Can Off-Shore Outfall Pipes Disperse Nutrients and Bacteria From Stormwater Runoff?

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Abstract

Recent research has shown that nutrients, mainly nitrate and phosphate, can behave as pollutants to fresh and marine waters if present in large enough quantities. Nitrogen and phosphorus-based nutrients are often the limiting factors of primary production in fresh and marine waters; as such, general increases in their levels can spur phytoplankton production and cause algal blooms, some of them toxic, to occur. When the organisms in these blooms begin to die, the rapid decomposition of such a large mass leads to highly depleted oxygen levels in the water column, As the frequency of algal blooms, particularly Harmful Algal Blooms (HABs), has risen in the past two decades, it is important to monitor nutrient levels in coastal waters and examine the relationship between increased nutrient levels and the development of algal blooms. The purpose of this paper is to examine the plume from a storm water discharge pipe roughly 1,100 feet off the coast of Myrtle Beach, SC. This pipe was recently installed to disperse storm water runoff that is well known to have chronically high levels of contaminant bacteria away from the swash zone. High nutrient levels were expected in this runoff due to the close proximity of many golf courses and residential properties. A nutrient assessment of this new discharge system did show elevated bacterial counts as well as higher-than-normal concentrations of chlorophyll. This means that although the pipe is redirecting water offshore, it is also possibly contributing to algal bloom formation. Furthermore, it appears that some of this diverted water is making it's way back to the swash zone and causing a possible contamination hazard for people or animals in the area.

Introduction

➢Along the Grand Strand of South Carolina (from NC-SC state line to Winyah Bay), stormwater flows are diverted into pipes that discharge onto the beach backshore. Approximately 200 pipes are currently in place from Cherry Grove to Garden City. Some stormwater also flows through about ten tidal creeks (swashes) some of which are illustrated in Figure 1.

➢Intensive monitoring over the past five years has demonstrated that the pipes and swashes are significant sources of contaminant bacteria to the surf zone. Swimming advisories are generally posted during the 24 hours following rain events due to exceedance of federal swimming water standards for Enterococcus.

➢Since bacteria levels are high, sewage is likely also transported as part of the stormwater runoff. Remineralization of this sewage could introduce nutrients, nitrogen and phosphorus, into the receiving waters. Elevated nutrient levels could stimulated algal blooms, leading to eutrophication and overgrowth of toxic algae.

➢In an effort to divert contamination away from the surf zone, the city of Myrtle Beach, SC has recently installed two 5-foot diameter pipes to reroute stormwater discharge from the Yaupon Drainage Sub-basin (189 acres) to an outfall located approximately 1,100 feet offshore. These replace three pipes that formerly discharged onto the beach. They are each sized to carry a peak flow of 16.2 cfs following a 1" rainfall. If this works well, offshore discharge pipes will be installed all along the Grand Strand to replace existing pipes on the backshore.

➢This study tested the hypothesis that the stormwater runoff from Yaupon and adjacent sub-basins is a significant source of nutrients to the surf zone and can cause eutrophication.

See DDC Engineers, Inc. web pages at:

http://www.ddcinc.com/NewFiles/projectspage.html

For more information about offshore stormwater discharge pipes

Numeric Eutrophication Criteria

The following water quality criteria were used to assess the level of eutrophication in the stormwater water and the receiving surf zone water. Note that the estuarine and river criteria are still in draft form.

Analytes	Estuary	River Ecoregion XIV Level III Ecoregion 63	SC
Total Phosphorus (ppm P)	0.01	0.0525	0.06
Total Nitrogen (ppm N)	0.1	0.55 to 0.87	1.50
Nitrate + Nitrite (ppm N)	NA	0.04	NA
Chlorophyll a (ppb)	5	0.44	40
Turbidity (NTU)	NA	3.89	50

DO criteria for estuaries: Anoxia : 0 mg/L

Hypoxia : >0 mg/L and ≤ 2 mg/L

Biological stress : >2 mg/L and ≤ 5 mg/L

•**Estuary**: NOAA's National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries (Bricker et al. 1999)

•**Rivers**: US EPA Office of Water's Ambient Water Quality Criteria Recommendations (draft)

•**South Carolina Coastal Plain**: R. 61-68 Water Classification and Standards (for lakes only)

Methods

The following were measured in surface grab samples collected once a day for seven days:

- ➢Salinity
- ➢Enterococcus bacteria
- ➢ Dissolved oxygen
- ➢% saturation of dissolved oxygen
- ➢Nitrogen (nitrate + nitrite)
- ➢Phosphate
- ➢Chlorophyll a and Phaeophytin
- ➢Turbidity

➢Salinity, DO and temperature were measured in-situ with an H2O Scout 2 Hydrolab or Hach portable meters.

➢ A Hach portable turbidimeter was used to measure turbidity on site.

