.70	26.50	148.00	1286
Mean value	**23.30**	**8.77**	**7.70**	**53.30**	**247**	**9.53**	**2.41**	**3.29**	**10.90**	**215**
Low value	4.00	4.00	4.00	4.00	58	2.00	2.00	2.00	2.00	59
Median value	12.50	8.10	5.50	20.30	156	9.00	2.00	2.30	3.50	150
n (sample size)	34	36	36	35	32	35	36	36	35	32
GPD dosed	450	498	253	537	na	450	498	253	537	na
GPD targeted	480	600	480	720	na	480	600	480	720	na
% of targeted dosing	94%	83%	53%	75%	na	94%	83%	53%	75%	na
Mean % removal	91%	96%	97%	78%	na	96%	99%	98%	95%	na
Median % removal	95%	97%	98%	92%	na	96%	99%	99%	98%	na

System Artifact Assessment and Maximum Loading

On May 22, 2012 we reversed the dosing in order to take any uniqueness of tank or system configuration out of the formula that might influence the results. Therefore Unit #1 received the influent equalization of target of 480 GPD at 15 minute intervals and Unit #3 received the target of 480 gallons per day dosing using the Standard 40 intervals of 3 times a day at 35%, 25%, and 40%. The actual dosing averages between these two units were within 2% of the target dosing and were within 7% of each other. Unit #2 was increased from the addition of one bedroom (600 GPD) to the equivalent of 3 additional bedrooms and targeted at 840 gallons per day using influent equalization. Unit #4 was taken out of service due to the large volume of wastewater being dosed at the site. Unit #2 averaged 741 GPD which was within 12% of the targeted amount and was 150 gallons more than this unit had been receiving previously. It was also almost 100 gallons more than unit #4 was receiving previously and 270 gallons per day more than units #1 and #3 received during the same time. We think these numbers are excellent for evaluating the effectiveness of the dosing schemes (figures 3-5).

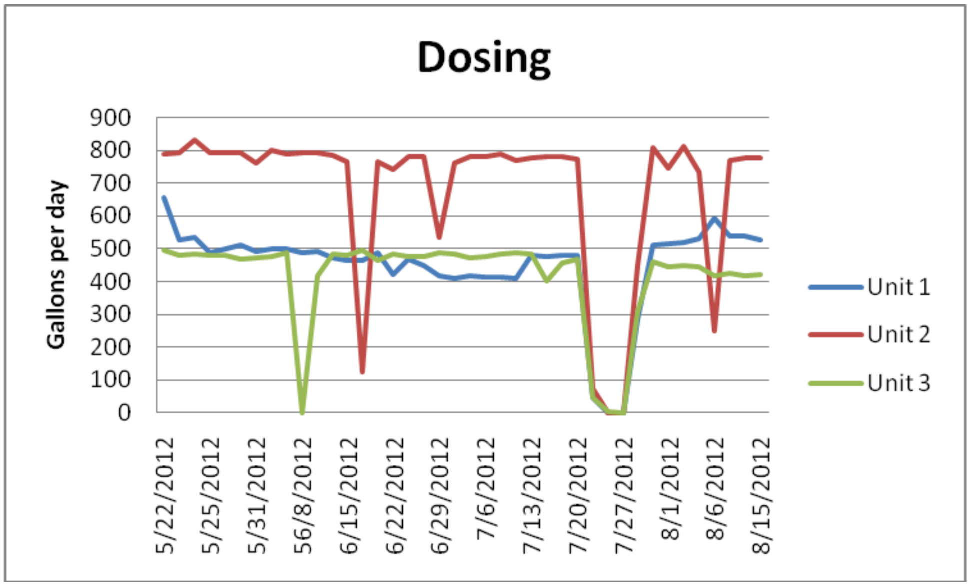

Figure 3. The raw numbers show that there were several times when the dosing failed. The lack of dosing the third week in July is the effect of the vacation stress employed during this study.

