Stormwater Monitoring of Beachwood Beach and Avon Road West Beach

A bacteriological and anthropogenic analysis of stormwater

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Abstract

During the summer, a myriad of people flock to bathing beach. People assume that the water that they are swimming in is perfectly safe. Many municipalities utilize storm drain system; often times, the outfall pipes for these systems lead out into water on or very close to bathing beaches. The water coming from the outfall pipes can be infested with bacteria and pollutants as a result of rainfall events. As rainwater builds in a storm drain pipe, the materials inside of it flows towards the outfall pipe. The materials inside of these pipes can be fecal matter from dogs and other animals to litter from the street; however the bacteria that pollute these pipes can also come from human sources. If there are high bacteria counts, then this could lead to illness for beach bathers. It is possible for a septic system to leak or be illegally connected to storm drain systems. Historically, one of the dirtiest beaches in New Jersey is Beachwood Beach and, just recently, Avon Rd. West Beach in Pine Beach and both have stormwater pipes on the beaches. To monitor the effects of the pipes, *E. coli*, *Enterococcus sp.*, optical brightener, and various abiotic factors were monitored during storms and dry weather. The results indicate that there are pollutants in the pipes, thus causing elevated levels of bacteria at these bathing beaches.

Introduction

Millions of people every year enjoy going to bathing beaches to swim. In 2010, 24,091 closing and advisories were issued for these beaches throughout the country. The most common reason for these closings and advisories is because of beach pollution (NRDC, 2011). This is most frequently caused by stormwater runoff.

As it rains, the water builds up in the street. Eventually, the water makes its way to a storm drain. Any pollutants that are on the impervious streets are washed away into the storm sewers. Fertilizers, cigarettes, pesticides, excrement, and other pollutants are taken into the storm drain systems. Many people dispose of garbage, such as bags of dog excrement, in these storm drains (Kirwan, 2005). In order to avoid larger objects such as a plastic bag of dog excrement from going into the drain, a large grate with small holes are placed on the storm sewer. This way, only very small objects and easily dissolved compounds make their way into the storm sewers; however, not all drains have these grates and many have large openings. From these sewers, the water flows into pipes and the water will eventually be led to a water body.

This water can carry fecal matter. This can be a result of excrement in the pipes; however, it is possible that there is an illegal connection with septic systems. The fecal matter can leak into the runoff water in the storm drains (Kirwan, 2005). This fecal matter is then transported to the outfall pipe and into whatever body of water that it drains into. These bodies of water, often times, are bathing beaches. Because this runoff enters the beach system, the water quality of the area is negatively impacted (Dickerson, Hagedorn, & Hassell, 2007). In the case of fecal matter being introduced, excess bacteria is brought into the system which can affect the health of any organism.

Figure 1: The stormwater pipe at Beachwood Beach.

When a human swims in water that has a high level of fecal coliforms, there is the possibility of sickness. Usually, ear infections, sore throats, typhoid fever, hepatitis and similar ailments are common; however, gastroenteritis is very prevalent in these cases (NRDC, 2011). Other more serious diseases could be contracted by swimming in the water because fecal coliform is treated as indicator bacteria. When there is a high level of fecal bacteria, it is very probable that dangerous pathogenic organisms are present in the water (NRDC, 2011). These organisms can cause much more serious health problems and can potentially kill people. This makes water quality monitoring a very important aspect of beach health.

The local health department, specifically in Ocean County, New Jersey tests every Monday during the beach bathing season. The Health Department tests bacteria levels to see if it is harmful for people to swim in the water (New Jersey Department, 2011). They used to use a type of fecal coliform called *Escherichia coli*, or more commonly known as *E. coli*. The maximum limit for this was 200 colony forming units (CFU) per 100 mL. *E. coli* is a rod shaped bacteria that is often found in the intestines birds and mammals. Most of the different types of this bacterium are harmless; however, there are a couple of strains that can be harmful.

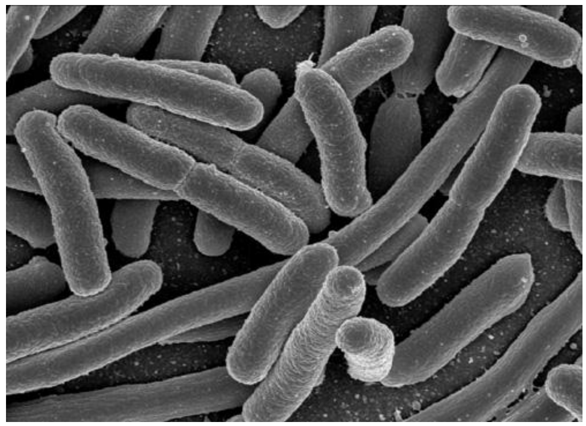

Figure 2: *E. coli* in water (Photo courtesy of Lake Huron Centre for Coastal Conservation).

After the Beaches Environmental Assessment and Coastal Health (BEACH) Act, *Enterococcus spp.* became the standard for marine water. The maximum limit for these bacteria was 104 CFU/100 mL. Just *E. coli* is a subgroup within fecal coliforms, *Enterococcus spp.* is a subgroup within the fecal streptococci (NRDC, 2011). Because it can survive in saltwater more readily, *Enterococcus*, it is used as the standard for marine waters. *E. coli* is used as the standard for freshwater systems.

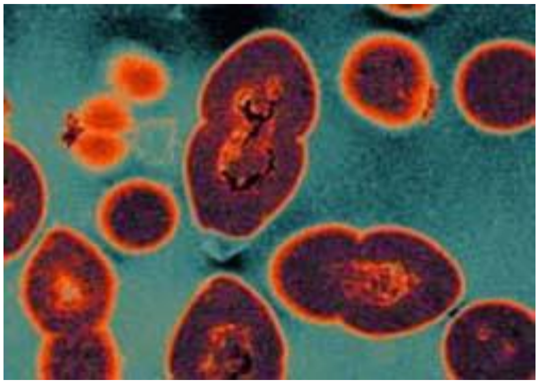

Figure 3: *Enterococcus sp.* in water (Photo courtesy of University of North Carolina at Chapel Hill).

Even though these bacteria are used for beach monitoring, it is not always known if they are from a human source. It is possible that these bacteria are the result of excrement from wildlife, not humans. In order to show if there is a human signature in a system, the bacteria are correlated with optical brighteners (Dickerson, 2007). Optical brighteners are a type of fluorescent dyes that can be found in laundry detergents, paper, and other products (Kashcig, 2003). This compound enhances the color of a substance. Since it is associated with human sources, it is used to decide if there is a human impact on a system. Optical brighteners can be one of many compounds that can be found in the stormwater in the storm drains. Because of the wide use of detergents and similar compounds, they are found in human wastewater that typically contains laundry effluent (Boving, Merritt, & Boothryd, 2004). If there is a high level of optical brighteners and a high level of bacteria, it can be inferred that there is a human source affecting that ecosystem.

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Regardless of origin, bacteria levels that are above the standards are harmful to humans. As a result, beaches can be closed. The National Resources Defense Council (NRDC) collects the data that local health agencies collect on bathing beaches and compiles a list. The NRDC gives tallies up the amount of times that a beach violates the standard for bacteria (NRDC, 2011). If a beach is found to continually violate, then it is placed on the "Beach Bum" list. In New Jersey, Beachwood Beach in Beachwood Township in Ocean County is a continual violator of the standards. In 2010, it was over the limit 27% of the time. In the past, Beachwood Beach has been on the "Beach Bum" list numerous times (NRDC, 2011). The Avon Road West Beach in Pine Beach, New Jersey violated the standard 15% of the time and was on the "Beach Bum" list for the first time in 2010 (NRDC, 2011). Both of these beaches have stormwater outfall pipes on the bathing beaches

Methodology

Beachwood Beach, Beachwood, NJ, 08722 and Avon Road West Beach, Pine Beach, NJ, 08741 were the study locations due to their high bacteria levels. Beachwood Beach was deemed Location 1 and had four sites. With each site, a code was created. For Location 1, Site 1, the code was L1S1. For Location 1, Site 2, the code was L1S2. This followed suit for the rest of the sites. Avon Road West Beach was Location 2. This location had three sites and the code names followed suit (e.g. L2S3 is Location 2, Site 3).

