Blame the Moon:

A Critical Analysis of "Environmental Sources" of Enterococcus in Southern California Coastal Waters

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The Hypothesis of Environmental Sources of Enterococcus

The hypothesis posits that natural components of coastal ecosystems (tides, sand, kelp, plants, groundwater, birds, and wetlands) generate enterococcus bacteria and falsely cause beaches to appear contaminated by human sewage.

By introducing hypothetical uncertainty of false positives in monitoring data, enterococcus is argued to be an inherently unreliable measure of water quality.

***Regulators are warned** by researchers to account for great uncertainty when developing enterococcus standards.*

Major faults in the hypothesis are exposed by a critical analysis

The studies that conclude environmental components are the source of high enterococcus concentrations in coastal waters violate several basic principals of scientific investigation.

The conclusions are not supported by the results, and the studies do not satisfy the criteria for causation because they lack appropriate control sites, lack specificity, consistency, coherency and strength of association, and are not biologically plausible. Site selection bias and lack of critical analysis was also prevalent.

Most of the studies discussed were conducted in south Huntington Beach (SHB) near one of the largest sewage outfalls in the country: 240 m/g/d of effluent is discharged less than 5 miles directly offshore (Figures 1 and 2).

Figure 1: Sewage Discharges into Southern California's Coastal Waters

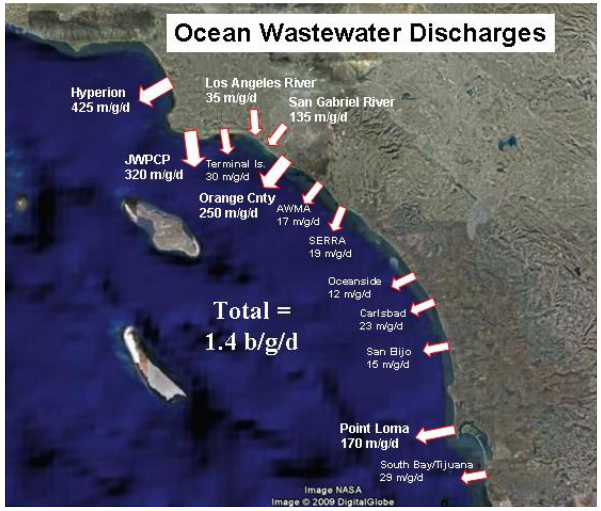
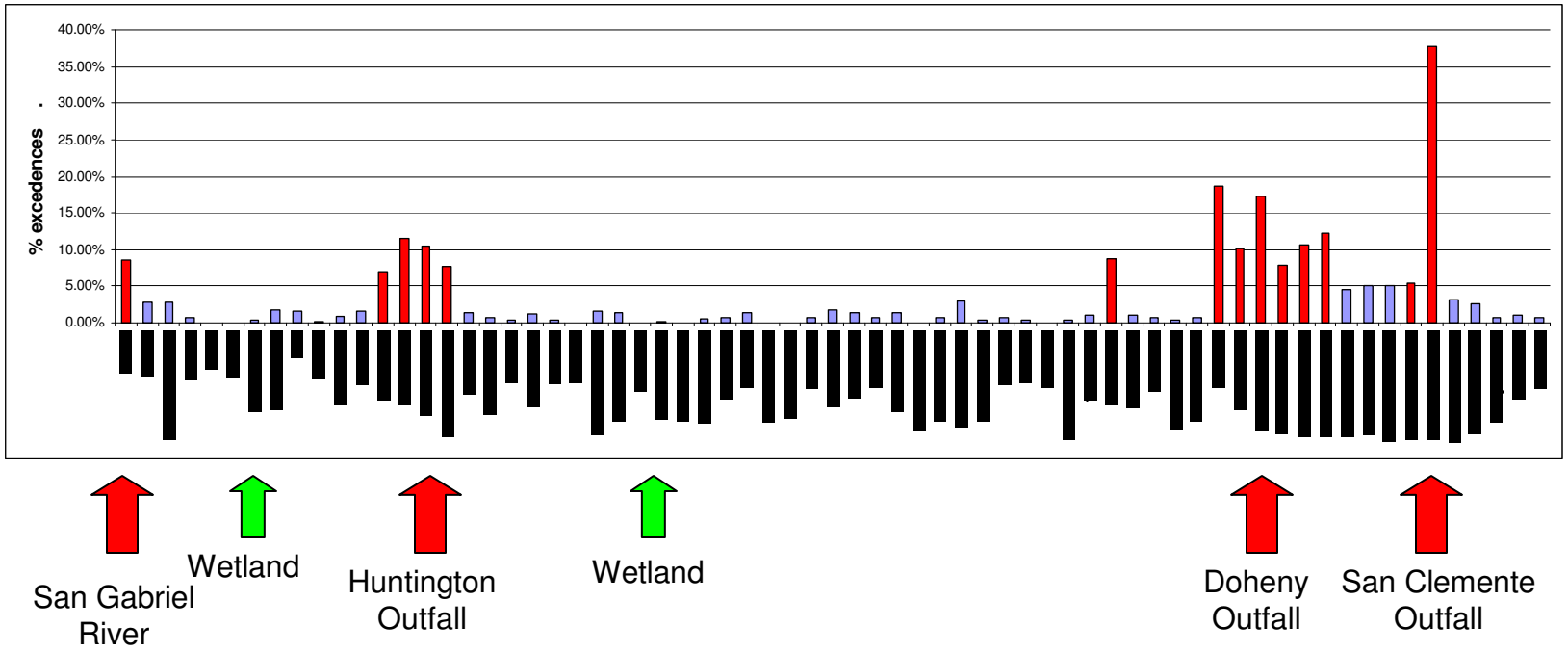


