

Minutes from Sand Meeting Held April 14, 2016

Location: New Orleans, EPA Recreational Beach Conference

Participants:

Aslan, Asli	Georgia Southern
Blazer, Manja	IDEXX
Boehm, Ali	Stanford University
Brandao, Joao	NIH@PT Department of Environmental Health
Edge, Tom	Environment Canada
Harwood, Jody	University of South Florida
Kinzelman, Julie	City of Racine
Kirs, Marek	University of Hawaii at Manoa
Kumagai, Wataru	Hawaii Dept of Health, Clean Water Branch
Lee, Jiyoung	Ohio State University
McLellan, Sandra	University of Wisconsin - Madison
Murakawa, Scott	Hawaii Dept of Health, Clean Water Branch
Okubo, Watson	Hawaii Dept of Health, Clean Water Branch
Piggot, Alan	University of Miami
Polk, David	Florida Department of Health
Schnars, Jeanette	Tom Ridge Environmental Center
Solo-Gabriele, Helena	University of Miami
Vogel, Laura	Western University
Weiskerger, Chelsea	Michigan State University (notes taker)
Whitman, Richard	USGS (retired)
Yamahara, Kevan	Monterey Bay Aquarium Research Institute
Zepp, Richard	US EPA
Zimmer-Faust, Amity	U.S. EPA

Meeting started at 6:05 pm and ended at 7:45 pm.

The goal of the meeting was to draw upon researcher experiences from all regions around the world to develop a consensus conceptual model that would explain the impacts of sand dynamics on FIB levels in both sand and water. With this consensus model, statements could be made about the impacts of climate change on microbe levels at the water/sand interface. The meeting was structured with three presentations followed by a focus on developing two consensus statements: one focused on the influence of sand dynamics on FIB levels and another focused on climate change impacts. The three presentations at the beginning of the meeting were given by Kevan Yamahara, Alan Piggot and Laura Vogel. A summary of these presentations is provided below.

Kevan Yamahara's Presentation:

Kevan presented a conceptual model from his dissertation, with a beach cross-section and a mass balance on bacteria. He suggested that there are different types of deposition/transport of FIB to and from the sand, including run up transport over the beach surface and through-beach transport to potentially brackish or saline groundwater. Recirculation also needs to be considered in the model. Concerning the mass balance, Kevan said that within even a few sand grains, deposition, growth/death, and removal can happen, and thus changing bacteria concentrations over time in sand and surf zones.

So the model should consider inputs, outputs, growth, death, and other factors that we haven't yet considered. Helena asked about changes in the sand reservoir, such as sand removal and erosion. Ali responded, saying that some research has found that erosion is important, but in the Coastal California system that they looked at, it was not as important as other systems. Kevan expressed an interest in through-beach transport and removal at a coarse-sand beach, and Joao mentioned a 2007 study of Richard Whitman's, where enterococci concentrations were shown to increase with depth in the sand. Richard pointed out that it really depends on where you are at the beach, and there are regional differences as well. He referenced a 2000 study that suggested that bacteria are only picked up in a seepage meter when waves are 3-4 feet or higher. The take-home was that you need energy to move bacteria around. Kevan supported this point, saying that groundwater studies have shown similar phenomena.

Helena talked about how the mass balance in the model may not be complete, that there should be 3 components: bacteria, water, and sediment. Jody said that we also would need 3 conditions: growth, stasis, and death; that bacteria are not always either growing or dying. Julie mentioned that some sort of tracking of contaminated sand movement along the shore would be beneficial, and Richard Whitman said that storage is also important, referencing low water storage and calm conditions such as those at dawn, when bacteria tends to settle out of suspension.

At this point, Jody brought the focus back to what we were trying to accomplish with the meeting. Kevan pointed out the framework for discussion about influencing factors for sand bacteria concentrations in our focal regions. This is a model that we can build upon to determine forcings in sand contamination. Jody suggested a possible opinion paper, and Richard Whitman suggested that this could be a starting point for a true workshop on health effects due to sand conditions and mechanisms. Alan talked about high vs. low energy beach characterization, and high vs. low energy events, saying that this could be a good starting point for modeling. Jody proposed some sort of quantitative or mechanistic model, and Ali suggested that we start with the conceptual model, then move to equations.

Laura Vogel's Presentation:

Laura began by talking about how a mass balance can quantify bacteria before and after a wave event. She also measured erosion before and after the wave event, and determined that the amount of bacteria in the reservoir accounted for the amount lost from the water after the wave event. Her graphs showed that large wave height led to a short-term peak in *E. coli*, but that the peak subsided to base levels quickly too. When two wave events occurred in quick succession, the bacterial concentration peaked 24 hours after the initial wave event, but not after the second wave event. This was likely because the bacteria had not been given the chance to build back up in the sand after the first wave event.