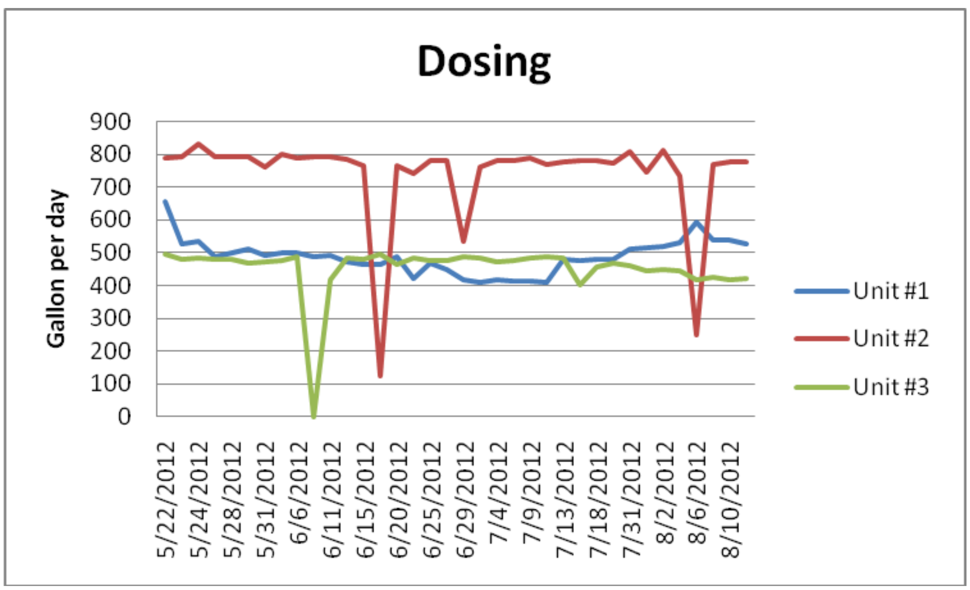

Figure 4. This figure exhibits the most representative dosing related to the units and their performance. The three dosing problems associated with Unit #2 may be the result of system stress due to the large dosing volume. The outlier in June for Unit #3 may just be a coincidence. The mean dosing values are within 2%, 12% and 6% of the targeted values for units #1- #3 respectively and units #1 and #3 are within 7% of each other. When median values are used the units are within 2%, 7% and 1% of the targeted values for units #1-#3 respectively and units #1 and #3 are within 2.5% of each other.

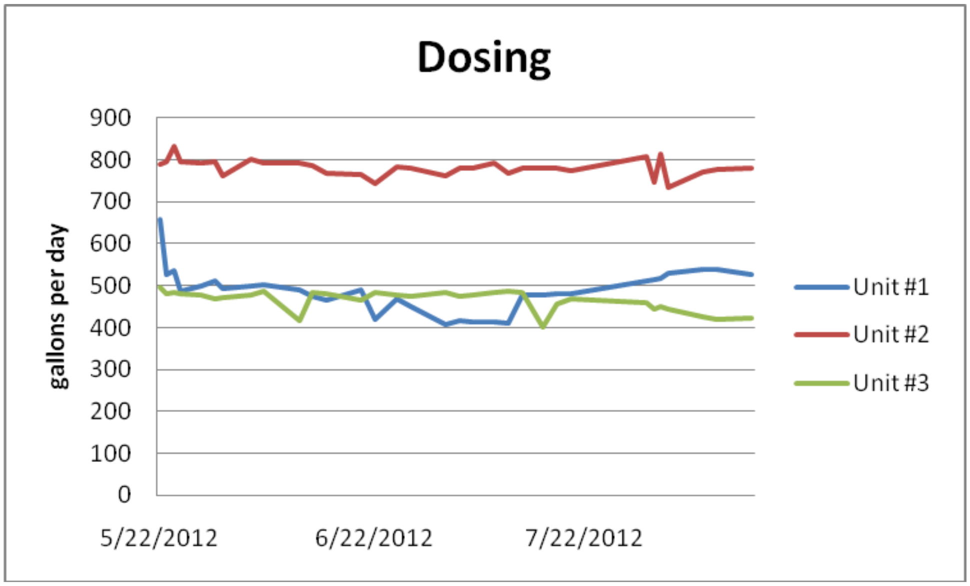

Figure 5. When all dates where dosing failures occurred are eliminated, then the mean dosing values are within 7% of the targeted value for Unit #2 (781 GPD of the target 840 GPD) and within 1% - 3% of the targeted value for Units #1 and #3 (488 GPD and 465 GPD compared to 480 gpd targeted respectively). Units #1 and #3 are within 5% of each other.

Influent Strength Effects

The analyses were evaluated using minimum detectable limits. Anomalous data due to equipment failure or errors have been removed. The average value for the raw influent TSS is 224 mg/l and the average value for the raw influent BOD is 118 mg/l.