Figure 2: **Orange County California: AB 411 Period - Dry Weather Single Sample Standard Exceedance Rate for Enterococcus (2005 – 2009)** ***Data provided by: County of Orange Health Care Agency - Environmental Health***



Research Alleging Environmental Sources of Enterococcus in Coastal Waters

Beach Sand

Sand has been alleged to be a source or reservoir of enterococcus in several SHB studies (Grant, 2001; Boehm, 2002; Boehm, 2005; Sanders, 2005; Ferguson, 2005). One reported enterococcus persisting in sand *"may cause beach water quality failures and calls into question the specificity of this indicator for determining recent faecal contamination."* (Ferguson, 2005).

The study results do not support the conclusion as control sites had *"… low or nondetectable levels in offshore and control site sediments."* (Ferguson, 2005)

The conclusion is biologically implausible as sand is a commonly applied filtrate used to capture a range of substances including microorganisms and chemicals.

Sand is used in tertiary treatment of human waste water (Bauer, 2010).

The conclusion lacks consistency and coherency as most beaches have sand, yet most beaches are characterized by consistently low bacteria concentrations.

It is biological implausible for a line of sand at the high tide mark to culture sufficient concentrations of bacteria needed to contaminate millions of gallons of open ocean beach water.

A physical transport mechanism is absent for sand at the high tide line to influence or drive water bacteria concentrations during low tides.

It is well established that known point sources (sewage outfalls and spills) contaminate coastal waters and beach sand (Elmanama, 2005; Ghinsberg, 1994).

Polluted waters contaminate sand - not visa versa.

The NEEAR studies were conducted at beaches near sewage outfalls.

An epidemiology study reported a positive association between enterococcus concentrations in sand and the risk of gastroenteritis in those exposed to the sand (Heaney, 2009).

The statistically significant association with risk shows enterococcus in the sand was not a false-positive, and indicates other pathogens were present.

Kelp

A study at SHB reported kelp fragments washed up on the high tide line are a source of enterococcus bacteria which are released into coastal waters during high tide events (Boehm, 2005).

The conclusion lacks biological plausibility as kelp is a photosynthetic marine alga that has no association with enteric bacteria.