In another plot, Laura showed that, on a fine sand beach, over 90% of the bacteria came from the sand, with most of that being from unsaturated sand. Watson supported Laura's argument, saying that when the winter surf comes in and brings ~30 ft waves, enterococci tend to spike on beaches more than during the calmer summer months. Sand gets scoured out and bacteria increases at the sand/soil interface. Richard agreed, saying that in Lake Michigan, bacteria levels tend to drop in the saturated zone.

There was some confusion as to the definition of "saturated sand". It was clarified that saturated sand is below the water table, while unsaturated sand looks "dry". In response to a question from Jody, Laura

explained how she normalized sand weight to determine the proportion of bacteria that came from saturated and unsaturated sand at the study beach.

Alan Piggot's Presentation:

Alan began by talking about the interest in how bacteria attach to sand grains, how we can prevent attachment, and how we can foster detachment. He suggested that bacteria grow in large communities, as a biofilm, in order to protect themselves, control nutrients, concentrate microenvironments, and acquire new genetic traits. These biofilms can also form channels and act as fluids if necessary. Alan said that bacteria are in sand likely because they are ambient in their biofilms, due to the low energy conditions on beaches that foster biofilm development and accumulation.

Alan suggested somewhat of an anomaly in bacterial deposition on beaches that shouldn't be susceptible to high bacteria. These beaches are not enclosed, but still have high bacterial counts. Bathymetry maps show that this may be due to shoaling factors, which decrease wave energy and deposit bacteria on the beaches that otherwise shouldn't have high bacteria. Alan also said that high energy events can cause biofilm dispersion, rendering a lack of ability to accumulate. Additionally, Alan talked about how EPS interacts with FIB. He said that EPS tends to exclude FIB as the community develops, due to competition for nutrients. Joao mentioned that fungi may also be responsible for biofilm development, due to competition effects, and Tom brought up disturbance ecology, suggesting that we might frame the entire discussion in terms of succession and disturbance ecology.

General Discussion:

Richard Whitman talked about how transects show spatial variability in bacteria at artesian springs; bacteria reached a maxima just for the margins of the standing water but *E. coli* was very low at the organically rich perimeter. On beaches, maxima was at the higher extent of swash runup.

Alan indicated that tidal flushing was able to remove only about 3% of the microbial community for sands collected at beaches in Florida. Intense shaking was necessary to remove the bulk of the bacteria from the sand. He also mentioned that there may be UV inactivation of bacteria near the surface of the sand. Joao mentioned that in an experiment, radiation of FIB with UV light for 3 seconds rendered the bacteria unable to grow. Richard Whitman then referenced an early experiment where detritus was exposed to UV radiation. The radiation was able to kill 95% of the bacteria, but could never kill 100% of the contaminants. There are niches that UV light cannot reach.

At this point, Joao brought up black molds, saying that these molds can help shelter the bacteria from UV radiation. Helena asked whether these molds are being measured, and Joao said that black molds are sometimes found at beaches.

Helena and Kevan then talked about an experiment in which they found a high level of elution with quartz sand. Everything came off of the sand in Kevan's experiment at first flush. However, this may be sand-type dependent. Kevan mentioned that in his experiments the sediment grains were very coarse and this may have contributed to the high elution fraction. For the sands in Florida, only a small fraction <5% was found in the pore water fraction; Ali also mentioned a sequence of column experiment and found that organisms such as bacillus and proteobacteria mobilized at very high rates.

Jiyoung then thought about how we should approach these topics. She said that there are two levels being discussed: Alan was talking about the microscopic scale, and Kevan focused on the macroscopic

scale. She said that we need to look at how the scales interact and how the small scale may feed back into the large scale. Along with the varying scales, Richard Zepp suggested that we need to start discussing viruses on beaches, and how they interact with biofilms and sand. He also said that we should include near misses related to climate change (almost-hurricanes, large storms off the beach, etc.), and resulting storm surge effects on bacteria. Along those lines, Alan brought up sea level rise and the resulting large-surface-area, low energy beaches that will be susceptible to more violent storms. In these cases, it is envisioned that bacteria would proliferate. In relation to Hawaii, Watson talked about how beaches there will be under water and sand will not be near the high water mark. Sand will either need to move up toward the new shore, or beaches will not have sand but rather soil. Watson was very concerned with resulting sewage contamination. What happens to manholes, ejection wells, and storm drains? The effects will be broad across the islands. Areas impacted include tourism, land planning and management, home ownership, and state and local government.