Figure 4: This exhibits the Beachwood Beach site with each sampling site: L1S1 (39° 56' 31.75" N, 74° 11' 08.08" W), L1S2 (39° 56'32.29" N, 74° 11' 06.36" W), L1S3 (39° 56' 34.39" N, 74° 11' 03.27" W), and L1S4 (39° 56' 29.21" N, 74° 10' 56.65" W).

Figure 5: This exhibits the Avon Road West Beach Site with each sampling site: L2S1 (39° 56' 27.79" N, 74° 10' 20.24" W), L2S2 (39° 56' 28.66" N, 74° 10' 17.07" W), and L2S3 (39° 56' 26.60" N, 74° 10' 08.59" W).

The equipment utilized included two incubators, IDEXX® Quanti-Tray Sealer, IDEXX 51-Well Quanti-Tray®, IDEXX Quanti-Tray/2000, Enterolert® media, treated petri dishes, pipettes, Coliscan Easygel® media, YSI 85, Turner Design AquaFluor™ Handheld Fluorometer, disposable cuvettes, 10 nalgene laboratory bottles, sodium thiosulfate treated WhirlPaks®, nitrile gloves, kimwipes, and deionized water. Before any sampling session (unless sampling sessions were within 24 hours of each other), the equipment was calibrated. The AquaFluor® Handheld Fluorometer was calibrated for optical brighteners using a standard that the Department of Environmental Protection provided: 5% detergent. This fluid was intended to read 50 on the meter. Another calibration solution was provided for the DEP for turbidity. The solution was 100 NTU.

Figure 6: The two incubators (on left) and the IDEXX® Quanti-Tray Sealer (on right).

There were two types of sampling sessions that occurred: baseline and storm sampling. Baseline sampling occurred on 6/27/11, 7/7/11, 7/18/11, 7/25/11, and 8/1/11; this was implemented to see what the levels are like during dry weather days. All dates but 7/7/11 were Mondays; this was done so that the *Enterococcus* values could be compared to the Ocean County Health Department's data.

For water sampling, chest waders and gloves were used. The water samples were taken in water that was approximately up to the sampler's waist or thigh area. The samples were taken about 8-12 inches down from the surface of the water. Then the WhirlPak® was opened and filled up. The WhirlPak was closed and then whirled and tied up. This was done at each sampling site. Once the water sample was collected, the Whirlpak® was deposited into a cooler filled with ice. Samples were collected according to the procedures set forth in NJDEPE, Field Sampling Procedures Manual (Chapter 7, Section F, and Bacteriology), Trenton, NJ, 1992; and in Chapter IX (Public Recreational Bathing) of the State Sanitary Code, N.J.A.C. 8:26-1 et seq. (revised May 2000).

Figure 7: Two full WhirlPaks® from Beachwood Beach.

The parameters collected from the samples were salinity (YSI 85), conductivity (YSI 85), dissolved oxygen (YSI 85), percent saturation (YSI 85), temperature (YSI 85), optical brighteners (AquaFluor™ Handheld Fluorometer), turbidity (AquaFluor™ Handheld Fluorometer), *E. coli* (Coliscan Easygel®), and *Enterococcus spp*. (IDEXX®). Each of the parameters was collected according to the protocols of their respective methods and devices.

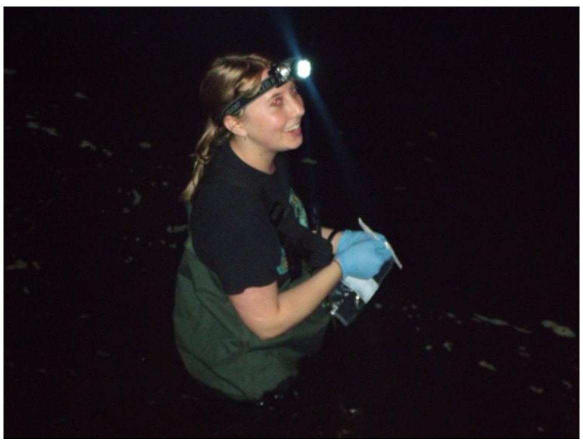

Figure 8: A researcher with gloves on collecting a WhirlPak®.

Using the National Oceanic and Atmospheric Administration's Doppler Radar, storm monitoring could be done. If a storm seemed substantial (having at least a dark green color on the radar) then sampling was done. Water sampling was done within the first flush of the storm. On 6/28/11 and 7/3/11, only Beachwood Beach was sampled. During this time, the YSI 85 was taken into the field and used directly in the water. After these storm sampling events, the water samples were collected and then transported to the laboratory. There the YSI 85 and the other equipment was used. This was done for baseline as well starting on 7/7/11. By doing this method, both Beachwood Beach and Avon Road West Beach were able to be sampled in the same storm. Due to time constraints, travel time, and storm intensity, the first flush was not sampled on 6/28/11, 7/3/11, and 7/29/11; however, the second flush was always sampled. Due to the measures taken in this study and the Quality Assurance Plan, this sampling was placed under the Tier B level of the NJDEP's Volunteer Water Quality Monitoring Program. In this tier, planning the study, training for the techniques used, and calibrating the equipment correctly and according to NJDEP guidelines are required.

Figure 9: The YSI 85 model that was used in the study.

Results

Table 1: The rainfall amounts for each of the storm sampling events.

Date	Rainfall (inches)	
	A	B
6/28	n/a	0.01
7/3	n/a	0.1
7/8	0.02	0.11
7/25	0.06	0.06
7/29	n/a	1.25

Table 2: The average levels of each of the parameters in each location during baseline testing.

Parameter	L1S1	L1S2	L1S3	L1S4	L2S1	L2S2	L2S3
Percent Saturation (%)	84.8	85	91.4	89.4	89.4	95.4	91.8
Dissolved Oxygen (mg/L)	6.57	6.62	6.88	6.79	6.4	6.9	6.8
Conductivity (mS/cm)	17.52	17.65	17.47	19.7	23.83	23.57	24.38
Salinity (‰)	10.3	10.5	10.5	11.5	13.7	13.8	14
Temperature (^{o}C)	25.4	25.3	25.6	26.3	28	27.9	27.9
pH	6.9	7	7	7.1	7.7	7.9	7.9
Optical Brighteners	83.56	95.34	90.77	99.23	87.94	395.47	135.85
Turbidity (NTUs)	6.207	4.44	3.351	4.369	5.718	3.633	3.258
E. coli (CFUs/100mL)	650	880	1380	760	260	440	280
Enterococcus (mpn)	18	16	24.2	20	18.2	26.8	16

Table 3: The averages of all the parameters during the first flush for each location.