➢Nutrient concentrations were determined using methods developed by Parsons et al.(1984).

➢Enterococcus was measured using the IDEXX Enterolert technique.

Sampling Design

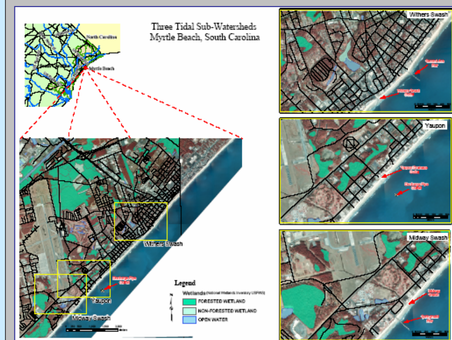

Figure 1. Sampling sites including close-ups of individual drainage sub-basins (Midway Swash, Yaupon and Withers Swash).

Figure 2. Yaupon Drive drainage basin on the South side of 25th Avenue South

➢Sampling Sites: (1) Yaupon Drainage Sub-Basin (Figure 2) that serves discharge pipe, (2) Surf Zone adjacent to drainage basin, (3) Springmaid Pier (12.8 km south of drainage sub basin) and (4) Second Avenue North pier (30.6 km north of drainage sub basin). The piers were chosen as sampling sites because they extend into the ocean approximately (250m). the same distance as the drainage pipe (335 m) and should reflect the effects of long-shore flow of stormwater discharge.

➢The sampling site in the surf zone adjacent to the drainage basin reflects the impact of pollution washed back onto the beach by incoming waves and serves as a measure of potential impacts on the swimming zone.

➢Sampling was conducted from 4/14/04 and 4/20/04 following a significant rain event (1.7 in) on 4/13/04. Pre-storm sampling was also performed on 3/17/04 and 4/5/04.

Results

Graphs show tidal stage (F = flooding, E = ebbing), longshore current direction (arrows) and error bars reflect 1 SD.

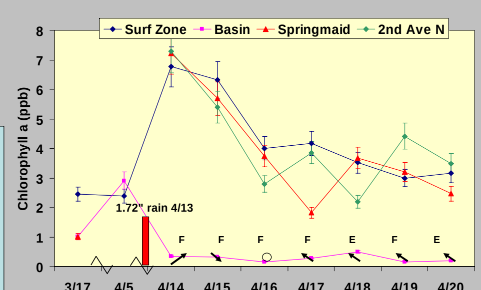

Figure 3. Chlorophyll a

➢Concentrations were lowest in drainage basin and declined after rain event.

➢Evidence for bloom within one day after end of rain was seen at all the ocean sites. Chlorophyll to Phaeophytin ratio (4.0 to 5.5) peaked two to three days after end of rain.

➢Concentrations in ocean during bloom exceeded NOAA draft estuarine eutrophication criteria

➢Concentrations in basin prior to and immediately after rain event exceeded US EPA draft river criteria.

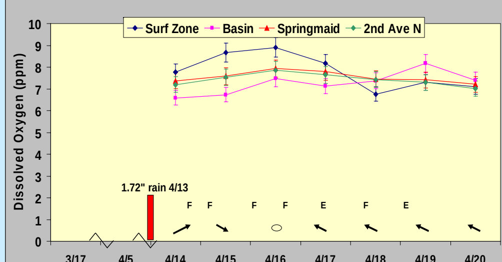

Figure 4. Dissolved Oxygen

➢DO concentrations increased through day 3, after which there was a general decline.

➢This is further evidence for bloom formation during days 2 & 3 following rain event.

➢In the Basin, overall increase in DO over the entire sampling period indicates a slow re-growth of phytoplankton following their removal via stormwater flushing although chlorophyll concentrations did not return to pre-rain levels.

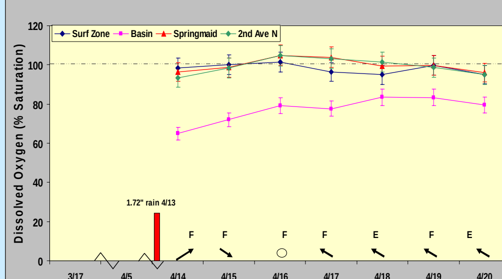

Figure 5. % Saturation of DO

➢All samples from the drainage sub-basin were undersaturated, suggesting presence of oxygen-demanding substances like sewage.

➢All ocean sites reached supersaturation by the third day after the rain event, suggesting the occurrence of a phytoplankton bloom.

➢By end of sampling period, all sites were undersaturated, suggesting die-off and remineralization of bloom biomass.