The TSS concentrations showed an extremely large peak August 6, 2012 and two other large peaks June 8, 2012 and July 25, 2012 (figure 6). No correlation between influent strength and effluent concentrations has been confirmed at this time. Because there is a delay from influent to effluent and the delay varies by dosing scheme and volume it is difficult to interpret.

When comparing the TSS concentrations of effluent between units #1 and #3 there appears to be an artifact of the system influencing the effluent because the influent equalization (IE) unit (#1) does not appear to be performing better than the Standard 40 dosed unit (#3) and this was reversed in the earlier data. However, the effluent value differences decrease during the last portion of the study (figure 7).

There are three large spikes in TSS for Unit #2 which was dosed at an average of 741 GPD (excluding the Vacation Stress between July 20 and July 29, 2012 when all dosing was stopped for 9 days). The two spikes in TSS experienced by Unit #2 in June correspond to the anomalous dosing on those days which was caused by a hose coming loose in both cases. However, the spike in TSS concentration for Unit #2 on July 20, 2012 was taken before the dosing was ceased for the Vacation Stress and appears unrelated to dosing. It should be noted that all units performed acceptably (immediately) after the Vacation Stress and systems were put back on line (figure 8).

The TSS values for Unit #2 showed the largest mean value (107 mg/l), Unit #1 had the second largest mean value (16.3 mg/l) and Unit#3 had the lowest value at 5.4 mg/l. The unacceptably large value of Unit #2 is the result of several anomalously high readings where it appeared to fail (the maximum TSS value was 1860 mg/l) and the median TSS concentration for Unit #2 was 4.0 mg/l. The system recovered without any maintenance or adjustments after each of these high readings (figures 7 and 8).

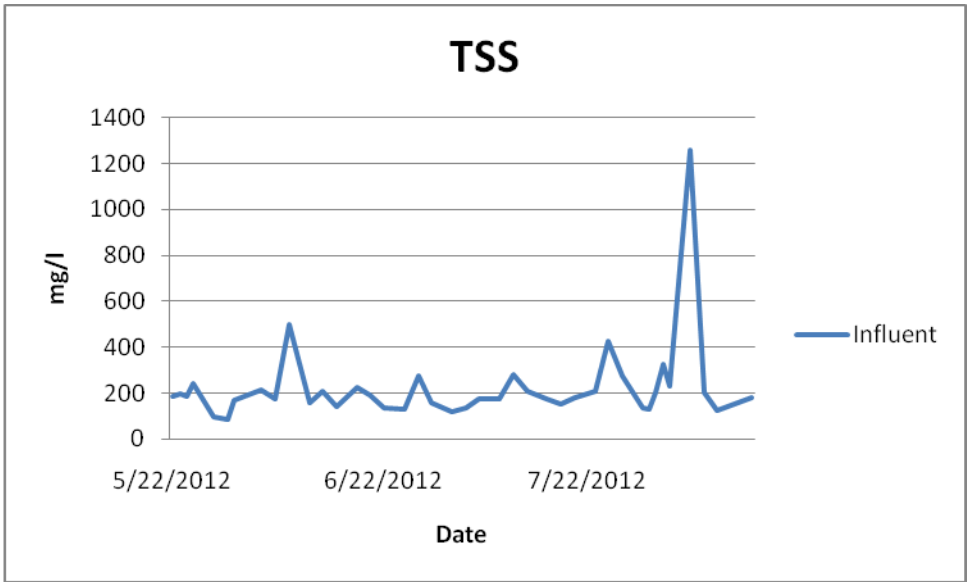

Figure 6. The TSS concentrations for the wastewater influent. Notice the extremely large peak August 6, 2012 and two other peaks June 8 and July 25, 2012.