Parameter	L1S1	L1S2	L1S2i	L1S3	L1S4	L1S4i	L2S1	L2S2	L2S2i	L2S3
Percent Saturation (%)	95.5	94.1	85.2	93.4	96.9	95.2	95	92.4	88.9	93.8
Dissolved Oxygen (mg/L)	7.48	7.38	6.55	7.32	7.49	7.19	7.04	7.06	6.49	6.87
Conductivity (mS/cm)	15.27	16.75	15.96	18.35	21.93	21.61	22.61	20.05	24.48	25.42
Salinity (‰)	9.6	9.5	9	10.5	12.7	12.6	14.1	14.8	14.5	15.2
Temperature (^{o}C)	26.7	26.6	26.6	26.7	26.7	26.6	26	26.4	26.2	25.9
Optical Brightners	110.8	123.25	158.58	120.9	56.45	100.6	86.42	95.91	103.92	82.88
Turbidity (NTUs)	7.663	9.484	8.889	5.506	14.947	5.203	5.091	5.474	7.317	6.821
E. Coli (CFUs/100 mL)	1000	800	17850	1400	700	2100	900	200	2500	1000
Enterococcus (mpn)	77.5	75	88	85.25	77.5	77.5	72	35	40	60

Table 4: The averages of all the parameters during the second flush for each location.

Parameters	L1S1	L1S2	L1S2i	L1S3	L1S4	L1S4i	L2S1	L2S2	L2S2i	L2S3
Percent Saturation (%)	95.3	95.8	84.7	89.8	92.5	90.8	84.3	89.7	85.5	88.5
Dissolved Oxygen (mg/L)	7.36	7.47	6.97	6.75	7.35	6.73	6.75	7.06	6.12	6.59
Conductivity (mS/cm)	16.31	16.09	10.47	17.08	17.82	20.13	23.98	20.16	19.58	24.82
Salinity (‰)	9.1	9.4	5.8	9.7	10.9	12	14.5	14.5	11.6	14.8
Temperature (^{o}C)	25.4	25.2	23.6	25.3	25.6	25.3	25.2	25.8	25.9	26
pH	7.4	7.3		6.8	6.8					
Optical Brightners	106.79	104.21	181.13	127.68	97.55	94.5	101.52	86.82	105.11	87.18
Turbidity (NTUs)	4.491	3.583	7.313	4.035	4.398	4.682	5.749	3.839	4.334	5.203
E. Coli (CFUs/100mL)	10740	4825	18725	1440	840	1175	3967	967	8333	933
Enterococcus (mpn)	4899	1435	4938	362	265	246	3416	695	2792	227

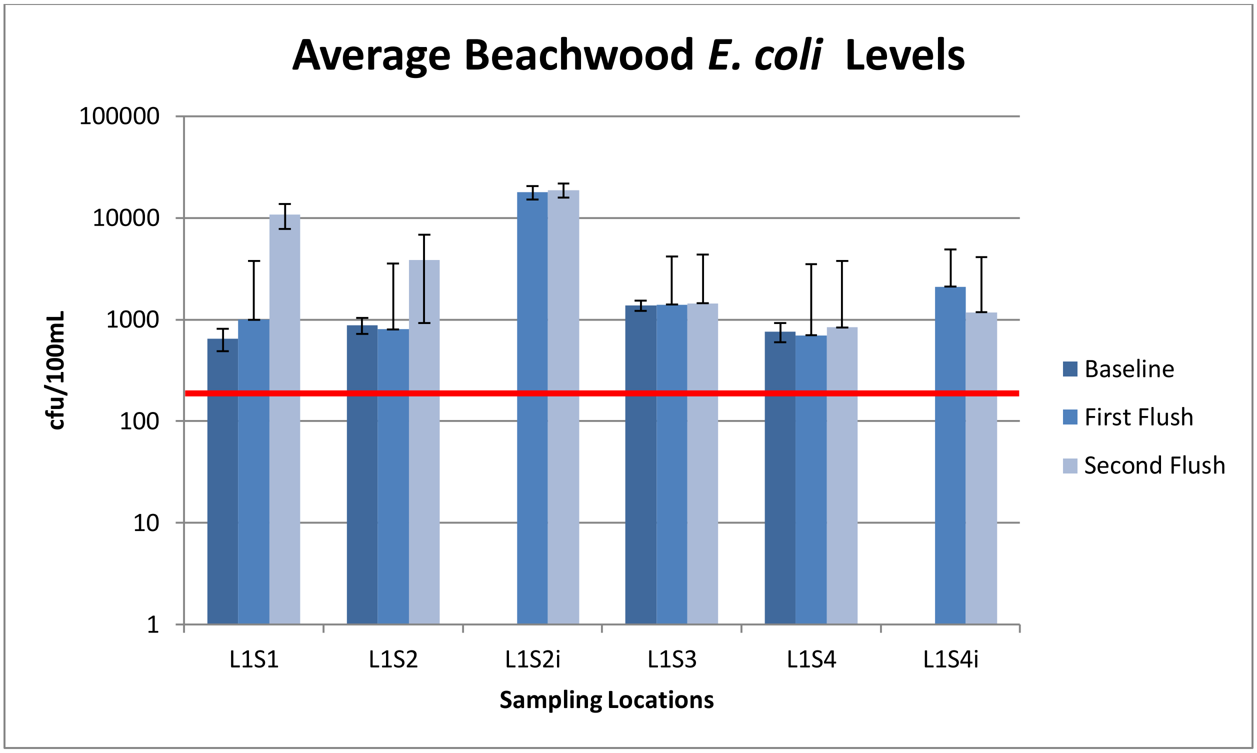

Figure 10: The average of the Beachwood levels for *E. coli* for baseline, first flush, and second flush for each location. The red line is the limit for *E. coli* in freshwater.

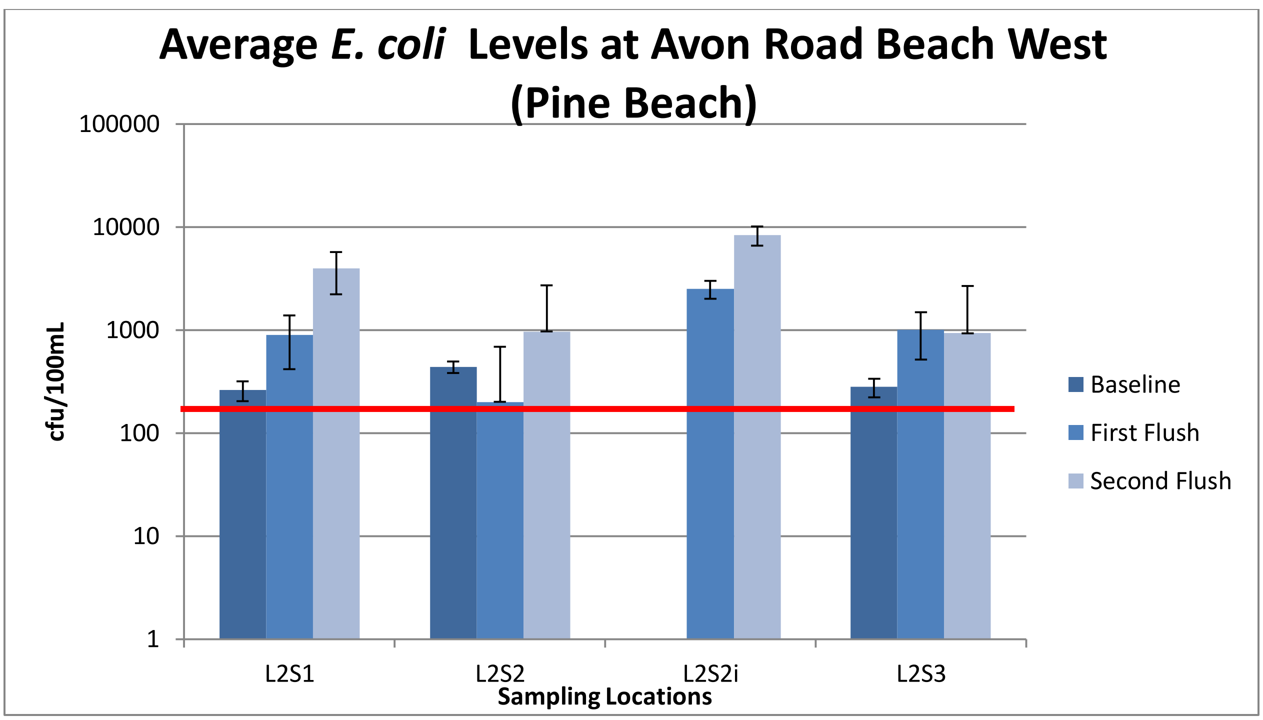

Figure 11: The average *E. coli* levels for Avon Road West Beach. The red line represents the limit for *E. coli* in freshwater.