Kelp is an indicator species of clean healthy ocean water.

The conclusion lacks consistency and coherency as beaches with the highest density of kelp have excellent water quality (Monterey for example).

Southern California's kelp forests have declined dramatically in only the past 50 years due to high nutrient loads and thermal pollution.

Groundwater

Another SHB study investigated the daily exchange of sea and groundwater along the coastal fringe, and concluded that groundwater can negatively impact coastal water quality if it were contaminated (Boehm, 2004), and groundwater could be a source of nutrients which contribute to the growth and persistence of enterococcus in coastal waters. "*This work … presents evidence that supports an association between groundwater discharge and fecal indicator bacteria*."

The study results do not support the conclusion as groundwater samples tested clean.

There are no underground sources of enterococcus other than leaking pipes; in which case the bacteria would be appropriately indicating human waste.

Groundwater has lower nutrient availability than sea water, so it is unlikely to promote growth of bacteria in coastal waters.

The conclusion lacks consistency and coherency as varying degrees of ocean-groundwater exchange occurs at most beaches.

Plants and Dirt

A study at SHB reported 8-13% of enterococcus isolates from coastal waters were from species *"associated with plants and soil and rarely associated with human infection."* (Ferguson, 2005).
The conclusion lacks biologically plausibility as plants and soil can not culture enteric bacteria in sufficient concentrations to contaminate ocean beaches.
The study results do not support the conclusion as low to undetectable levels of enterococcus were measured at control sites.
The conclusion lacks consistency and coherency as beach waters near undeveloped watersheds (high percentage of plants and soil) have lower enterococcus concentrations compared to urbanized watersheds.
A physical transport mechanism is lacking for plant-sourced bacteria to reach beach waters as most creeks and drains only flow from rain events.
The study lacks critical analysis as it does not address the 87%-92% of enterococcus isolates that are considered opportunistic pathogens (Willey, 1999).

Shorebirds

The presence of birds at SHB studies (Grant, 2001; Kim, 2004; Boehm, 2005) has lead researchers to conclude, *"Bird feces are a significant source of enterococcus…"* (Grant, 2001). The presence of birds at Doheny Beach has lead researchers to justify an epidemiology study at the site as a bird-impacted beach (Critical Path Science Plan, EPA, 2007).
Doheny is one of the most contaminated beaches in California, and a small bird colony residing in a pool of fresh water runoff is the alleged problem.
Rarely mentioned, the site also has a large sewage outfall that discharges millions of gallons every day directly offshore.
Bird guano is small in volume but does contain high concentrations of enterococcus. Bird colonies can impact water quality under highly qualified conditions (small water bodies with restricted flow such as ponds and harbors). However,
It is biologically implausible for a bird colony to generate enough guano to consistently contaminate ocean water at such high levels (hundreds to thousands of enterococcus cfu/100 ml seawater); Bird feces at the beach are literally a drop in the ocean.
The conclusion lacks consistency and coherency as most beaches have birds, yet most beaches are characterized by clean coastal waters.
A concentration/response effect is lacking as beaches with the highest bird densities have good water quality.
Waters contaminated by bird droppings generate low to negligible risk because of the limited presence of human pathogens (Soller, 2010).
The Doheny epidemiology study found elevated health risk associated with swimming. This conflicts with the bird-impacted beach claim as bird guano does not generate high risk outcomes.

Moon and Tides

Two studies at SHB observed enterococcus concentrations tended to be higher when samples were collected at high tide (Boehm, 2002; Boehm, 2005).
Enterococcus from bird feces are alleged to be growing on the sand and kelp and are suspended by the incoming tide, resulting in erroneous false-positives in monitoring data. *"…tide should be considered in the design and interpretation of beach monitoring program data."* (Boehm, 2005).
The study results do not support the conclusion as high enterococcus concentrations were also observed during other tidal phases including low tide.
The conclusion lacks consistency and coherency as all beaches experience tidal influence, and most beaches are clean regardless of tidal phase.
There is insufficient evidence that tides drive enterococcus concentrations in coastal waters absent a known source of water contamination.
High tide lines accumulate with higher concentrations (residue) of all floating items in the ocean including kelp, driftwood, garbage, seashells, and bacteria.

