



The Effects of Beach Slope on Bacterial Counts in Near Shore Sediments and Its Potential Impact on Surface Water Quality

Brandon A. Begotka^{1,2}, Julie Kinzelman^{2,3}, and Robert Bagley²

¹Carthage College, Kenosha, WI 53140, ²City of Racine, Racine, WI 53403, ³Univ. of Surrey, Guildford, UK

Contact Information:

Brandon Begotka
bbegotka@carthage.edu
Julie Kinzelman
City of Racine Health Dept.
730 Washington Avenue
Racine, WI 53403
(262) 635-8591
julie.kinzelman@cityofracine.org

ABSTRACT

Incidences of poor surface water quality attributed to non-point (indirect) pollution frequently lack correlation to specific events such as rainfall. The inability to identify the cause of fecal contamination hinders the remediation effort necessary for the reduction of swimming advisories. In 2004, the City of Racine posted 22 advisories or closures at its main public bathing beach, North Beach. Of these advisories, 46% (10) followed measurable precipitation, another 50% occurred in conjunction with waves in excess of one foot. Previous spatial distribution studies demonstrated that the density of *Escherichia coli* was higher in near shore sediments and that this density could be influenced (decreased) through an alteration in mechanical grooming practices (Kinzelman *et al* 2003, Kinzelman *et al* 2004). Although initiated in 2003, the alteration in grooming alone was not providing the level of reduction anticipated. Therefore, a more intensive spatial (lateral) distribution study of the near shore sediment at North Beach was undertaken to determine what other remediation steps may be necessary to achieve 10% or fewer postings during the official swimming season. For this study, North Beach was divided into four transects and three sediment samples were collected from each transect four days a week for fourteen weeks. A sample was taken at the berm crest, a second was taken midway between the berm crest and the lifeguard stands (~30 m from the berm crest), and a third sample was taken at the lifeguard stand (~50-60 m from berm crest) as illustrated in Figure 1. All sediment samples were analyzed for *E. coli* using membrane filtration and m-TEC agar (APHA, 1998). Using log transformed data, the mean *E. coli* concentration at N3 appeared to be higher than at the other 3 transects (N1, N2, N4) [$p = 0.02$ at the 0.05 significance level]. The mean density of *E. coli* isolated from the berm crest (15.6) was an order of magnitude lower than samples collected from either the midpoint (120.2) or lifeguard stand (117.8). Of note, samples collected at the lifeguard stand were frequently in an area which remained hydrated throughout the duration of the study. When this occurred, samples were found to have a disproportionately higher density of *E. coli*. Core samples were taken in these areas to determine vertical distribution. Each 25-cm sample was divided into 5-cm sub-sections. The first 5-cm sub-section (surface), an area normally subject to the effects of grooming, contained double and up to two orders of magnitude more *E. coli* than the last 5-cm sub-section. Continuous hydration of a beach sands may promote elevated bacterial counts that in turn may adversely impact surface water quality under the right environmental conditions (Alm *et al* 2003, Kinzelman *et al* 2004). The positive influence of mechanical beach grooming was absent in the areas with lower elevation and, therefore, beach sands remained in a perpetually wetted condition. Adjusting the grade or slope of the beach could have alleviated this condition and potentially reduced the number of poor water quality advisories due to the interaction of waves with near shore sands.



Figure 1: The three sampling sites at each of the four transects. Berm crest, midway between the lifeguard stand (30 m), and at the lifeguard stand (50 – 60 m). Notice the hydrated strip at the lifeguard stands.