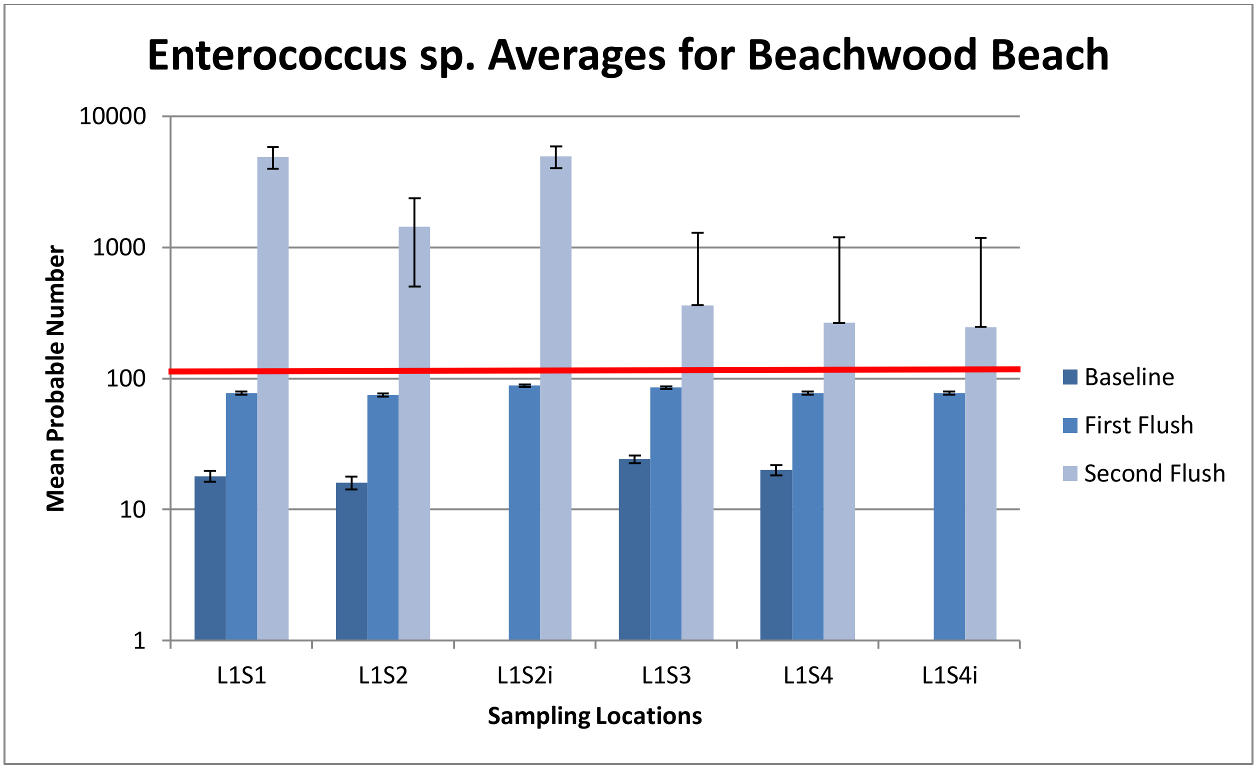

Figure 12: The average *Enterococcus sp.* Levels at Beachwood Beach for each location. The red line is the limit for *Enterococcus sp.* in marine waters.

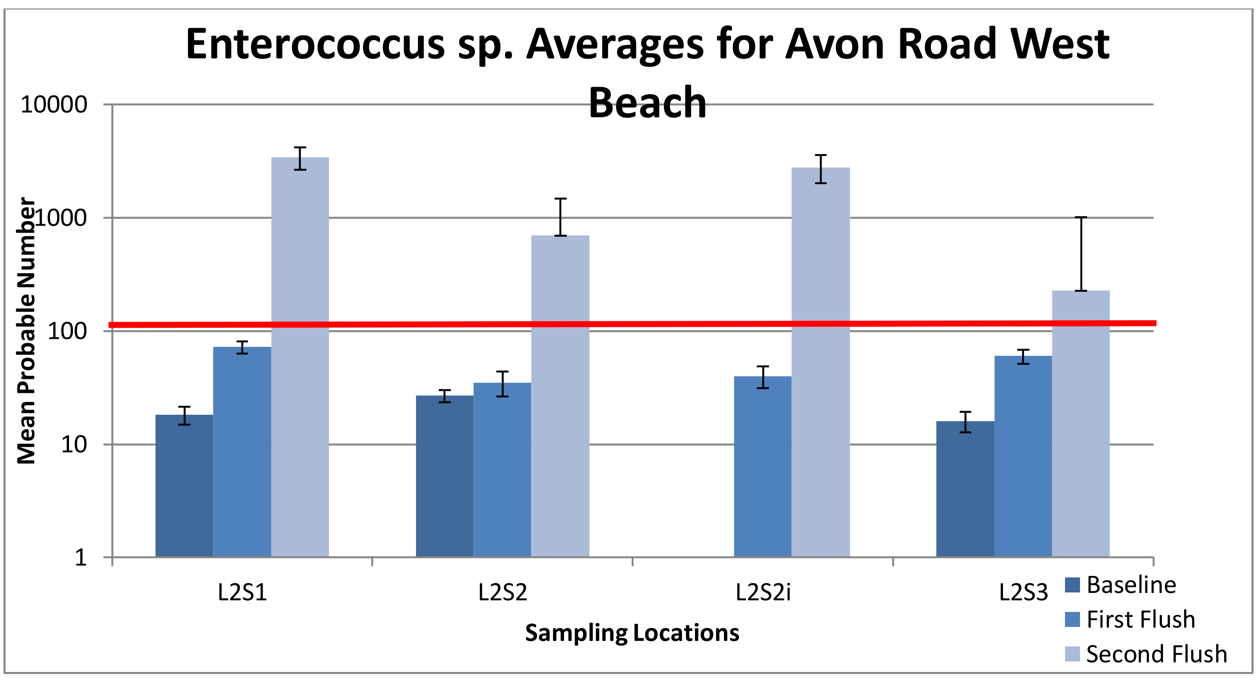

Figure 13: The average *Enterococcus sp.* levels for Avon Road West Beach for all locations. The red line represents the limit for *Enterococcus sp.* in marine water.

