Caribbean Coastal Pollution Project (CCPP)

Tracking the Sources of Coastal Zone Contamination in the Maya Riviera Region of Mexico

Report on Research Project
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INTRODUCTION:

The geology of the Yucatan peninsula in Mexico consists of highly-permeable karst limestone deposits. Fresh water percolates rapidly through the porous substrate into the subterranean aquifer. Along the Caribbean coast of the Yucatan peninsula, flooded caves provide a hydrological conduit that links the inland recharge areas to springs that discharge into the coastal zone. The Riviera Maya region of the Caribbean coast is a rapidly growing tourism and recreational area. Plans for growth in tourism and intensive land development mean that the permanent and transient population base in the region will expand rapidly over the next 20 years. The fresh water resources within this region are especially to contamination from tourism and development. For instance, sewage is currently pumped from municipalities and hotels into the saline water zone below the freshwater aquifer. As has been shown in the Florida Keys of the USA, this waste disposal practice can contaminate the overlying freshwater aquifer and the coastal zone. In addition, there is potential for percolation of contaminants from the surface to the freshwater aquifer by transport through the porous substrate or through contamination of cenotes. In order to evaluate contamination of groundwater and the coastal zone in the Riviera Maya region, we conducted a monitoring study of selected groundwater discharge zones along the Caribbean coast between Puerto Aventuras and Tulum using passive sampler technologies. Two types of passive samplers (i.e. SPMDs, POCIS) were deployed for a period of one month (December, 2008 to January, 2009) in cenotes and underwater caves at 5 sites in this region (Figure 1). Once retrieved, the samplers were analyzed for several different classes of contaminants that can be used as indicators of the sources of contamination. Working with a local NGO, Amigos de Sian Ka'an, the results of this study were shared with regional stakeholders, which lead to discussions of best management practices for reducing the likelihood of contamination in the region.

METHODS:

Passive sampler deployments:

A total of 5 sites were selected for deployment of passive samplers. As indicated in Figure 1, the sites near the town of Tulum and the recreational/residential complex of Puerto Aventuras are located within regions that have extensive cave systems and underground rivers that discharge into the coastal zone. Two sites were located in drowned cave systems below the town of Tulum; Herradura Cave and Ak Tulum Cave. The two sites at Puerto Aventuras were a cave system that discharges into Chac Ha Lal Caleta and an un-named cenote located in the commercial district of the complex, referred to in this study as "Tree" cenote. The reference site was a cave system upstream of Carwash cenote, which is located about 15 km to the northwest of Tulum.

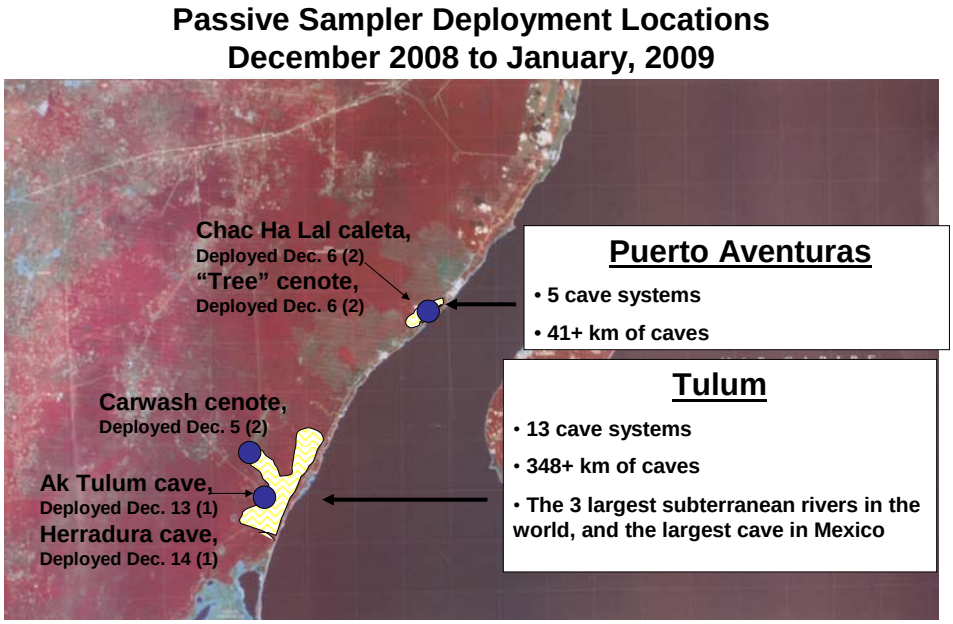

Figure 1: Sites of deployment of SPMD and POCIS passive samplers in the Riviera Maya region of Mexico.