INTRODUCTION

Racine, WI, located on the southwest shore of Lake Michigan, frequently posts water quality advisories at its main public beach (North Beach). Various techniques have been developed in an attempt to reduce the effects of non-point pollution contributing to these postings each swimming season. One technique lessens the density of *E. coli* in near shore sediments through an alteration in mechanical grooming techniques. This remediation tactic provides a reduction in the amount of the bacteria available for transport to the water column (Kinzelman *et al* 2003). During the 2003 beach season, in spite of this alteration in grooming practices, twenty-eight postings were necessary due to *E. coli* levels in excess of the US EPA single sample limit. In 2004, a more intensive spatial distribution study of bacterial counts in the near shore sediment was conducted to investigate the relationship between *E. coli* density in near shore sand and the coastal processes which provide an interaction between these sediments and Lake Michigan. In previous years the grade of the beach appeared to slope towards the shore, providing drainage for surface run-off. In 2004 the slope of North Beach was interrupted by a large swale extending North to South parallel to the shoreline. This swale retained water and beach sands remained in a perpetually wetted condition, exempt from the drying effects of the deep grooming. The purpose of this study was to examine the lateral and vertical distribution of *E. coli* in beach sands as a function of location (distance from shore and relationship to water table) in order to determine what effect beach grade/slope may play in contributing to non-point source contamination.



Figure 2 & 3: A core sample is taken by inserting the Ames recovery probe with butyrate liner into the sand to a depth of about 15 cm.



Figure 4: Locating the water table.

MATERIALS & METHODS

For this study, North Beach was divided into four transects (N1 – N4) and three sediment samples were collected from each transect four days per week for fourteen weeks (Figures 2 & 3).

Field Methods

Lateral Distribution. Four days per week (Monday – Thursday) sand samples were taken at the berm crest, midway between the berm crest and the lifeguard stands (~ 30 m from the berm crest), and at the lifeguard stands (~50-60 m behind berm crest). All sand samples were collected using an AMS soil recovery probe with a 2.8 cm bore & sterilized butyrate liners. Sand samples were transported to the laboratory on ice packs and analyzed within one hour of collection.

Vertical Distribution. A study was conducted to determine the vertical distribution of *E. coli* in a core samples. Multiple core samples, 25 cm in length, were obtained from both the lateral distribution study sites and from areas continuously hydrated throughout the duration of the study in the manner stated above.

Groundwater. Water table depth was determined by digging with a shovel (Figure 4) until the water table was reached at four distances (0, 5, 10, and 20 m) from the berm crest for each of the four transects (N1 – N4). In each case, when the water was reached, the depth to water table was measured using a reel-type measuring tape and recorded.

Laboratory Analysis

At the laboratory core samples were weighed, measured, and transferred to sterile vessels. Core sizes for the lateral distribution study ranged from 12.1 – 19.7 cm. Core samples for the vertical distribution study, 25-cm total length, were split into five 5-cm sections prior to analysis. All samples were eluted for 30 sec. by vigorous hand shaking in a phosphate dilution buffer (pH = 7.2 ± 0.2) & then serially diluted by pipette. Concentrations of *E. coli* in all samples were determined by the membrane filtration technique using m-TEC agar (APHA, 1998). *E. coli* colonies were confirmed by the substrate test (negative urease activity) (Figure 5). *E. coli* densities in the sand samples were calculated (actual count x dilution factor) and expressed per gram dry weight of sample (wet/dry conversion factor = 0.817).

E. COLI CONCENTRATION (cfu/ml)			
LOCATION	MINIMUM	MAXIMUM	MEAN
BERM CREST	0.0	> 156.9	15.6
MIDPOINT	0.0	>3495.1	120.2
LIFEGUARD STAND	0.0	499.2	117.8



Figure 5: *E. coli* on m-TEC agar.

Table 1: Lateral distribution of *E. coli*.