Richard then brought the discussion back to management, asking managers what they need from researchers, in order to make good decisions. Watson brought up the idea that beach visitors will be interested – why are we studying FIB, and should they be worried. He also mentioned that localized bacteria could pose a problem with research, management and communication. David was really concerned with what is normal? What *should* be at the beach vs. what is abnormal? Sand ecology is different than water ecology, so what is a threshold for “okay” concentrations of bacteria in sand? What is the demonstrable risk associated with sand-attached bacteria, because kids eat beach sand all of the time? How do we test for it? Are viruses truly better indicators, and if so, how can we provide infrastructure and funding for monitoring? Some overall questions from Richard and Tom included: Are we learning that we have been closing beaches unnecessarily? Also, how clean is clean enough? Should we aim for 0 closures? How do we account for the idea that sand is a natural reservoir for bacteria, and we will never fully remove contaminants? How do we communicate to the public that having beaches open 100% of the time is an unrealistic expectation? Julie talked about how people understand that the beach is not a chlorinated pool – there is some expectation of bacteria at beaches. People make the choice to swim there anyway.

Joao brought up 2 premises of microbial source tracking: find the sources of the pollution and make sure that the pollution is human-caused. However, if we see similar levels of bacteria in sand and water, shall we assume that it's not human caused? Julie said that we cannot assume that this type of relationship is causative...what if human usage or other factors interrupt transport? There are good correlations between wave height, turbidity, and bacteria, but transport could also be due to slope, interstitial head, groundwater flow, and any other mechanisms of transport. This also highlights the problem with using indicators – what if usage interrupts the transport of pathogens differently than it does the transport of indicators in sand and water?

Joao said that there is some research that suggests that simple interaction with sand is enough to foster infection, so maybe transport is ubiquitous throughout the sand? David talked about how QMRA is being developed at regulatory levels, but is site-specific and not standard. Watson discussed the potential for use of *Clostridium* as an indicator; in Hawaii, *Clostridium* correlates better with beach contamination than FIB, with a threshold of 50. This is also an indicator in the food industry...with levels at 150 or higher, restaurants sanitize everything. However, it is different in Hawaii. There, people understand that rain flushes contaminants into the water, so they heed warnings. Likewise, people avoid turbid water, because it is harder to see sharks. Watson ended with the idea that if each state could develop an EPA-approved secondary tracer, it would help. Marek countered that the EPA claims that there has been no reliable evidence of *Clostridium* effects in the contiguous US. Helena mentioned

that Florida has high and variable background levels of *Clostridium*, making tracking contamination difficult using this indicator. This is where local knowledge comes into play, according to Watson. Ducks can carry *Clostridium*, so knowing where ducks are locally will help determine the efficacy of *Clostridium* as a secondary indicator. Helena suggested that *Clostridium* generally cannot grow in aerobic conditions, so it may factor into the biofilm picture. Richard Whitman said that in pore water, there are only 1-2 ppm of oxygen, so *Clostridium* may actually be a good candidate for QMRA for sand.

Julie emphasized that QMRA would be a site-specific moving target, due to heterogeneity in sand grain size, infiltration of spores, and resuscitating. What happens to the QMRA if the beach changes, due either to natural or human causes? Jiyoung brought up the idea that environmental protection and human health protection go hand in hand. She emphasized that the two best ways to avoid infection at the beach are to avoid head immersion and to avoid consuming food at the beach. If we could communicate to people that they should either not eat or wash their hand well before and after eating at the beach, that would likely reduce infection, because food consumption provides a transport mechanism for bacteria.

A couple of beach managers were concerned with beach nourishment and grooming effects. These managers employ swimming restrictions, but still encourage people to go to the beach and play in the sand without swimming. Helena and Richard both brought up research that has indicated that with clean, new sand, bacteria levels tend to be low, but still increase to baseline levels after about 2 weeks. Alan also said that sand mixes because of changing beach morphology and wave energy, leading to that baseline amount of bacteria that we see after inputting new sand. Julie also said that when sterile granite slabs were put into rivers, biofilms and FIB formed over two weeks as well.

Jiyoung ended the discussion with some talk about geese and protozoa prevalence in water and sand. Because geese are all over sand and can carry protozoa like *Cryptosporidium sp.* Joao suggested that analyzing for protozoa is patchy at best because they are rare anyway. Richard indicated that, while protozoans are a distinct part of the ecosystem, they can be very difficult to work with.

Wrap up with draft consensus statements (led by Richard and word-smithing by Helena, Joao, and Laura):

Consensus Statement #1: Hydrometeorological trends impact sand dynamics. We concur unanimously.

The use of the term climate change in the consensus statement was discussed. However, a decision was made to not include it as a consensus from the meeting due to the fact that climate change has not been embraced by all jurisdictions.

Consensus Statement #2: The geomorphological and hydrometeorological conditions affect FIB dynamics in sands. This includes macroscale processes that involve waves, tides and weather conditions whose impacts are dependent upon frequency and magnitude. Characteristics that influence microscale processes include, in part, sand texture, biofilm composition, and moisture. The relative importance of the macro- and micro-scale processes varies by location according to regional and site-specific geological and environmental conditions.