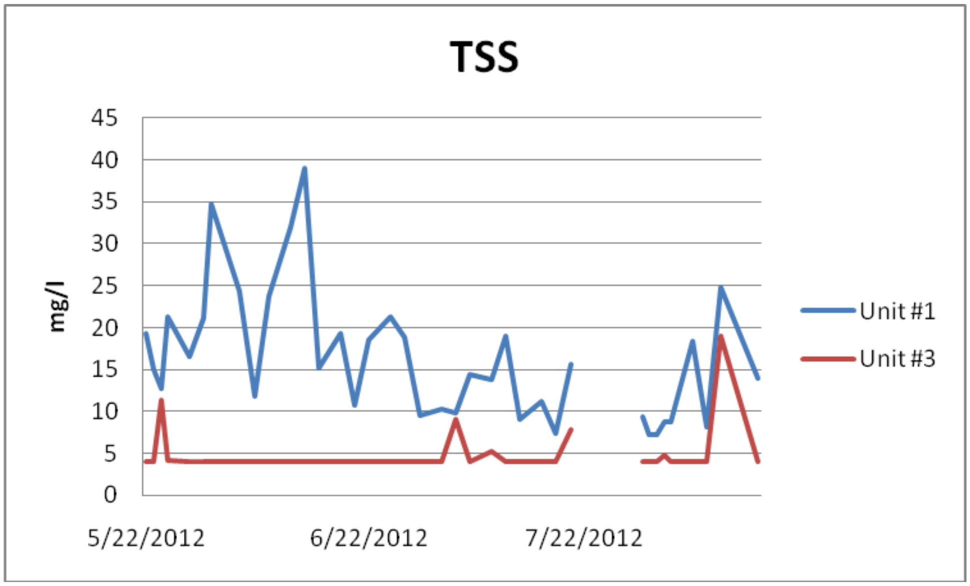

Figure 7. A comparison between units #1 and #3. The gap in the third week of July is the vacation stress where the dosing was stopped for 9 days.

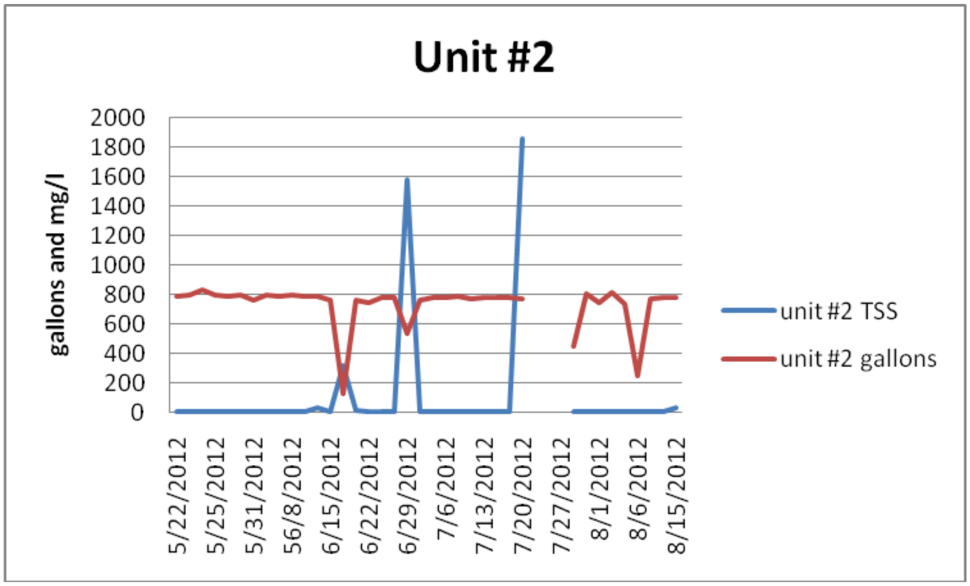

Figure #8. There are three large spikes in TSS for Unit #2 which was dosed at an average of 741 GPD (excluding the Vacation Stress between July 20 and July 29, 2012). The two spikes in TSS experienced in June correspond to the anomalous dosing on those days which was caused by a hose coming loose in both cases. However, the spike on July 20, 2012 was taken before the dosing was ceased for the Vacation Stress and appears unrelated to dosing.

The $CBOD_5$ concentrations for the influent fluctuated quite a bit but there was not a $CBOD_5$ spike that correlated with the extremely large spike in TSS that occurred in August (Figure 9). At the average dosing rate of 488 GPD for Unit #1 (IE) the mean $CBOD_5$ values were 4.0 mg/l while Unit #3 (Std 40) received 465 gallons per day producing an average effluent concentration of 2.6 mg/l for $CBOD_5$. Although Unit #3 performed better than Unit #1, the effluent values were more similar to each other toward the end of the study (Figure 10). Unit #2 which was dosed an average of 741 gallons per day using influent equalization had a mean $CBOD_5$ value of 2.8 mg/l. Although this average is lower than the mean effluent concentration of $CBOD_5$ for Unit #1 which received fewer gallons per day, Unit #2 experienced the two highest concentration spikes in $CBOD_5$ concentrations among the units (Figure 10). Because these spikes were the result of aberrant dosing due to a loose hose they were removed for statistical comparison purposes. Even after these two explainable spikes were removed there is a rather large value for TSS on June 18, 2012 of 323 mg/l. The mean values for TSS and CBOD5 in units #1, #2, and #3 before and after the switch in dosing is shown in Figure 11.