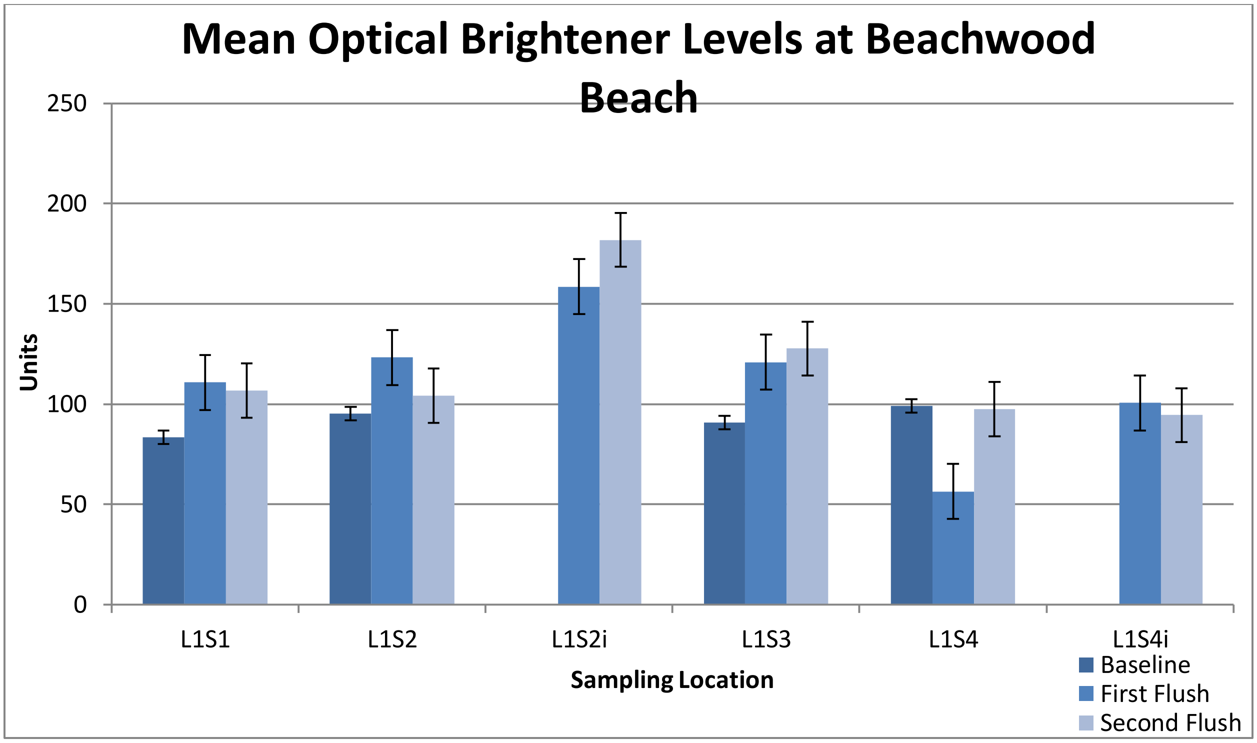

Figure 14: The average of the optical brightener levels for Beachwood Beach in each location.

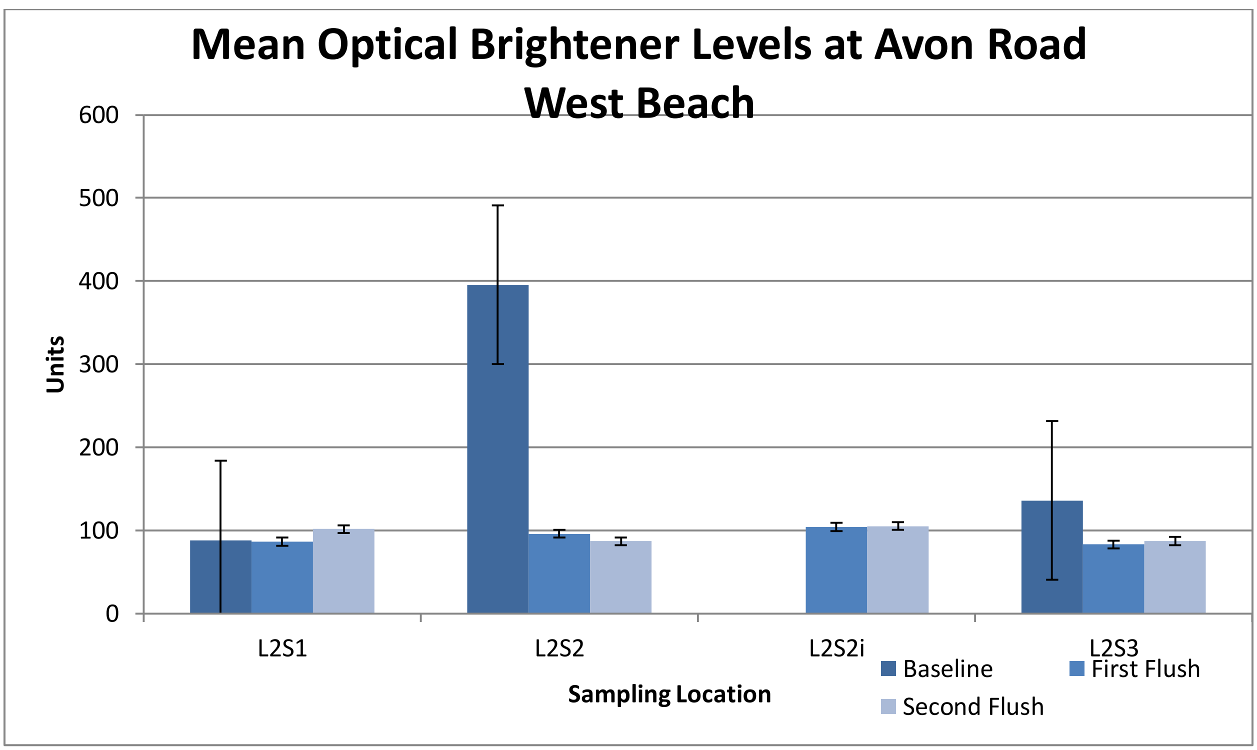

Figure 15: The average optical brightener levels at Avon Road West Beach at all the locations.

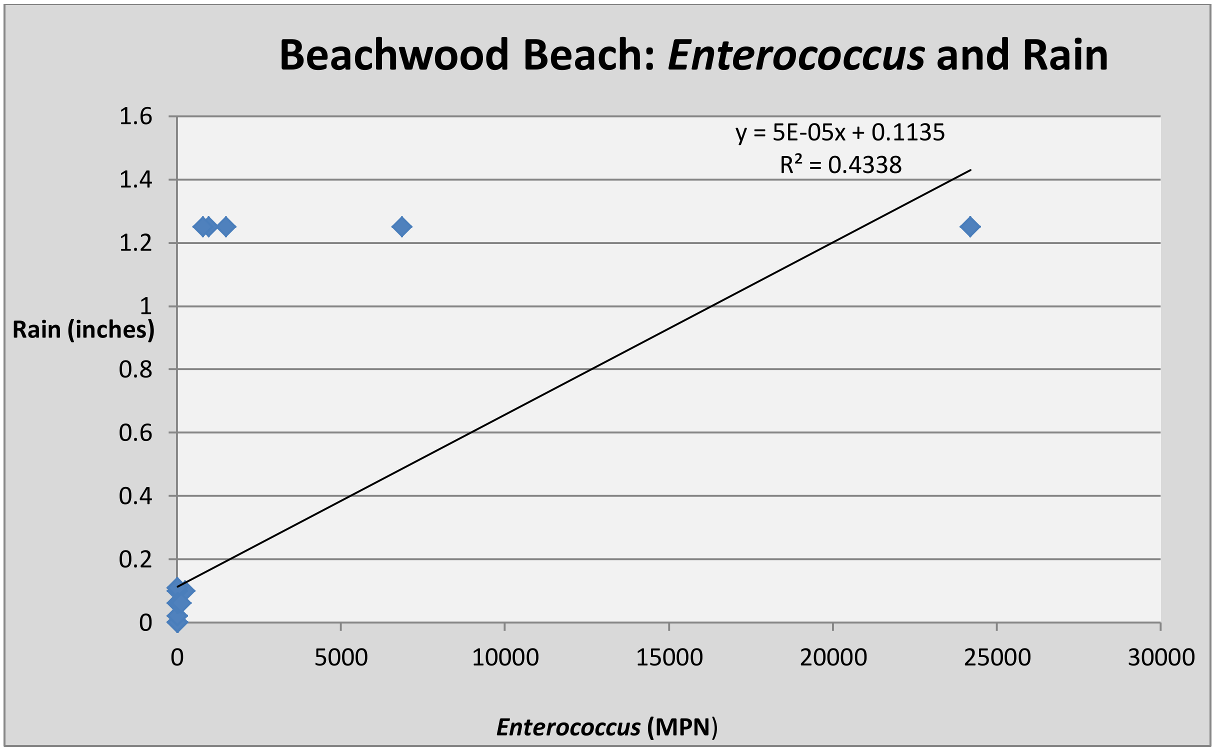

Figure 16: The *Enterococcus sp.* levels from Beachwood Beach compared to the corresponding rain amounts.