Semi-permeable membrane devices (SPMDs) and polar organic contaminant integrated samplers (POCIS) were deployed in stainless steel cages; each containing 3 POCIS and 3 SPMDs. SPMDs accumulate compounds with low water solubility, such as PCBs and organochlorine pesticides, while POCIS accumulate more water soluble compounds, such as current use pesticides and pharmaceuticals. Figure 1 shows the numbers of cages that were deployed at each site (i.e. either 1 or 2 cages), and the date of deployment in December, 2008.

Passive sampler extraction and analysis:

During the first 2 weeks of January, 2009, the passive samplers were retrieved from the deployment sites and were immediately transported to the CINVESTAV Marine Geochemistry Laboratory in Merida, Mexico. The SPMDs were extracted by dialyzing

the devices overnight in hexane (Metcalfe et al., 2008). The POCIS were extracted by removing the solid phase adsorbent and placing this material in a glass column, and then eluting the column with methanol (Li et al., 2010). Co-extractives were removed from the SPMD extracts by gel permeation chromatography. The extracts were analyzed by gas chromatography with either electron capture detection (i.e. GC-ECD) or mass selective detection (i.e. GC-MS), or by liquid chromatography with tandem mass spectrometry (i.e. LC-MS/MS). All results were expressed as ng amounts of the analyte detected per POCIS or SPMD. The concentrations of the analytes in water (i.e. ng/L) were estimated from the amounts accumulated in the passive sampler using published data on water sampling rates for the device for each chemical (i.e. litres per day).

RESULTS AND DISCUSSION:

The analytical results indicate that the freshwater resources below Puerto Aventuras and Tulum were contaminated by pharmaceuticals, personal care products and compounds of domestic origin that could only have originated from domestic sewage. Figure 2 shows the results for the analysis of POCIS samplers for pharmaceuticals and illicit drugs (i.e. cocaine). These data show that these compounds, which could only have originated from domestic sewage (Table 1) were present in freshwater resources near Tulum and Puerto Aventuras, while these compounds were not detected at the reference site (i.e. Carwash cenote).