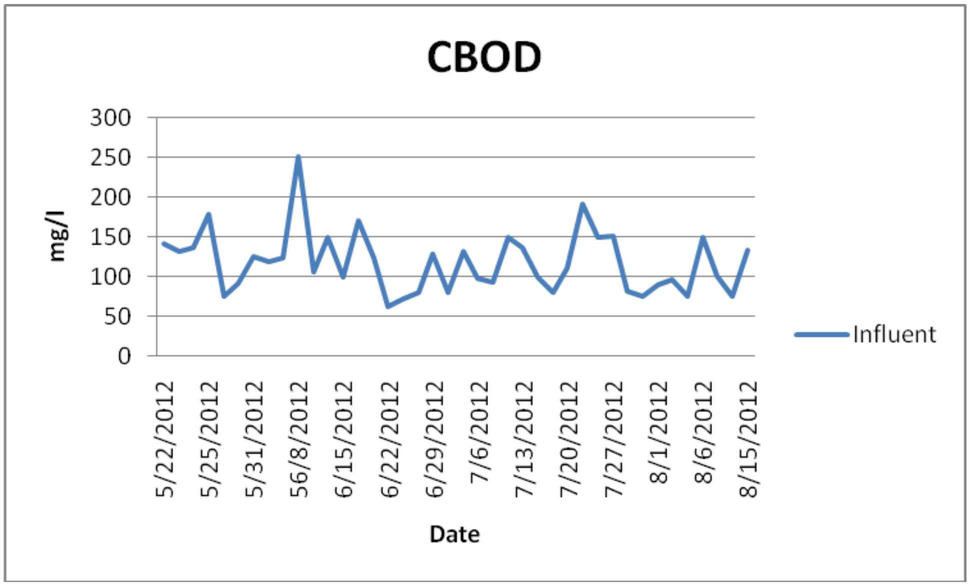

Figure 9. The CBOD concentration of the influent.

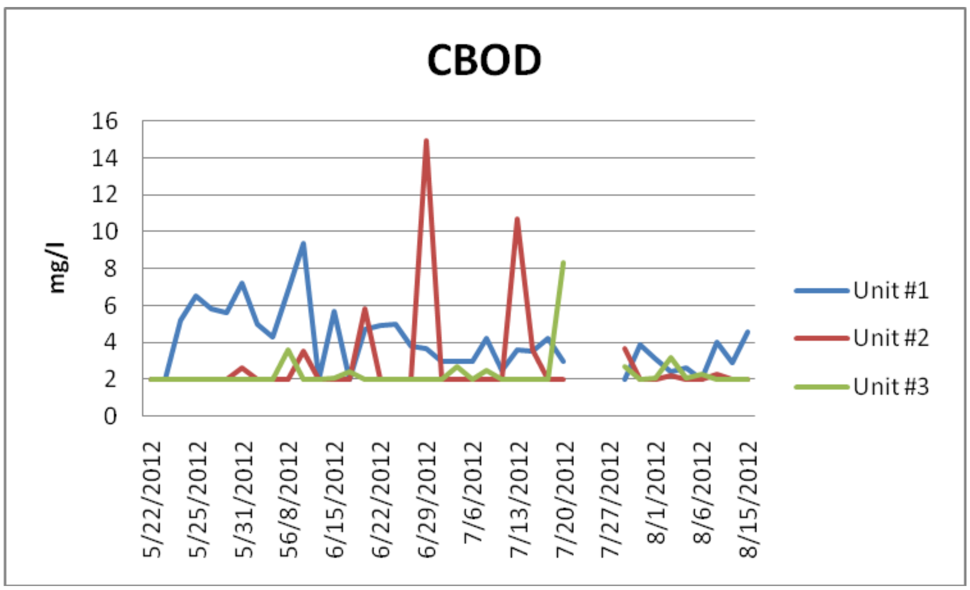

Figure 10. Comparisons of CBOD concentration of effluent from the three units.