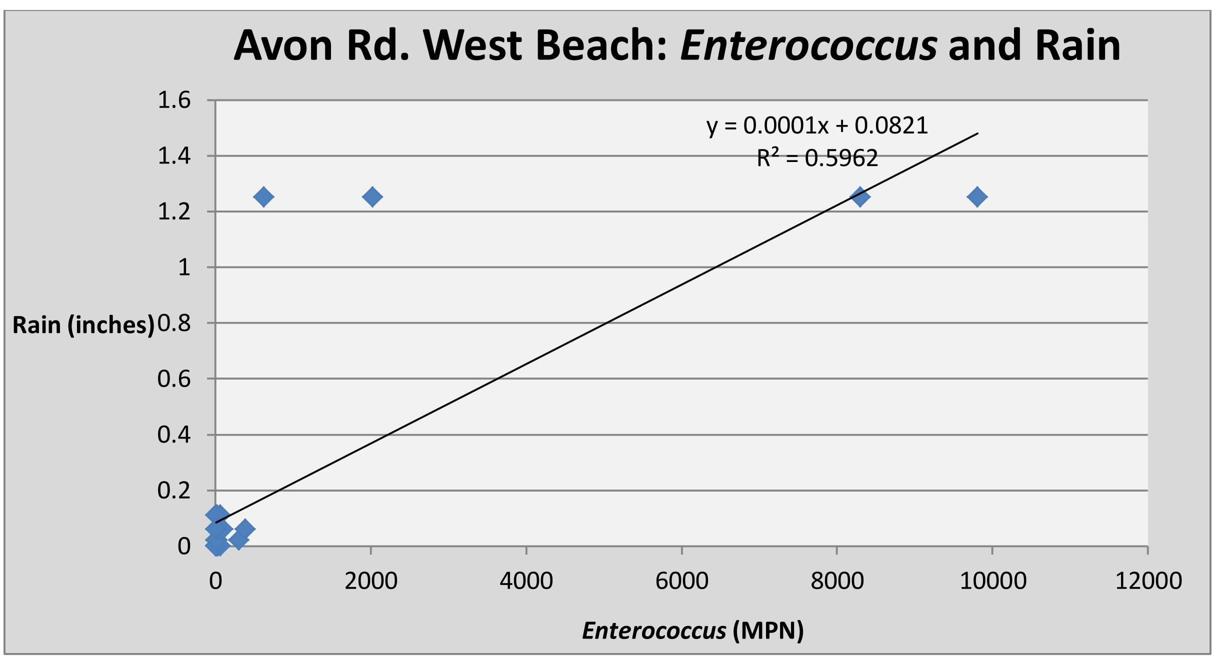

Figure 17: The *Enterococcus sp.* levels from Avon Rd. West Beach compared to the corresponding rain amounts.

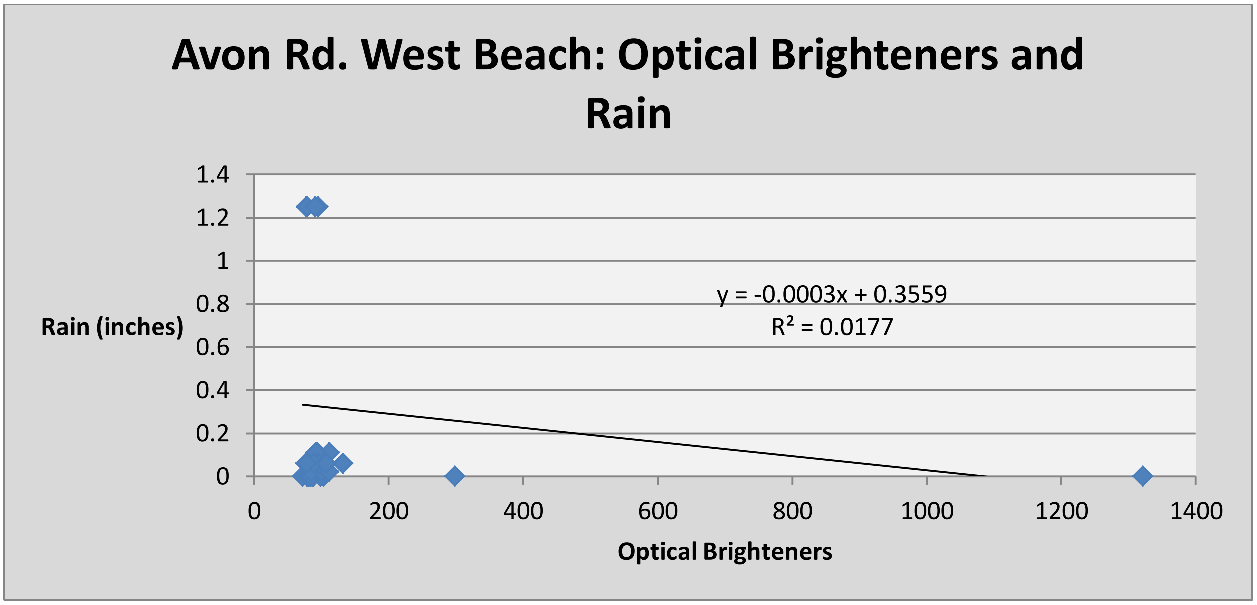

Figure 18: The optical brightener values with the corresponding rainfall amounts at Avon R. West Beach.

Table 5: The Health Department *Enterococcus sp.* data and the IDEXX data from Beachwood Beach and Avon Road West Beach.

Date	Beachwood (CFU/100 mL)		Avon (CFU/100 mL)	
	Health Dept.	IDEXX	Health Dept.	IDEXX
6/27/11	10	11.892	34.641	18.371
7/18/11	10	10	10	10
7/25/11	40	13.269	10	14.581
8/1/11	20	11.892	30	18.566

Table 6: The *Enterococcus sp.* data from the NJDEP's Leed's Point Laboratory and the IDEXX data from Beachwood Beach on 8/1/11.

Location	Leed's (CFU/ 100 mL)	IDEXX (CFU/100 mL)
L1S1	30	10
L1S2	20	10
L1S3	37	10
L1S4	3	20

Table 1 shows the rainfall data for each of the storm sampling dates. On 6/28/11 the second flush experienced 0.01 and the first flush was not captured. On 7/3/11, the second flush experienced 0.1 inches and the first flush was not sampled.

The first flush was sampled on 7/8/11 and it had 0.02 inches of rain; the second flush had 0.11 inches. On 7/25/11, the first flush had 0.06 inches and the second flush had the same. On 7/29/11, the first flush was not sampled and the second flush had 1.25 inches of rain.

Table 2 shows the averages of all the parameters collected for each location during baseline sampling. The percent saturation ranged from 84.8% to 95.4%. The dissolved oxygen levels were between 6.4 mg/L to 6.9 mg/L. The conductivity ranged from 17.47 mS to 23.83 mS. Salinity varied between 10.3 ppt and 14 ppt. Temperature was between 25.3°C to 28°C. The pH values ranged from 6.9 to 7.9. The optical brightener levels were between 83.56 and 395.47. Turbidity varied between 3.258 NTU and 6.207 NTU. *E. coli* was between 260 CFU/100 mL and 1380 CFU/100 mL; *Enterococcus sp.* was between 16 MPN and 26.8 MPN.