Coastal Wetlands

A study at SHB concluded a wetland was a major source of enterococcus and generated false-positives in monitoring data (Grant, 2001). *"This … calls into question the use of ocean bathing water standards based on enterococci at locations near coastal wetlands."*
A subsequent more comprehensive study of the same wetland contradicts the conclusion (Reeves, 2004).
The conclusion lacks consistency, coherency and a concentration/response effect as coastal wetlands contain all the alleged environmental sources of enterococcus (many are bird sanctuaries), yet nearby beaches are typically characterized by low bacteria concentrations.
It is well established that wetlands are a pollution sink and not a source.
Municipalities use (and construct) wetlands to treat and remediate municipal waste.
Wetlands can reduce inputs of fecal indicator bacteria by 97% (Kay, 2005).

SUMMARY

The hypothesis that natural components of coastal ecosystems are responsible for enterococcus contamination of beaches lacks adequate evidence. The supporting studies violate basic principals of scientific investigation because they lack established methods for hypothesis testing, and do not satisfy the criteria for causation.

Lack of falsifiability. Most of the studies lacked appropriate control sites and the conclusions are based on inadequately tested hypotheses.
Lack of specificity, consistency and coherency. Most beaches have sand, birds, tides, etc., yet are characterized by low bacteria concentrations.
Lack of a concentration/response effect. Wetlands with high concentrations of all alleged sources have consistently low water bacteria levels.
Lack of strength of association. Epidemiology studies report health risk is associated with elevated enterococcus concentrations in recreational marine waters (positive-positives). The epidemiological and microbiological evidence does not support the claim of false-positives.
Lack of biologically plausibility. For the hypothesis to hold true, unrelated components in nature align to selectively culture the one enteric bacterium used to test marine water quality. Further, the alleged sources selectively culture enterococcus at only certain beaches, yet not for the majority. Systematic species specific differential mis-classification bias is biologically improbable.
Lack of biological plausibility. The alleged sources (tides, sand, kelp, etc.) can not physically mass culture the single isolate in sufficient concentrations to consistently contaminate millions of gallons of open ocean beach water.
Selection bias. Most of the supporting studies were conducted in south Huntington Beach near a large sewage outfall.
Lack of critical analysis. The studies failed to consider other plausible explanations for elevated enterococcus concentrations, such as sewage outfalls.

WEIGHING THE EVIDENCE

Two widely established scientific observations directly refute the hypothesis of environmental sources of enterococcus.

Most southern California beaches have sand, birds, tides, etc…, and most beaches are characterized by low enterococcus concentrations

- References: *Figure 2; Noble, 2000; Surfrider, 2010; NRDC, 2010*
- Dry weather water quality for southern California beaches is good: 91% of beaches with A or B grades (Heal the Bay, 2010).
- Only some beaches frequently exceed health standards (Figure 2).

Decades of epidemiology studies confirm health risk associated with increasing enterococcus concentrations.

- References: *Saliba, 1990; Pruss, 1998; Wade, 2003*
- The statistically significant dose-response relationship directly conflict with claims of false-positives.
- All epidemiology studies were conducted in the environment with alleged natural sources present.
- Any background "noise" due to natural sources was present and accounted for in the elucidation of the dose/response relationships.
- **The current single sample standard** (104 cfu) is calculated from a generous 75% confidence interval (34 cfu = "acceptable" 1.9% HCGI), which **allows a wide range of variability in bacteria concentrations before the standard is exceeded**.
- Enterococcus is the only indicator bacterium accepted by the U.S. EPA and W.H.O. for monitoring recreational marine waters for fecal contamination.
- Recent studies confirm enterococcus is a stronger predictor of risk than other indicators (Colford; Wade; Fleming; Kay; 2009 EPA Beach Conference).