Understanding Submarine Groundwater Discharge and Its Influence on California Coastal Water Quality

Alexandria Boehm, Stanford University
Adina Paytan, UC Santa Cruz

SUMMARY

Submarine groundwater discharge (SGD) is a mechanism for bringing nonpoint source pollution to the coast. This is particularly true in areas where urban or agricultural practices pollute groundwater. This project sought to understand some of the effects of SGD on coastal water quality at Stinson Beach in Marin County, a community in which residents' wastewater is treated on-site via septic systems. In particular, the following four hypotheses were tested and eventually shown to be true:

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Stanford graduate student Nick de Sieyes installs a monitoring well at a Northern California beach.

1. The season, tides and wave conditions modulate the volume of SGD, its quality and its fresh-versus-saline composition.
2. Land use and geology influence "nutrient," carbon, trace metal and fecal indicator bacteria (FIB) levels.
3. FIB and nutrient pollution (e.g., nitrogen and phosphorous) can sometimes move freely through the beach aquifer and are not removed via interactions with sediments.
4. SGD influences nearshore water quality as much as surface runoff in some cases.

METHODOLOGY

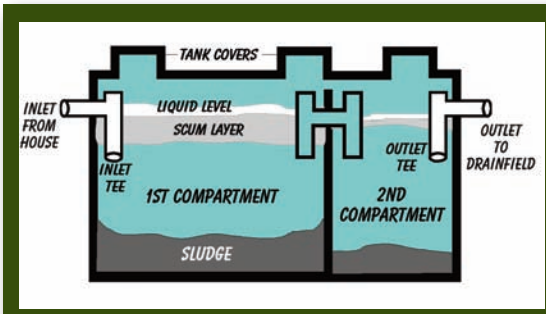
SGD was calculated at multiple timescales and wave conditions using radium and salinity as tracers. Chemical and biological fluxes associated with SGD were calculated by multiplying appropriate groundwater end-member concentrations by their respective discharge rates. These same fluxes were compared with measured fluxes of nutrients and bacteria from local surface sources, such as Bolinas Lagoon and perennial streams. Transport properties of FIB and nutrients in porous media were measured via laboratory bench-top column experiments.

The primary field site was the Calles district of Stinson Beach, a residential area with a high density of septic leach fields (about 12 leach fields per 15,000 square meters) located about 300 meters from the coast.

In July 2006 and March 2007, researchers conducted field experiments to estimate SGD rates, associated nutrient fluxes and their seasonal variations with tidal and wave conditions. Fluxes were compared to those from surface runoff.

An ancillary research topic investigated at the Calles site was the contribution of submarine groundwater to fluxes of total mercury and monomethylmercury. This work, conducted in collaboration with additional UC Santa Cruz researchers, demonstrated that SGD is an important source of both total and monomethylmercury to coastal waters.

In January 2008, scientists began collecting field data at a large leach field at Stinson Beach within the National Park Service's Golden Gate National Recreation Area. The park receives up to 100,000 visitors a month, and conventional septic systems and leach fields service all its waste. A large, dense array of groundwater monitoring wells was installed downgradient from one of the leach fields to observe the fate and transport of septic-effluent contaminants headed to coastal waters.



Schematic of a septic system. Michigan State University Extension

FINDINGS

This was the first study in California to show definitively that septic tanks can affect coastal water quality through SGD. Chemical fluxes associated with SGD were shown to be comparable to that from surface runoff. Mercury and monomethylmercury were also shown to be present in SGD. The mercury originates from sediments where it is naturally present; however, processes related to septic pollutants likely enhance methylation, in which inorganic mercury is converted into highly toxic, bioavailable methylmercury. Results highlight the importance of protecting shallow groundwater from coastal septic systems and the potential


Stanford/A. Boehm

The Stanford team: professor Ali Boehm (upper left), with (clockwise) summer intern Eric Foote, graduate student Nick de Sieyes, graduate student Kevan Yamahara, and Ken Willis, Boehm's husband.

for groundwater to contaminate coastal waters with forms of mercury that accumulate in the marine food chain. These discoveries are all timely given recent debates over California Assembly Bill 885, which proposes new regulations for septic systems.

OUTREACH

Findings are being shared primarily through peer-reviewed publications. One published in 2008 in *Limnology and Oceanography* discusses fresh and saline components of SGD and associated nutrient fluxes. Another, published in 2009 in *Environmental Science & Technology*, documents discharge of total and monomethylmercury in SGD. The third, which has been submitted for publication, compares seasonal, tidal and wave-driven variability in SGD and associated fluxes. In preparation is a fourth paper that discusses a field and modeling study of the temporal and spatial variability of a septic-effluent plume flowing through the beach to sea.

IMPACTS

Findings from the project were incorporated into the Bolinas Lagoon Ecosystem Restoration Project and Marin County Local Coastal Plan as evidence that septic systems are capable of measurably degrading groundwater quality. Findings were also presented to the Stinson Beach County Water District. A Sea Grant press release highlighting the research resulted in several articles on the topic in California newspapers.

COLLABORATORS

Daphne Hatch, Golden Gate National Recreation Area, National Park Service

Kristen Ward, NOAA's Gulf of the Farallones National Marine Reserve

STUDENTS

Nicholas de Sieyes, Ph.D.
Lilian Lam, B.S.

PUBLICATIONS

Submarine groundwater discharge of total mercury and monomethyl mercury to central California coastal waters. Black, F.; A. Payton; K. Knee; N. de Sieyes; P. Ganguli, E. Gray and R. Flegal. Environmental Science & Technology. 2009. 43(15):5553–5659.

Fresh submarine groundwater discharge at Stinson Beach, California, is enhanced during neap tides. de Sieyes, N. R.; K. M. Yamahara; B. Layton and A. B. Boehm. Limnology and Oceanography. 2008. 53(4):1434–1445

Submarine groundwater discharge to a high-energy surf zone at Stinson Beach, California, estimated using radium isotopes. de Sieyes, N. R.; K. M. Yamahara; A. Paytan and A. B. Boehm. Submitted.

Fate and transport of a septic effluent plume in coastal groundwater at Stinson Beach, California: a field study. de Sieyes, N. R.; A. Paytan and A. B. Boehm. In preparation.

CONTACTS

Alexandria Boehm
Civil and Environmental Engineering
Stanford University
(650) 724-9128
aboehm@stanford.edu

Adina Paytan
Institute of Marine Sciences
UC Santa Cruz
(831) 459-1437
apaytan@ucsc.edu

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California Sea Grant, University of California, San Diego, 9500 Gilman Drive, Dept. 0232, La Jolla, CA 92093-0232
Communications Phone: (858) 534-4446