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Participants:

Aslan, Asli	Georgia Southern
Barash, Shari	USEPA
Blazer, Manja	IDEXX
Boehm, Ali	Stanford University
Brandao, Joao	NIH@PT Department of Environmental Health
Briggs, Shannon	Michigan Department of Environmental Quality
Citriglia, Mark	NEORSD
Edge, Tom	Environment Canada
Fleisher, Jay	Nova Southeastern University
Harwood, Jody	University of South Florida
Kinzelman, Julie	City of Racine
Kirs, Marek	University of Hawaii at Manoa
Kumagai, Wataru	Hawaii Dept of Health, Clean Water Branch
Larimer, Lisa	USEPA
Lee, Jiyoung	Ohio State University
Loftin, Virginia	NJDEP Bureau of Marine Water Monitoring
Moore, Hannah	Oregon DEQ
Murakawa, Scott	Hawaii Dept of Health, Clean Water Branch
Nshimiyimana, Jean Pierre	Singapore-MIT Alliance for Research and Technology - CENSAM, Singapore Center on Environmental Life Sciences Engineering, Singapore Center on Environmental Life Sciences Engineering, NTU & MIT
Okubo, Watson	Hawaii Dept of Health, Clean Water Branch
Piggot, Alan	University of Miami
Polk, David	Florida Department of Health
Root, Patsy	IDEXX
Schnars, Jeanette	Tom Ridge Environmental Center
Solo-Gabriele, Helena	University of Miami
Thulsiraj, Vanessa	Mount Saint Mary's University
Vogel, Laura	Western University
Weiskerger, Chelsea	Michigan State University (notes taker)
Whitman, Richard	USGS (retired)
Yamahara, Kevan	Monterey Bay Aquarium Research Institute
Zepp, Richard	US EPA
Zimmer-Faust, Amity	U.S. EPA

Meeting started at 12:05 and 1:15 pm

1. Welcome and Powerpoint presentation.

Helena Solo-Gabriele, Joao Brandao, and Richard Whitman thanked the audience and introduced themselves. They went over the attached Powerpoint presentation. The purpose of the meeting

was to continue the discussions from the email exchange held prior to the Recreational Beaches Conference. The exchange focused on evaluating the dynamics of bacteria releases from beach sands, focusing on the influence of wind, waves, tidal action and other factors. The focus of the meeting was to also forecast possible climate change impacts given knowledge about the drivers for bacterial releases. Input received during the Powerpoint presentation included:

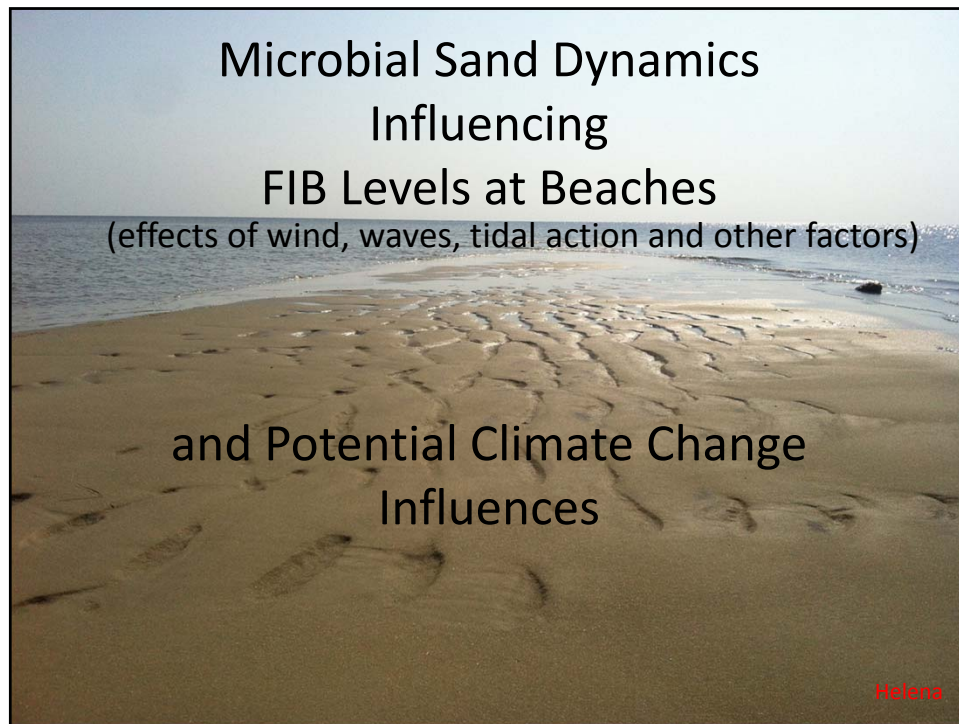
- Richard asked for input about factors that would influence sand bacteria releases under climate change scenarios. These included: More resuspension and higher wave heights (Julie Kinzelman). Indirect effects through the browning of water by the release of dissolved carbon. The dissolved carbon attenuates the UV light penetration thereby limiting inactivation of bacteria (Richard Zepp). Jay Fleisher provided input concerning the history of climate change, stating that there is uncertainty with the degree and timing of change.
- Helena asked for input about Hawaii's FIB levels. Watson Okubo emphasized the role of rivers and streams in contributing FIB to beaches. He explained that many of the rivers are covered by trees thereby limiting inactivation by UV. He anticipates more bacteria under climate change scenarios. He also talked about wave energy and how bacteria can accumulate in the sand before they are flushed out during storm events.
- Helena asked for input about California's FIB levels. Kevan Yamahara emphasized the importance of sand fines and grain size. Ali Boehm emphasized that enterococci were shown to grow in the sand. Coarse sediments were shown to increase bacteria during high tides and these bacteria would be eluted. *S. aureus* and MRSA were also observed in beach sands.
- Helena asked for additional input on Florida's beaches. David Polk emphasized that there are differences in sediment characteristics and sand size. He emphasized the potential influence of migratory birds. They may be attracted to urban areas (e.g., landfills) and then roost along the coast at the beaches. The number of birds can be high.
- Richard presented the input received that referenced beaches in the Gulf Coast of Florida and the Great Lakes. Helena mentioned that Claire Robinson of Western University provided a detailed description for why wave impacts results in different FIB patterns in different areas. She agreed to share Claire's email with the group (see appendix to these minutes). It was mentioned that bacteria presence is often seasonal, with little bacteria seen in the winter. Richard suggested that this indicates that bacteria repopulate each year. Shannon Briggs argued that Sheridan Haack has indeed found bacteria in sand during the winter in Michigan. The role of berms in minimizing wave runup was also briefly discussed.
- Joao Brandao presented the observations from Portugal Beaches and also presented the input received concerning beaches in the United Kingdom. He showed some of his sampling data, and talked about a few of the positive and negative influences on bacteria at beaches. He suggested that one of the major factors dealt with artificial sand at these beaches, while sand grain size has a relatively minimal impact on bacterial trends.
- Joao Brandao went over the goals of continued discussions which will be taking place on Thursday from 6 to 8 pm. He went over the table that is to be consolidated by region. He went over the table focused on climate change.