Table 3 exhibits the averages of all parameters from each location during the first flush. Percent saturation varied between 85.2% and 96.9%. The dissolved oxygen levels ranged from 6.55 mg/L and 7.48 mg/L. Conductivity varied from 15.27 mS and 25.42 mS. Salinity was between 9 ppt and 14.8 ppt. Temperature varied from 26°C and 26.7°C. The optical brighteners were between 56.45 and 158.58. Turbidity varied from 5.091 NTU to 14.947 NTU. The *E. coli* was between 200 CFU/100 mL and 17,850 CFU/100 mL. The *Enterococcus sp.* was between 35 MPN and 88 MPN.

Table 4 presents the averages of all the parameters in each location from the second flush. Percent saturation ranges from 84.3% to 95.8%. Dissolved oxygen was between 6.12 mg/L and 7.47 mg/L. The conductivity varied between 10.47 mS and 24.82 mS. The salinity was between 5.8 ppt and 14.8 ppt. The temperature varied from 23.6°C and 26°C. The pH varied from 6.8 to 7.4. Optical brighteners were between 86.82 and 181.13. Turbidity ranged from 3.583 NTU to 7.313 NTU. *E. coli* varied from 840 CFU/100 mL to 18725 CFU/100 mL. *Enterococcus* ranged from 227 MPN to 4938 MPN. Figure 11 – 15 graphically display the information that is shown in Tables 2 – 4. Figure 16 shows the *Enterococcus sp.* data with the corresponding rainfall amount for Beachwood Beach. The r^2 value is 0.4338 and the equation of the line is $y = (5 \times 10^{-5})x + 0.1135$. Figure 17 shows the *Enterococcus sp.* levels with the corresponding rainfall amounts at Avon Rd. West Beach. The r^2 value is 0.5962 and the equation of the trendline is $y = 0.001x + 0.0821$. Figure 18 shows the optical brightener levels with the corresponding rainfall amounts at Avon Rd. West Beach. The r^2 value was 0.0177 and the equation was $y = 0.0003x + 0.3559$.

Table 5 shows the values the Ocean County Health Department received from sampling. These values ranged from 10 CFU/100 mL to 40 CFU/100 mL of *Enterococcus sp.*. The data from the IDEXX test ranged from 10 MPN to 18.581 MPN. Table 6 exhibits the values from the Leed's Point Laboratory and the IDEXX values. The Leed's Point Laboratory's data ranged from 3 CFU/100 mL to 37 CFU/100 mL. The IDEXX values were either 10 MPN for L1S1, L1S2, and L1S3; it was 20 MPN for L1S4.

Discussion

The data collected indicates that there is a large problem in Beachwood Beach and. The *E. coli* readings at this location were very high and astronomical on some occasions. On 7/8/11 at L1S2iB, the *E. coli* level was 41,900 CFU/100 mL (Figure 19). This is significantly higher than the 200 CFU/100 mL limit. This was in water that had a salinity of 0.9 ppt, which is considered to be freshwater still; therefore, the limit of 200 CFU/100 mL is valid in this case. This reading is supported by other high readings that were found in Beachwood in all locations for *E. coli*. On average, the site with the highest *E. coli* value was L1S2i (18,725 CFU/100 mL) (Figure 10) during the second flush.

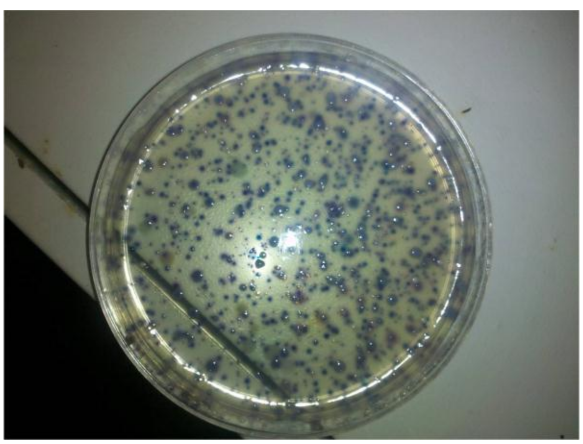

Figure 19: The Coliscan Easygel plate for L1S2iB on 7/8/11 with 41,900 CFU/100 mL of *E. coli*.

L1S2 also seems to affect L1S1. On 7/29/11, the *E. coli* was 51,000 CFU/100 mL. It seems that the water from the pipe migrated to L1S1 and caused these high readings. L1S2i also had the highest average of *Enterococcus sp.* levels (4937.8 MPN) (Figure 12) The entire IDEXX® tray fluoresced on 7/29/11. The corresponding amount is >24196 MPN (Figure 22). On average, the optical brightener levels were very high (181.83) (Figure 14). These high readings indicate that there is a large problem with this stormwater pipe. The high optical brightener levels indicate that there is a human signature in that region. L1S2 averaged 104.21 for this parameter. This is much lower than the 181.83 from L1S2i. For the *Enterococcus sp.* levels, the average for the second flush was above the limit (Tables 2 – 4). In fact, all locations in Beachwood Beach were above the limit for *Enterococcus sp.* during the second flush, on average. This shows that the water coming from the pipes is harboring a large amount of bacteria that is polluting the bathing beach water. Because the numbers from the second flush are higher than the numbers from the first flush, it can be concluded that the problem in the pipe is far from the outfall pipe: it seems that it takes a long time for whatever substances are polluting the pipe to come out.

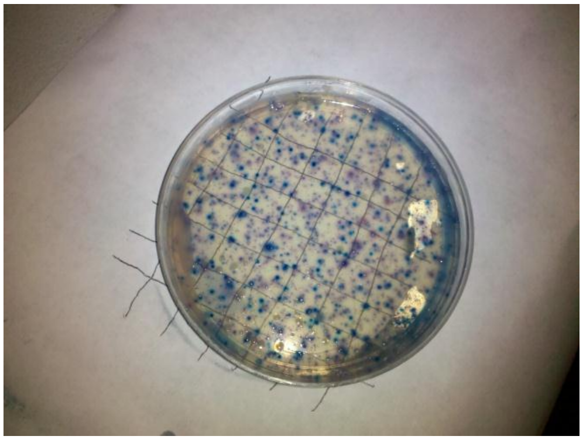

Figure 20: The Coliscan Easygel plate for L1S1B on 7/29/11 with 51,000 CFU/100 mL of *E. coli.*

At L1S4i, there does not seem to be as large a problem with this pipe. The water that emitted from the pipe during storms did not have very high bacteria levels; however, the levels were still above the limits for *E. coli* and for *Enterococcus sp.*.

Overall, Beachwood Beach had high levels for *E. coli*, *Enterococcus sp.*, and optical brighteners. When comparing the *E. coli* data from the first flush to the baseline data through ANOVA, there was no significant difference (P = 0.2911, df = 1, F = 6.5491, α = 0.05). This can be attributed to the idea that the main problem in the storm pipes at Beachwood Beach is farther away from the outfall pipes. When comparing the *E. coli* data from the second flush to the baseline data, there was a significant difference between these values (P = 0.0072, df = 1, F = 7.6784, α = 0.05). This shows that the *E. coli* levels were raised after and during a rainfall event. The *Enterococcus sp.* levels showed no significant difference when the first and second flush data were each separately compared to the baseline data; however, the second flush was close to being significantly different (P = 0.0856, df = 1, F = 3.0870, α = 0.05). Since the p-value was close to the α-value, it can be hypothesized that if there was a larger sample size, then there would be a significant difference between the two populations. When comparing the optical brightener data from the first flush to the baseline data, there was no significant difference (P = 0.2665, df = 1, F = 1.3069, α = 0.05); however, there was a significant difference when comparing the second flush to the baseline (P = 0.0105, df = 1, F = 7.4211, α = 0.05). This further confirms the idea that the problem in Beachwood's storm drain system is far from the outfall pipe. Regardless of flushes, when there is rain at Beachwood Beach, the *E. coli*, *Enterococcus sp.*, and optical brightener levels increase significantly.