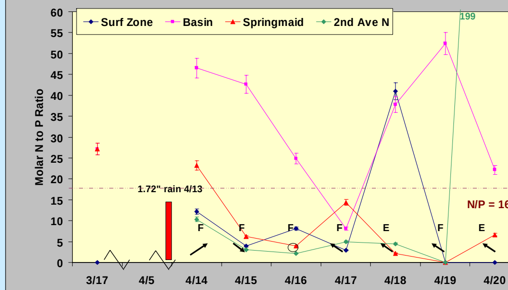

Figure 6. Molar N to P ratio

➢Values above Redfield Richards molar N to P ratio of 16 suggest nitrogen loading to the surf zone from stormwater runoff.

➢In general, molar N to P ratios decreased through the third day following the rain event.

➢Most likely caused by decreasing nitrate + nitrite levels as these are the limiting factor in marine waters.

➢This nitrogen uptake was likely associated with formation of a phytoplankton bloom.

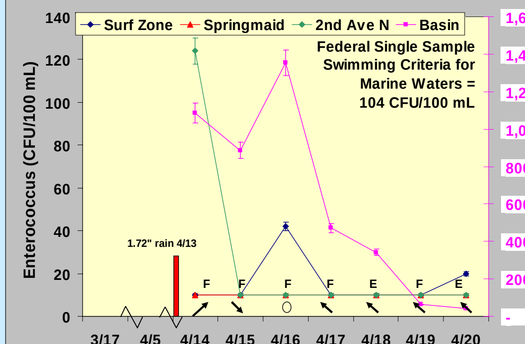

Figure 7. Bacteria

➢Bacteria counts in the basin were above the federal limit for nearly the entire sampling period, while oceanic sites were over for only one day (4/14).

➢The high bacteria counts seen at 2nd Ave. and the surf zone at Yaupon indicate that bacteria can be flushed into the surf zone but then quickly decline due to the toxic effect of saline waters.

➢Bacterial counts were relatively low compared to long-term averages following rain events, so the sampled event was not a large one in terms of non-point source impacts.

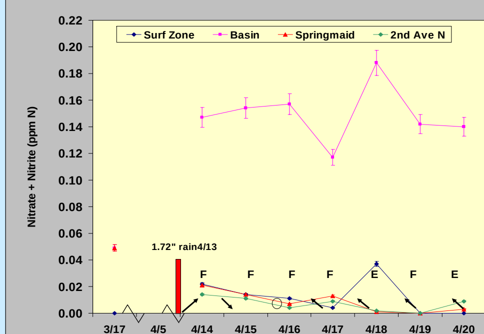

Figure 8. Nitrate + Nitrite

➢Concentrations in the basin exceeded draft river eutrophication criteria. None of ocean samples exceeded estuarine draft criteria (Total N).

➢Concentrations showed an overall declining trend throughout the sampling period except on 4/18, when a spike in the basin coincides with a spike in the adjacent surf zone. The chlorophyll concentration in the basin also doubled between 4/17 and 4/18.

➢The concentration decline in the ocean water coupled with the increase in chlorophyll suggests that nitrogen was limiting phytoplankton production.

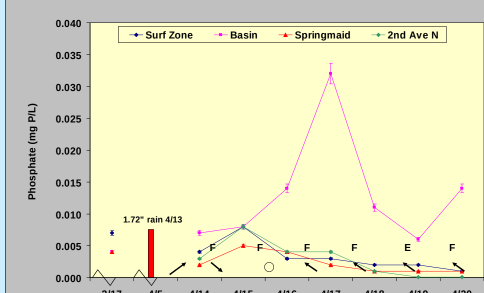

Figure 9. Phosphorous

•Concentrations in basin always exceeded those in ocean. Basin concentration peaked four days after rain event.

•Phosphate levels in the ocean samples also declined through the sampling period suggesting planktonic uptake.

•Oceanic levels fell within the low estuarine eutrophication criteria. Basins concentrations did not exceed river criteria but fell in medium estuarine eutrophication range.

Conclusions

➢It is likely that the new outfall pipe designed to carry stormwater away from the surf zone is at least partially responsible for the algal blooms found in this study.

➢Algal blooms could also be supported by discharges from adjacent swashes (Midway and Withers)

➢Data from another rain event (1.7" on 5/3/04) showed same magnitude plankton bloom on same time scale (1 day) after end of rain. This suggests a reproducible phenomenon.

➢The amount of freshwater (0 psu) introduced into the nearshore was not enough to significantly lower the salinity (33.5 psu). Bacterial levels also did not rise very high in surf zone. Due to antecedent dry conditions, not much runoff appeared to be discharged into the surf zone.

➢Even for relatively small runoff events, significant phytoplankton blooms resulted causing chlorophyll concentrations to exceed eutrophication criteria. Thus the potential for occurrence of Harmful Algal Blooms exists and could be exacerbated by redirection of stormwater through offshore pipes.

Acknowledgements

➢Environmental Quality Laboratory, Burroughs and Chapin Center for Marine and Wetland Studies

➢SC Department of Health and Environmental Control

➢City of Myrtle Beach

➢DDC Engineering