SAN DIEGO RIVER CONTAMINATION STUDY

Increasing Preparedness in the San Diego River Watershed for Potential Contamination Events

APRIL 21, 2020

SAN DIEGO STATE UNIVERSITY

Authored by: Natalie Mladenov, Matthew Verbyla, Alicia M. Kinoshita, Richard Gersberg, Federick Pinongcos, Jose Calderon, Mireille Garcia

SAN DIEGO STATE UNIVERSITY

EXECUTIVE SUMMARY

Introduction

Distinguishing anthropogenic fecal pollutant inputs to streams is currently one of the most pressing environmental challenges for urban water managers. Although stormwater enters urban waterways from municipal separate storm sewer systems (MS4s) rather than from combined sewer systems (CSSs), streams and rivers in Southern California often exceed water quality targets for fecal indicator bacteria, and human pathogens have been detected during wet weather conditions. Pathogenic microorganisms and other pollutants may be introduced to streams from both surface and subsurface sources, and the relative importance of different sources is not yet well understood. In this study, microbial source tracking (MST) markers and chemical markers were measured in water and soils to evaluate pollutant inputs to the San Diego River and its tributaries from untreated wastewater and fecal waste associated with homeless encampments. The study was conducted from January 2018 to March 2019 and focused on the two hydrologic years following the Hepatitis A outbreak in San Diego, which included cases among the unsheltered population in San Diego. The MST and chemical markers used can help distinguish human-associated fecal pollution from general fecal pollution (which can also originate from other warm-blooded animals).

Dry weather contaminant inputs

Water samples collected during dry weather conditions at locations directly upstream and downstream of three active homeless encampments along the San Diego River and two of its tributaries had greater downstream concentrations of fecal indicator bacteria, *Escherischia coli* and fecal enterococci, but these bacteria may also originate from non-human fecal sources, such as pets and birds. By contrast, a human-associated microbial indicator of fecal pollution, the HF183 marker of *Bacteroides*, was only detected sporadically, and the concentrations were too low to conclude if there was a significant difference between upstream and downstream samples. There was also no significant change in the concentrations of caffeine and sucralose, two chemical pollutants associated with human waste. Overall, there was no evidence that homeless encampments are causing increases in the concentration of microbial pollutants in water during dry weather conditions.

"Homeless encampments did not have a significant influence on microbial pollution of surface waters during dry weather."

On the other hand, soils sampled in the vicinity of open defecation sites during homeless encampment cleanups tested positively for *E. coli*, enterococci, and HF183. However, HF183 was not detected in the soils one month after cleanup. There is evidence that the soils (but not the adjacent waters) within a former encampment are contaminated with fecal pollution, and therefore, environmental workers should use personal protective equipment (e.g., gloves) when handling or working around soils at former encampment sites, especially soils located near sites with evidence of open defecation.

"Homeless encampments did result in microbial contamination of soils at encampment sites, even after site cleanup."

Wet weather contaminant inputs

Knowledge of the fate and persistence of biological and chemical markers from untreated wastewater exfiltrating from cracked and aging sewer infrastructure or discharging into waterways from sanitary sewer overflows (SSO) is essential to evaluate contributions of human fecal material to the San Diego River and its tributaries. Untreated wastewater had substantially higher caffeine (approximately 200 µg/L on average) than sucralose (approximately 25 µg/L). A caffeine/sucralose ratio of greater than 2 was found to be indicative of wastewater inputs to surface waters. The MST markers, HF183 and pepper mild mottle virus (PMMoV), a virus found in pepper-based sauces consumed almost exclusively by humans, were also measured in this study. The bacterial marker, HF183, was more than an order of magnitude higher in wastewater (>10^6 copies/100 mL) than the viral marker, PMMoV (approximately 10^5 copies/100 mL).

Experiments were also conducted to evaluate the persistence of microbial pollutants in soils from simulated sewer exfiltration and SSO events during wet weather. For soils spiked in the laboratory with untreated wastewater, *E. coli* concentrations decreased exponentially from >10^7 MPN/100 mL on the first day of the experiment to ~100 MPN/100 mL, levels that were still measurable, even 4 months after spiking. The MST markers, HF183 and PMMoV, were also measured at concentrations of 100 copies/100 mL to 1000 copies/100 mL four months after spiking. PMMoV had greater persistence in dry soils than HF183.

"Wastewater-spiked soils continued to be a source of E. coli, enterococci, HF183, and PMMoV even after 4 months."

To simulate storm conditions, wastewater-spiked soils were also flushed repeatedly on the day after spiking. After 20 consecutive flushes, wastewater-spiked soils remained a source of *E. coli* , enterococci, and HF183, but not PMMoV. PMMoV was flushed away from soils after the first 2 flushes, possibly due to its smaller size and greater mobility in soils. These results provide new information on the typical concentrations of MST markers in wastewater contaminated soils that may serve as a guide for future tracking of wastewater inputs during storm events.