Because *Enterococcus sp.* is the bacteria standard for marine waters in New Jersey, this parameter is more important than *E. coli* in the Beachwood Beach system. When correlating *Enterococcus sp.* levels with the corresponding rainfall amount, there is a positive relationship between the two parameters (Figure 16). The Significance F value was 3.44×10^{-8}, thus showing there is a correlation between them; the r^2 value was 0.4338. Even though this value is not very high, it still indicates that there is a positive correlation between *Enteroccocus sp.* and rainfall amounts. Technically, there can be a slight increase in the amount of *Enterococcus sp.* in the water, but it should not be as drastic as it has been observed at various sites at Beachwood Beach. As it rains at Beachwood Beach, the

Enterococcus sp. levels increase significantly. This combined with the other results show that there is a severe problem at Beachwood Beach and that it is most likely human related. This human source could quite possibly be waste. On, 7/8/11 storm sampling, one of the researchers was collecting a sample from L1S2. He stated that there was a black cloud coming out from the pipe and that the odor of septic was emanating from the pipe. Also, the drain in the parking lot of Beachwood Beach smelled horrific on that sampling day. These observations and the parameters collected indicate that Beachwood Beach has a very large issue.

Avon Road West Beach does not have as severe a problem as Beachwood Beach does; however, there is still an issue at this beach. According to the Pine Beach Council, there are plans to replenish the side of the beach where the testing is being done so that it can be opened as a bathing beach.

The main problems at Avon Road West Beach are from the pipe at L2S2. This pipe does have high levels of *E. coli* and *Enterococcus*. The average amount of *E. coli* at L2S2i was 8333.33 CFU/100 mL during the second flush. During the first flush, the average was 2500 CFU/100 mL (Tables 2 – 4). Both of these counts are above the limits for *E. coli*. For *Enterococcus sp.* levels, on average, the baseline and first flush data was under the 104 CFU/100 mL limit; however, the second flush levels were above the amounts (Figure 13). This could mean that the issue with the storm pipes in Pine Beach could be farther away from the outfall pipes.

Figure 21: The manhole cover for the pipe at L2S2 at Avon Rd. West Beach.

The optical brightener levels at L2S2i were not extremely high (Figure 14). At L2S2, the mean optical brightener level was 395.47 (Tables 2 – 4); however this number is including the outlier of 1322 which was observed on 7/18/11 during baseline sampling. Because of the proximity of the location to the boats, it is possible that someone cleaned their boat and the cleaning agents they used spread throughout the water. The optical brightener levels at L2S1 (104) and L2S3 (298.6) were above normal levels for each location (Tables 2 – 4).

The optical brightener levels from the first flush and the baseline data were significantly different ($P = 0.0108$, $df = 1$, $F = 90760$, $\alpha = 0.05$). This was also the case for the second flush ($P = 0.0031$, $df = 1$, $f = 11.0362$, $\alpha = 0.05$). Even though there was a significant difference in the data, the levels did not follow a consistent pattern. There was no correlation between the increasing optical brightener levels and the increasing rain amounts. The r^2 value was 0.0177 and the Significance F value was 0.4457. Both of these values indicate that there is no correlation between the amount of optical brighteners and rainfall amounts. This would mean that there is not a large human impact on that system in regards to stormwater runoff. Also, at L2S2i, the pipe, the optical brightener levels never exceeded 112.6 which is higher, but not drastically higher, than the closest baseline value of 82.28 at L2S2. The sporadic higher optical brightener levels could be attributed to the presence of boats and other watercrafts. At L2S1, there are a plethora of boats docked. The boat owners could clean their boats and the cleaning agents that they would use contain optical brighteners.

The higher level of *E. coli* and *Enterococcus sp.* could mean that the wildlife could be causing the high bacteria levels. It could also mean that there is some type of buildup of pollutants somewhere in the storm drain systems. This would also account for the higher levels of *E. coli* and *Enterococcus* during the second flush. However, when comparing the second flush *E. coli* levels to the baseline data, there was no significant difference ($P = 0.0708$. $df = 1$, $F = 3.0651$, $\alpha = 0.05$); the same was true when comparing the first flush to the baseline data ($P = 0.08737$, $df = 1$, $F = 3.4645$, $\alpha = 0.05$). Also, there was no significant difference when comparing the *Enterococcus sp.* values from the second flush to the baseline data ($P = 0.0856$, $df = 1$, $F = 3.0870$, $\alpha = 0.05$). This was the same case when comparing the first flush to the baseline ($P = 0.1334$, $df = 1$, $F = 2.5914$, $\alpha = 0.05$). Even though there is no difference between the sets, it could be a problem of sample size. The p-values were close to the α-value.

Figure 22: The entire glowing IDEXX Quanti-Tray/2000 for L1S2iB on 7/29/11 with >24196 MPN for *Enterococcus sp.*

When comparing the *Enterococcus sp.* data to the rainfall amounts, there was a positive correlation between the two parameters. The r^2 value was 0.5961 and the Significance F value was 8.89×10^{-8}. The r^2 value indicates that there is a decently strong correlation between them and the Significance F shows that the corresponding points are correlated. Overall, because of the lack of optical brightener levels and the higher bacteria levels, the problems at Avon Road West Beach are not mainly caused by a direct human issue.

In order to back up the results more, the values collected were averaged and compared to the Ocean County Health Department's data. There was no significant difference between the results using ANOVA ($P = 0.1510$, $df = 1$, $F = 2.3079$, $\alpha = 0.05$). The 8/1/11 baseline data was compared to the values that the NJDEP's Leed's Point Laboratory had and there was no significant difference either using a two-way t-test (P = 0.3764, df = 1). If this were to be replicated, then it would be beneficial to collect rain samples. These samples could then be run for the bacteria tests. This would show that there is not a large bacteria influx from the rain and that the issue is in the storm pipes. Also, making the methodology more stringent and higher on the NJDEP's Volunteer Water Quality Monitoring level would be beneficial too.

Conclusions

Beachwood Beach has a serious issue that needs to be addressed. The optical brightener values are very high and the *Enterococcus sp.* and *E. coli* are too. All of this indicates that there is a problem that is driven by human activity that is occurring far away from the outfall pipe. It is possible that a septic system is leaking or there is an illegal cross connection. At Avon Rd. West Beach, the issue is still present but not as severe. According to the optical brightener levels there is not a large human source of problems. It is most likely that the storm drain pipes are clogged with various materials and the bacteria levels are increased due to this, since the optical brightener levels are not very high.

Recommendations

Action needs to be taken as soon as possible because dealing with this beach pollution affects human health. These beaches should be closed for 72 hours when a rainfall event is 0.10 inches or more occurs. Storm drains should also be inspected and cleaned on a monthly basis. This way, all materials that are washed into the systems can be disposed of correctly and not affect the runoff: this could be the solution to the problems at Avon Rd. West Beach. The storm drains can be inspected by utilizing cameras that the NJDEP gave the Ocean County Health Department. By using these cameras, municipalities can inspect the storm drains and can see what is causing the water quality problems. If it is true that there is a serious problem, then the municipality needs to address the issue because it is responsible for the health of beach bathers at their local beaches. By taking these steps the problems at each of these beaches can be remedied.

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