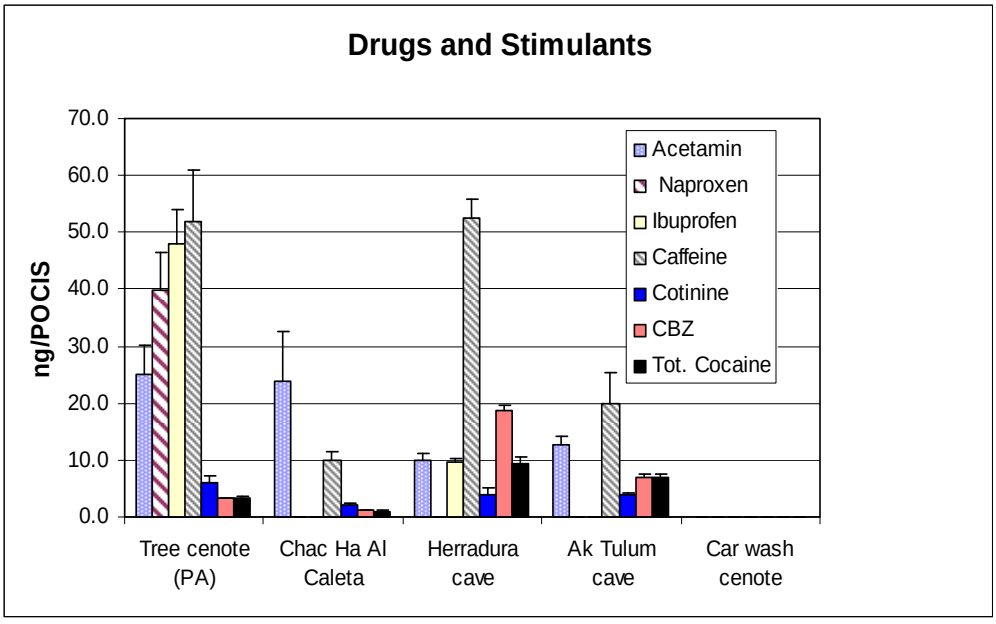

Figure 2: Mean (n=3) amounts of prescription and non-prescription pharmaceuticals, stimulants (i.e. caffeine, cotinine) and illicit drugs (i.e. cocaine and major metabolite) detected in POCIS samplers deployed at the 5 locations in the Riviera Maya region, Mexico from December, 2008 to January, 2009

Two sites in the vicinity of the community of Puerto Aventuras also showed evidence of contamination from pesticides and oil hydrocarbons (Table 1). The application of pesticides for turf care, especially for maintenance of a golf course probably contributed to the accumulation of pesticides in the passive samplers. The source of the oil hydrocarbons (i.e. PAHs) was probably runoff from a nearby highway, where there had been road construction over the deployment period.

Table 1: Probable sources, estimated concentrations and the locations where detected for various classes of contaminants monitored using SPMD and POCIS passive samplers in the Riviera Maya region of Mexico. PA = Puerto Aventuras,

Compound	Possible Source	Estimated Concentration	Locations Detected
SPMD extracts:			
PCBs	Industry, urban sources, atmospheric transport	Very low < 5 ng/L	PA, Tulum
Organochlorine pesticides	Agriculture, atmospheric transport	Very low < 5 ng/L	PA, Tulum
Polynuclear aromatic hydrocarbons (PAHs)	Urban/road runoff, industry, atmospheric	Moderate > 10 ng/L	PA
Brominated flame retardants (PBDEs)	Industry, sewage, atmospheric	Very low < 5 ng/L	PA
Synthetic musks	Sewage	Low <10 ng/L	PA, Tulum
Alkylphenol surfactants	Industry, sewage	Low <10 ng/L	PA, Tulum
Antibacterial (Triclosan)	Sewage	Moderate >10 ng/L	PA, Tulum
POCIS Extracts:			
Herbicides (2,4-D, etc.)	Turf care	Moderate >10 ng/L	PA
Fungicides	Turf care	Not detected	-
Caffeine	Sewage	Moderate >10 ng/L	PA, Tulum
Human use pharmaceuticals	Sewage	Low to moderate 5-15 ng/L	PA, Tulum
Illicit drugs	Sewage	Low <10 ng/L	PA, Tulum

CONCLUSIONS:

The data on chemicals from different classes accumulated in passive samplers deployed at 5 locations in the Riviera Maya region of Mexico show that there is potential for contamination of this coastal region of the Caribbean from domestic sewage and from the use of pesticides and fertilizers for turf care, as well as from road runoff. Contamination from sewage could result from leakage from septic systems and/or sewer lines, from injection of domestic wastewater into the salt water aquifer under laying the freshwater zone, or from the use of treated sewage for irrigation of lawns and turf. The latter practice is a common irrigation strategy in this area. Pesticide contamination is likely a result of the use of herbicides and insecticides on golf courses and lawns in recreational areas, such as Puerto Aventuras. These sources are likely to be a source of contamination in other regions of the Caribbean where there are freshwater discharges to the coastal zone through porous limestone. Future work should focus on evaluating whether contamination from these sources is occurring in other areas of the Caribbean, and determining whether these contaminants are impacting marine organisms in the near shore zone.

These results were presented at a community-based workshop organized in Tulum by the Amigos de Sian Ka'an on September 25, 2009. This workshop provided an opportunity for the study team to present their research results to regional stakeholders and to discuss the probable sources of contamination in the region. These discussions identified several best management practices that could be employed to reduce the likelihood of contamination of the aquifer, such as changes to sewage disposal practices, installation of liners below golf courses, and protection of recharge areas.

References:

Li, H., P. Helm, C. Metcalfe. 2010. Sampling for pharmaceuticals, personal care products, and endocrine disrupting substances using the passive polar sampler (POCIS): Temperature effects, predictive relationships and application to monitoring in the Great Lakes, Environ. Toxicol. Chem., in press.

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