To simulate the leaching of pollutants from open defecation sources into stormwater, runoff experiments were conducted using a runoff simulation device at sites adjacent to the river with human feces on the soil surface. These experiments revealed several important findings about open defecation. Concentrations of *E. coli* and enterococci remained unchanged after multiple flushes of human fecal material on soil surfaces; therefore, open defecation is likely to be a continuous source of fecal indicator bacteria over the length of a storm event. Also, the human microbial marker, PMMoV, and the chemical marker, sucralose, were measured in every runoff experiment and found to be persistent in human fecal material in the environment. However, both HF183 and caffeine, were either absent or present in very low (undetectable) concentrations in the runoff experiments, which may be due to the short lifetime of both HF183 and caffeine in the environment. Combined with earlier evidence of high concentrations of HF183 and caffeine in untreated wastewater, these runoff experiment results indicate that increases in caffeine and HF183 concentrations in surface water are likely an indication of untreated wastewater inputs rather than open defecation inputs.

"Caffeine and HF183 are found in high concentrations in untreated wastewater and almost undetectable in stormwater runoff from soil with open defecation."

Source tracking during storm events

Monitoring of pollutagraphs for the San Diego River and its tributaries during storm events from January 2018 to March 2019 revealed that *E. coli* and enterococci concentrations exceeded wet weather targets by several orders of magnitude, with the highest concentrations (> 10^5 MPN/100 mL) and loadings (>10^{13} MPN/d) observed during the two largest storm events. Samples were also analyzed for gene targets of a fecal indicator virus (coliphage PhiX174), human associated chemical markers (caffeine and sucralose), human-associated biological markers (HF183 and PMMoV), pathogenic human viruses (Hepatitis A virus [HAV] and norovirus GI [NoVGI]), pathogenic bacteria (*Campylobacter coli* and *Campylobacter jejuni*), dissolved organic carbon, total dissolved nitrogen, nitrate, and phosphorus. Samples collected from the San Diego River during a major storm (February 2018), which had strong evidence of SSO influence, had no detectable levels of HAV or *C. jejuni*, but the human pathogen, *C. coli* was detected. Subsequent storms also did not have measurable concentrations of HAV or *C. jejuni*; however, the human pathogen NoVGI was detected in the San Diego River during the first rain event of the 2018 hydrologic year, following 150 antecedent dry days.

The most telling information regarding sources of contamination comes from pollutagraphs of HF183, caffeine, and sucralose, which showed caffeine/sucralose ratios greater than 2 and large increases in HF183 during and after the peaks of storm hydrographs. The trends in concentrations of MST and chemical markers, as well as other chemical parameters, over the course of each storm suggest that untreated wastewater, from sewer exfiltration or SSOs, is the main source of microbial contamination in the San Diego River during storm events. Corresponding chemical analyses indicated that soils become saturated over the course of most storms, potentially mobilizing contaminants from the subsurface, where untreated wastewater may have accumulated around sewer pipes or where sewers may actively be leaking wastewater to the surrounding environment. Evidence also showed that, during very low volume rain events, in which surface runoff is the dominant mechanism for flushing pollutants into the water column, HF183 was undetectable and *E. coli* and fecal enterococci concentrations were one to two orders of magnitude lower than during larger storms. These results indicate that flushing of open defecation sources during surface runoff may transport pathogenic microorganisms into the water column, but that this source likely represents only a fraction of the microbial pollutant inputs that occur from untreated wastewater. Overall, untreated wastewater sources are likely responsible for the majority of elevated microbial pollutants detected in the San Diego River and its tributaries during storm events.

"Untreated wastewater was found to be the main source of San Diego River pollution during storm events."

This study suggests that efforts to address contamination of the San Diego River and its tributaries and meet wet weather pollution targets should prioritize replacement of cracked or failing sewer infrastructure or containment of sanitary sewer overflows. Despite the potentially lesser contribution of open defecation sites to pollutant loadings in the San Diego River during storm events, waste associated with homeless encampments remains an important source of fecal pollution to soils. Provision of improved water supply, sanitation, and hygiene facilities is recommended for unsheltered individuals experiencing homelessness in the region.

Acknowledgements

We acknowledge funding and support from the San Diego River Conservancy, California State Water Resources Control Board, Region 9, San Diego State University Division of Graduate Affairs, Office of Councilmember Scott Sherman (District 7) of the City of San Diego, Office of Councilmember Lori Zapf (District 2) of the City of San Diego. We are grateful for assistance with field work and access to data and study sites provided by the San Diego River Park Foundation and the City of El Cajon. A talented group of students assisted with field and laboratory work; we thank J. Calderon, F. Pinongcos, M. Garcia, M. Gil, J. Monroe, C. Batikian, H. Bertsch, B. Carlson, C. Carr, S. Chao, F. Espinosa, D. Garcia, A. Gaunin, C. Graves, A. Jaramillo, A. Kinney, L. Mendoza, I. Musaazi, E. Mikita, K. O'Marah, T. Sadeque, A. Sanchez, J. Simmons, E. Winterton, A. Wong, F. Zhao and many other SDSU students for the time and effort they donated to this project.

Cite this report as: N. Mladenov, M. Verbyla, A. M. Kinoshita, R. Gersberg, J. Calderon, M. Garcia, F. Pinongcos. 2020. Executive Summary. San Diego River Contamination Study. San Diego State University. San Diego, CA, USA, 6 pp