2. Open Discussion, Questions and Answers

- Jean Pierre Nshimiyimana asked about the influence of climate change on protozoan influence on FIB. Jody Harwood responded by describing her research where they evaluated the influence of protozoans and competing bacteria on FIB levels in sand and water. The influences are significant. Richard emphasized that these are all part of the beach system, and they interact to influence bacteria.
- Jiyoung Lee emphasized that extreme droughts should also be considered as a possible influence on the sand/water release of FIB. She indicated that the drying may influence the chemistry of the sediments. A discussion ensued about the potential impacts on biofilms under drought conditions. An agreement was made to add drought to the climate change table.
- Shannon Briggs emphasized the need to evaluate other markers, including coliphage and source tracking markers. There's a need to identify the source of the seeded bacteria.
- Tom Edge emphasized that the design of beaches (including the one shown earlier in the Lake Pontchartrain talk) is conducive, in many cases, to the accumulation of bacteria. Many designs are very protected and sheltered, inhibiting flushing of sand. There need to be guides for the design of beaches in terms of addressing the microbiological quality.
- Ali Boehm mentioned that separating the analysis into regions may not be the most productive. She recommended a mechanistic approach based upon a conceptual model and/or non-dimensional variables.
- Joao Brandao presented a hypothesis about oxygen in water. Under high energy wave conditions there will be more aeration of the water. His group has evaluated the decay of E. coli under highly oxygenated conditions.
- Shannon Briggs asked about expanding beyond FIB, to include other markers or increased MST. She and Julie Kinzelman discussed things like regional variation, biofilm and VBNC populations, and presented the idea of some sort of life cycle analysis for these FIB, to follow them through the beach system.
- Laura Vogel emphasized the need to look at the bacterial reservoir, the water versus the sand. Under frequent high wave conditions, bacteria do not have a chance to build up. The larger the wave height the higher concentration initially but then the levels decline quickly.
- Virginia Loftin ask about the focus on sand, if regulatory monitoring is based upon water. It was mentioned that sand can be a significant source of bacteria to the water and so for these conditions it would be important to measure the sand source.
- Joao Brandao emphasized the need to standardize the procedures for sand analysis. Ali Boehm mentioned that a study for sand methods was conducted in 2009.
- Ali Boehm recommended a conceptual model to assess the dynamics of sand/water in the release of FIB. She emphasized that some mechanisms will be active at some

beaches and not active at other beaches. Richard Whitman emphasized that the underlying physics controlling FIB release from sand is the same for all beaches. However, the mechanisms that dominate the release may be different at different beaches.