VERTICAL DISTRIBUTION OF E. COLI IN BEACH SANDS 9/7/04				
DEPTH FROM SURFACE (cm)	N1 - (BC) E. coli/g dry wt.	N1 - (HS) E. coli/g dry wt.	N2 - (LGS) E. coli/g dry wt.	N2 - (HS) E. coli/g dry wt.
0.0 – 5.0 cm	412	17	9	215
6.0 – 10.0 cm	28	0	0	87
11.0 – 15.0 cm	6	0	5	34
16.0 – 20.0 cm	0	0	0	2
21.0 – 25.0 cm	4	0	35	0

Table 2: Vertical distribution of *E. coli* in beach sands (9-7-04) [BC = berm crest, HS = hydrated strip, LGS = lifeguard stand]. On this sampling date core samples taken from sites N1(BC), N1 (HS), and N2 (LGS) were uniformly wetted. Site N2 (LGS) was dry from 0.0 – 20.0 cm but visibly moist from 21.0 – 25.0 cm.

RESULTS

Using log transformed data, the mean *E. coli* concentration at N3 appeared to be higher than at the other 3 transects (N1, N2, N4) [$p = 0.02$ at the 0.05 significance level]. The mean density of *E. coli* isolated from the berm crest (15.6) was an order of magnitude lower than samples collected from either the midpoint (120.2) or lifeguard stand (117.8) (Table 1). Of note, samples collected at the lifeguard stand were frequently in an area which remained hydrated throughout the duration of the study. When this occurred, samples were found to have a disproportionately higher density of *E. coli*. Core samples were taken in these areas to determine vertical distribution. Each 25-cm sample was divided into 5-cm sub-sections. The first 5-cm sub-section (surface), an area normally subject to the effects of grooming, contained double and up to two orders of magnitude more *E. coli* than the last 5-cm sub-section (Table 2) (Figure 6). An examination of the distance from the surface to the water table (Figure 7) demonstrated an uneven grade on the beach that may have accounted for the continuous hydration of a wet strip behind the lifeguard stands and subsequent higher bacterial counts in that area.

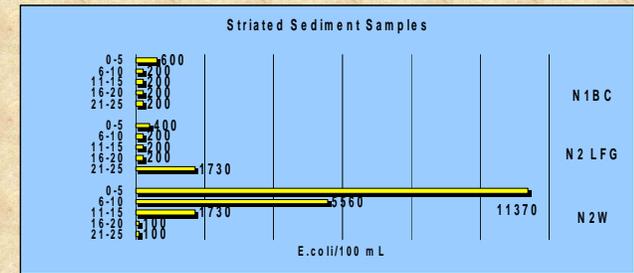


Figure 6: The results of the striated sediment sample analysis (y-axis = depth from surface in cm) indicate that the continuous hydration of beach sands near the lifeguard stands may have contributed to the higher bacterial counts in that area.

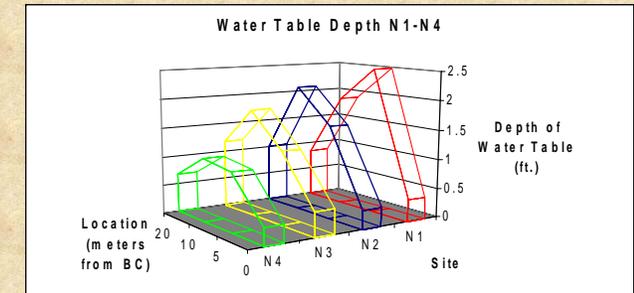


Figure 7: A study of the water table at North Beach in each of the four transects. Note that the depth to the water table level at 20 m is similar to the depth at the berm crest.

CONCLUSION

Continuous hydration of a beach sands may promote elevated bacterial counts, adversely impacting surface water quality under the right environmental conditions (Alm *et al* 2003, Whitman *et al* 2003, Kinzelman *et al* 2004). The proximity of the water table to surface sediments at the lifeguard stands contributed to the continuous hydration of sediments in that area. Additionally, the positive influence of beach grooming was absent in the areas with lower elevation adding to the perpetually wetted condition, increasing the *E. coli* available for transport to surface waters via runoff or high waves. A potential remedy would be to regrade the beach, ensuring that the surface sediments have an opportunity to dry. Adjusting the grade/slope of the beach may reduce the number of water quality advisories resulting from the interaction of waves with near shore sands.

ACKNOWLEDGEMENTS

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