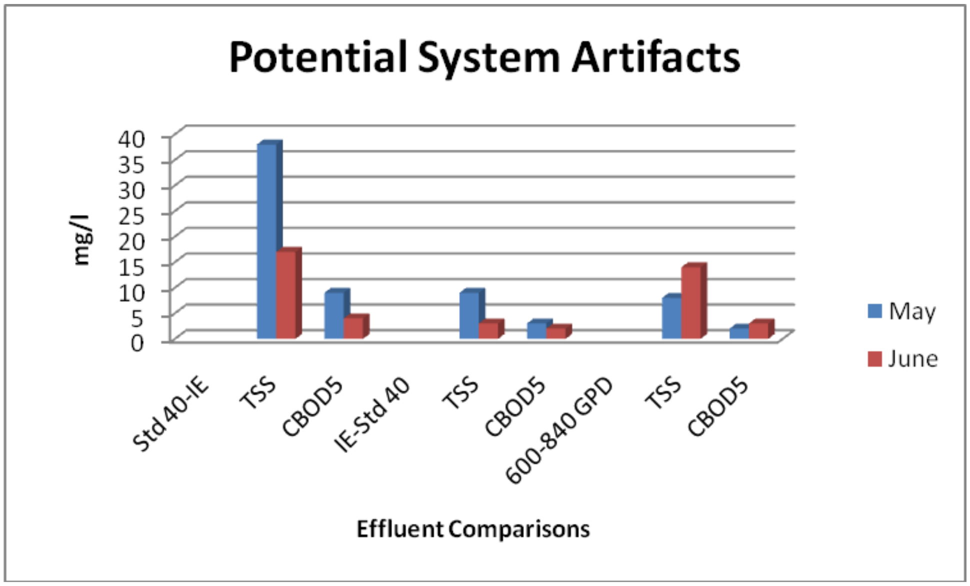

Figure 11. Comparisons of mean effluent concentrations before and after switching dosing schemes near the end of May. Unit #1 was switched from Std 40 to IE at 480 GPD, Unit #3 was switched from IE to Std 40 at 480 GPD and Unit #2 was switched from 600 GPD to 84 GPD.

Table 16. Average values for all samples between the start (September 2, 2011) until April 25, 2012 before changes in dosing schemes.

Parameter	TSS	TSS	TSS	TSS	TSS	$CBOD_5$	$CBOD_5$	$CBOD_5$	$CBOD_5$	BOD
Concentration	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
ATU #	1	2	3	4	Raw	1	2	3	4	Raw
Dosing method	Std 40	IE-600	IE-480	IE-720	na	Std 40	IE-600	IE-480	IE-720	na
Mean value	**21.60**	**6.22**	**6.60**	**26.40**	**189**	**7.80**	**2.37**	**2.64**	**6.58**	**195**
n (sample size)	95	95	95	84	87	95	95	95	84	87
Mean % removal	89%	97%	97%	86%	na	96%	99%	99%	97%	na

When all samples including those involved in the stress tests are averaged from September 2, 2011 to April 25, 2012, the patterns are quite strong. Units #2 and #3 perform better than units #1 and #4. The mean influent values are near the middle of the acceptable range.

Conclusions

1. The influent Equalization dosing scheme appeared to work very well with respect to TSS and $CBOD_5$.

2. The Power Outage and Vacation stresses did not seem to affect the Influent Equalization Treatment results adversely.

3. It appears that IE may allow larger volumes of wastewater to be treated equally well, if not better, than when systems are dosed in slugs similar to the design loading in Standard 40 with respect to TSS and $CBOD_5$.

Recommendations

Because there appeared to be an efficiency artifact inherent in one of the systems under study, it is recommended that further testing be conducted where IE compared to Standard 40 with triplicate systems to rule out statistically any system bias that may have occurred.

Although we were not able to dose consistently at 840 GPD, the effluent values from Unit #2 indicate that the increased loading volumes may be approaching the treatment limit. Somewhere in the 700-900 GPD range the systems do not appear to be as resilient to changes such as fluctuating influent strength. Further testing where influent strength and volumes are varied under controlled conditions would be helpful in developing the best dosing schemes.