APPENDIX: PPT Slides Used During Meeting



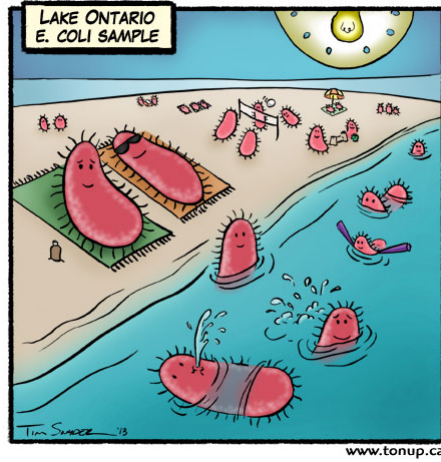
Summary of Discussions

- It appears as though there may be distinct differences in the role of sand and waves in controlling FIB in water between the Great Lakes and marine beaches.
- There are hypothesis about:
 - beach morphology (presence of a distinct berm and slopes),
 - influence of tides,
 - the influence of sand mineralogy,
 - bulk climatologic conditions.

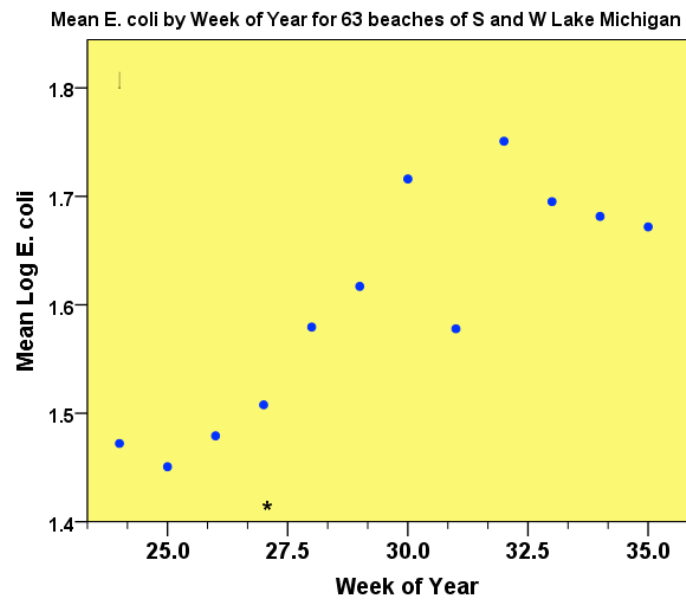
(Solo-Gabriele)

Helena

Climate Change

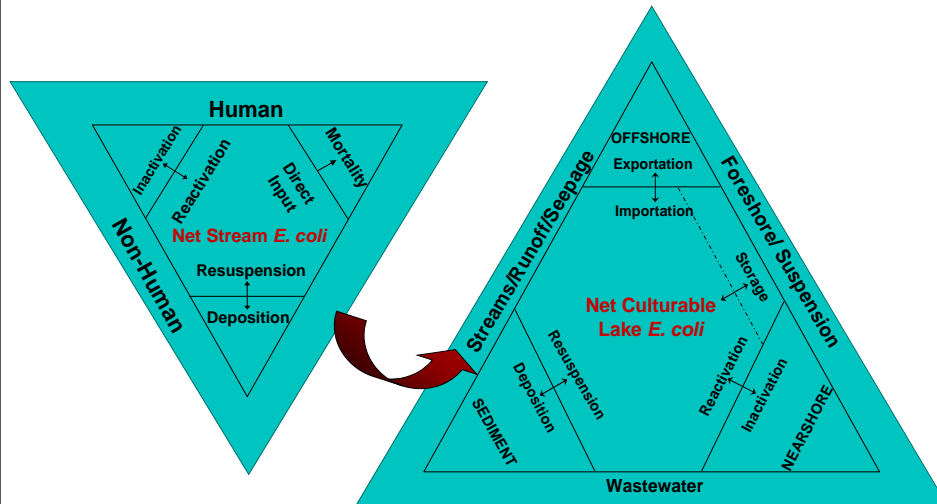


Richard



Richard

When examining indicator bacterial source, flux, and context, the entire Beachshed as a dynamic interacting system should be considered.



Question? Which vectors might change with climate change? Richard

Potential Climate Change Trends

- Increased Violent Storms
 - Thunderstorms, tropical and extra-tropical cyclone
 - Floods, blizzards, sewage releases, tornados, droughts
 - El Nino
 - Beach and dune stability, erosion
 - Sea breeze and current vectors, wave height, water clarity
- Sea and Lake Level Change
- Beach sand and Water Temperature
 - Biological influences
 - FIB and pathogen quantity and consequences
- Associated wetlands, estuary, canal, runoff, shoaling.
- Recreational usage
- Aesthetics

Richard

Input Received by Region

Hawaii

- River influence (Okubo)
- High surf, resuspends enterococci (Okubo)
- Low wave energy, high enterococci (Yan)
- Urban areas next to stream (Yan)
- Complex system with bacteria deposition, transport, and degradation in beach system (Yan)

Helena with help from Hawaiian colleagues

California

- Beach sand at enclosed beaches appear to have persistently higher counts as compared to open beaches (Ferguson)
- Within enclosed beaches, problem sites are related to wind & wave direction & to proximity to drainage outlets (Ferguson)

Helena with help from CA colleagues, Ali

Florida

- Sand in FL is fundamentally different as is colonization, survival, and env growth (Kleinheinz)
- Waves do not move water but tides do. So there is more net transport with tides. Inshore movement of FIO during high tide and offshore during low (Fleisher)
- Bay beaches have higher FIB than open coast beaches (Solo-Gabriele)

Helena

3

Gulf Coast of Florida

- Strong tidal currents drain land areas (Whitman)
- Tidal currents cause resuspension (Whitman).
- Tides cause deposition at head of swash. Enhanced in less energetic water. (Zepp)
- Tidal impacts on patterns of deposition-resuspension linked to hydrodynamics (Zepp)
- Poor quality beaches dominated by the Peace River and local runoff (Whitman)

Richard

Great Lakes

- We have a very small true tide in the Great Lakes (Kinzelman)
- Tides in the Great Lakes are 1 cm (Whitman)
- Wave run up due to onshore winds and perhaps seiche are more likely to be the drivers of wave energy here (Kinzelman)

Richard

Great Lakes (con'd)

- Possible for accumulation at top of foreshore due to wind-driven seiche (Zepp)
- FIB associated with wave action due to resuspension from the swash zone (Kleinheinz)
- Phenomena change with particle size, organic content, and season. (Kleinheinz)
- Sand types influence colonization, survival, and possible environmental growth of FIB (Kleinheinz)
- In the northern Great Lakes, we have seen virtually no overwintering of E.coli in sand. That is, in the winter when we look for E.coli in the frozen beaches and swash zones we find none, suggesting that each beach is repopulated each year. Or, they are VBNC.(Kleinheinz)

Richard

Great Lakes (con'd)

- Wave height is important (Whitman)
- Higher wave intensity more FIB (Mednick)
- Need to figure out how much is resuspension from swash and how much is from material settled in surf zone (Whitman)
- Mechanism of wave and sand interaction similar for freshwater and marine beaches.
- E.coli deposit in foreshore and are resuspended during wind events. Open beaches sediments are exported. In closed beaches sediments are trapped (Whitman)

Richard

4

Great Lakes (con'd)

- “Berm” by the water’s edge to minimize wave-wash up on the sand (Briggs quoting Kinzelman)
- Keep your beach high and dry. One of the ways to encourage high and dry sand is to add beach sand and berm up the beach at the swash zone (Briggs)

Richard

5

Portugal

- Sand is a reservoir of contaminants (Brandao)
- The dynamics of water and sand spiked by transient life on beaches, be those rodents humans, birds or prowlers, is highly influenced by local climate features (Brandao)

Joao

Portugal

Project 1: "Microbiologic Quality of Coastal Beach Sands"
(2000-2002)



5 Regions – Bimonthly
sampling during 13
months

3 beaches per region:

- 1 Beach awarded with the Blue Flag
- 1 Beach with no direct human interference
- 1 Beach with documented poor water quality

210 sand samples
105 water samples

Joao

Portugal

Factors that influence the quality of beach sand

Positive Influence

- Garbage removal -
- Garbage receptacles -
- Sand treatment -
- Surroundings -
Identification and treatment of
neighbouring contaminated
areas

Negative Influence

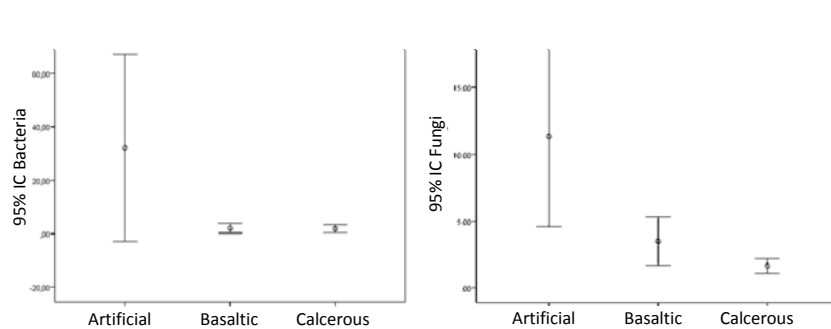
- Over-use of beach
- Admission of pets
- Accumulation of garbage
- Abandonment of remains
from fishing
- Rodents and prowling
animals

Joao

Portugal

Highlights:

- Microbial and granulometric data were analysed in Madeira archipelago sand beaches.
- Artificial beaches revealed more susceptibility to microbiological contamination.
- Granulometric parameters are not linked to sand microbial contamination/persistence.
- Bather's presence and anthropic settings explain sand contamination vulnerability.
- Overall results reveal the generally good quality of the sand beaches of Madeira.



Joao

United Kingdom

- Swept tidal area is related to FIO concentration (Kay)
- Spring tides result in high FIO (Kay)
- Non-compliance in high energy tidal waters (Kay)
- Balance between sedimentation, wash-off of bird sources not clear (Kay)

Joao

Goal

- Consensus statements about microbial sand dynamics at beaches
 - Organize by region
 - Overarching summary/comparison between regions
- Consensus statements about influence of climate change
 - Organize by physical factors (wind/waves, rainfall, sea level rise....)

Joao lead discussion

Physical Factors That Contribute to High FIB through Sand/Water Exchange



	Hawaii	California	Florida	Great Lakes	Portugal	UK
Large Waves			↓			
Large Tides/Seiche						
Currents						
Beach Slope						
Enclosed Beach						
Rainfall						
Temperature						
UV Light						
Mineralogy						

Climate Change Influence on Sand/Water Dynamic

Increase in Frequency of Intense Storms	Effects During Storm, Flooding, Influence on dunes and beach erosion
Sea/Lake Level Rise	
Water and Sand Temperature increases	
Direct Biological	Bacterial Growth
Indirect Biological	More Algae, Altered bird migration patterns

Working Groups

Thursday, from 6 to 8 pm

Joao

APPENDIX: Additional Email Received Since the PPT was Received.

From: Clare Robinson [mailto:crobinson@eng.uwo.ca]
Sent: Wednesday, April 13, 2016 12:26 AM
To: Solo-Gabriele, Helena M; Richard Whitman; João Brandão
Cc: Laura Vogel; Clare Robinson
Subject: Re: [beachnet] EPA Recreational Beaches Conference - Meeting at 12 noon

Dear Helena, Richard and Joao,

I followed the email exchanges on Beachnet last month regarding the sand/microbe hydrodynamics with considerable interest. Unfortunately I am not attending the EPA Recreational Beaches Conference this week, but thought I would share some of Laura's and my thoughts regarding the effect of waves on FIB concentrations in foreshore beach sand and shallow surface waters. Laura Vogel (PhD student) and I have done quite extensive sampling over the last couple of years at Great Lakes beaches examining the effect of waves and their potential role in the release of *E. coli* from the foreshore beach sand/pore water to adjacent surface waters. Note I am not a microbiologist but come at this problem with expertise in wave- and tide-induced groundwater-surface water interactions at beaches (i.e. tide- and wave-driven water exchange in foreshore and intertidal regions and erosional processes), as well as expertise in the physical colloid (bacteria) filtration processes. Also note that my discussion below is generalizing/simplifying things. I do recognize the processes are complex and many other factors come into play such as particle size, organic content, other FIB sources, alongshore currents, season, temperature etc.

Our data from Great Lakes beaches show, similar to other studies focused on marine and Great Lakes beaches, that there is generally higher *E. coli* in foreshore beach sand/pore water at low wave energy beaches (embayed beaches, sheltered beaches) than higher wave energy beaches. Our data suggest that under steady low energy wave activity *E. coli* accumulates in the foreshore sand/pore water. Accumulated *E. coli* is mobilized and released to surface waters (by erosion and/or interstitial pore water flow) if there is a period of high wave activity. This results in the positive correlation between wave height and *E. coli* surface water concentrations at Great Lakes beaches. This leads to depletion of amount of *E. coli* in the foreshore sand/porewater. Our data indicate that the amount of *E. coli* in the foreshore beach sand/porewater at some beaches is a function of the time elapsed since the last period of high wave activity (when the source was last depleted). Therefore the effect of waves in mobilizing *E. coli* in foreshore sand/porewater and subsequently leading to a water quality exceedance may be greater at beaches with low mean wave height that are exposed in infrequent periods when the wave activity is high. Compared to exposed marine beaches, this situation is more frequent on Great Lakes beaches because the waves are wind-driven and thus less regular.

The story is of course different if long-term mean wave height is considered (as done by Feng et al 2016) rather than the temporal variability in wave height. At beaches with higher long-term mean wave height, as explained in Feng et al, there is less opportunity for FIB to accumulate in foreshore/intertidal beach sand and the offshore mixing will be greater when the sand-associated *E. coli* is mobilized to surface waters. We have data for Great Lakes beaches that indicate that the higher the maximum wave height, the faster surface water *E. coli* concentrations decrease following peak concentrations observed at the start of high wave activity periods. We expect this is due to greater offshore mixing when the wave height is higher.

Perhaps this is all old information for beach gurus like yourselves and sorry for the information download but thought I would share our take on things and our basic conceptual understanding of wave effects. We do have a manuscript in revision with some of our data discussed above that (fingers crossed) will be accepted soon. Laura will be at the conference and at the meeting on Wednesday so will be able to share her thoughts on things.

Enjoy the conference and sorry I will not be able to meet you all there.

Regards, Clare



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