Optical Brightener Monitoring in Goleta Streams
A summary of monitoring results from August 2009 – November 2009

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Executive Summary

In 2009, Santa Barbara Channelkeeper conducted a water quality monitoring study to identify sewage discharges to streams from damaged or leaking sewer pipes, illicit sewer connections, and faulty septic systems by collecting samples from streams in Goleta, California and analyzing them for optical brighteners. Optical brighteners are compounds frequently added to laundry detergents to make clothes appear brighter and less faded. Most household wastewaters contain laundry detergent. The presence of optical brighteners in a stream is a strong indication that household wastewater is contaminating the stream.

From August through November 2009, 146 stream samples from 13 coastal streams and wetlands near Goleta, California were collected and analyzed for optical brighteners using an analytical method recommended by the State Water Resource Control Board's Clean Water Team. Samples were collected monthly in conjunction with Santa Barbara Channelkeeper's Goleta Stream Team water quality monitoring program. Sampling of selected monitoring sites was conducted on an hourly basis over two four-hour periods in mornings and afternoons. Additional sampling was conducted on selected streams to identify point source contributors of optical brighteners.

Optical brighteners were detected in four out of 13 streams that were sampled. Sampling results varied significantly at each location over time. Numerous samples resulted in "undetermined" results based on the analytical method used. Contemporaneous analysis of Stream Team samples for the indicator bacteria *Escherichia coli (E. coli)* produced results that consistently exceeded limits established by the US EPA for "full body contact" recreation in freshwater, however there was poor correlation between the presence of optical brighteners and levels of indicator bacteria in each sample.

Point source sampling was hampered by stream access issues and by irregular and episodic discharge events. Samples collected from upper San Pedro Creek consistently tested positive for optical brighteners. Preliminary analysis of sewer infrastructure maps and aerial imagery point towards septic tanks as a potential source of optical brighteners and indicator bacteria in upper San Pedro Creek. Although monitoring did not identify specific sources, results from this study indicated wastewater contamination in Goleta streams and identified problematic segments of streams, warranting further monitoring and investigation.

Introduction

Optical brightener monitoring is a method used to detect sewage discharges to streams. Optical brighteners are compounds frequently added to laundry detergents to make clothes appear brighter and less faded. Most household wastewaters contain laundry detergent. The presence of optical brighteners in a stream is a strong indication that household wastewater is contaminating the stream. Potential sources of such contamination include damaged or leaking sewer pipes, illicit connections of sanitary sewer pipes to the storm sewer system, and septic systems. While optical brighteners themselves are not harmful to human health or aquatic ecosystems, their presence usually signifies wastewater contamination that may contain pathogens and other harmful contaminants that can be harmful.

There are many advantages to monitoring for optical brighteners to detect sewage discharges. Conducting monitoring for optical brighteners is relatively inexpensive. Optical brighteners are relatively slow to decay and are detectable far from the point source (Iyer et al. 2006). Optical brighteners also have the advantage of only being produced by anthropogenic pollution, as opposed to other indicators which can have human or animal origins.

Standard methods for optical brightener detection use fluorescence as a primary indicator. One common drawback to these methods, however, is the occurrence of false positive results due to the presence of natural substances which also fluoresce. Hartel et al. (2009) found that optical brightener fluorescence decays faster in ultraviolet light than other organic substances naturally found in stream water. Therefore, optical brighteners can be differentiated from natural sources in stream samples by analyzing fluorescence before and after ultraviolet (UV) exposure. Cao et al. (2009) improved upon this method by incorporating analysis of differences in the decay curves between optical brighteners and natural substances, allowing for greater sensitivity and narrower detection limits. This method has been shown to be relatively accurate in detecting optical brightener concentrations in water of five parts per million and above, and it was found to produce no false positive results among control samples. The State Water Resource Control Board has adapted this method for use by citizen monitoring groups, and it was the method used in this study.

The objective of this study was to monitor Goleta streams for the presence of optical brighteners, attempt to pinpoint or narrow the potential source(s) of optical brighteners if found to be present, and to evaluate the adaptability of this method to local volunteer monitoring efforts. This study was conducted in coordination with Santa Barbara Channelkeeper's Goleta Stream Team Program, a volunteer water quality monitoring program. Stream Team volunteers meet once a month and collect water samples and measurements for a variety of water quality parameters including nutrient concentrations, indicator bacteria, temperature, pH, conductivity, turbidity and dissolved oxygen at distributed locations throughout the Goleta Slough, Bell Creek, and Tecolote Creek watersheds (**Figure 1**). A description of monitoring sites is included in **Appendix A**.

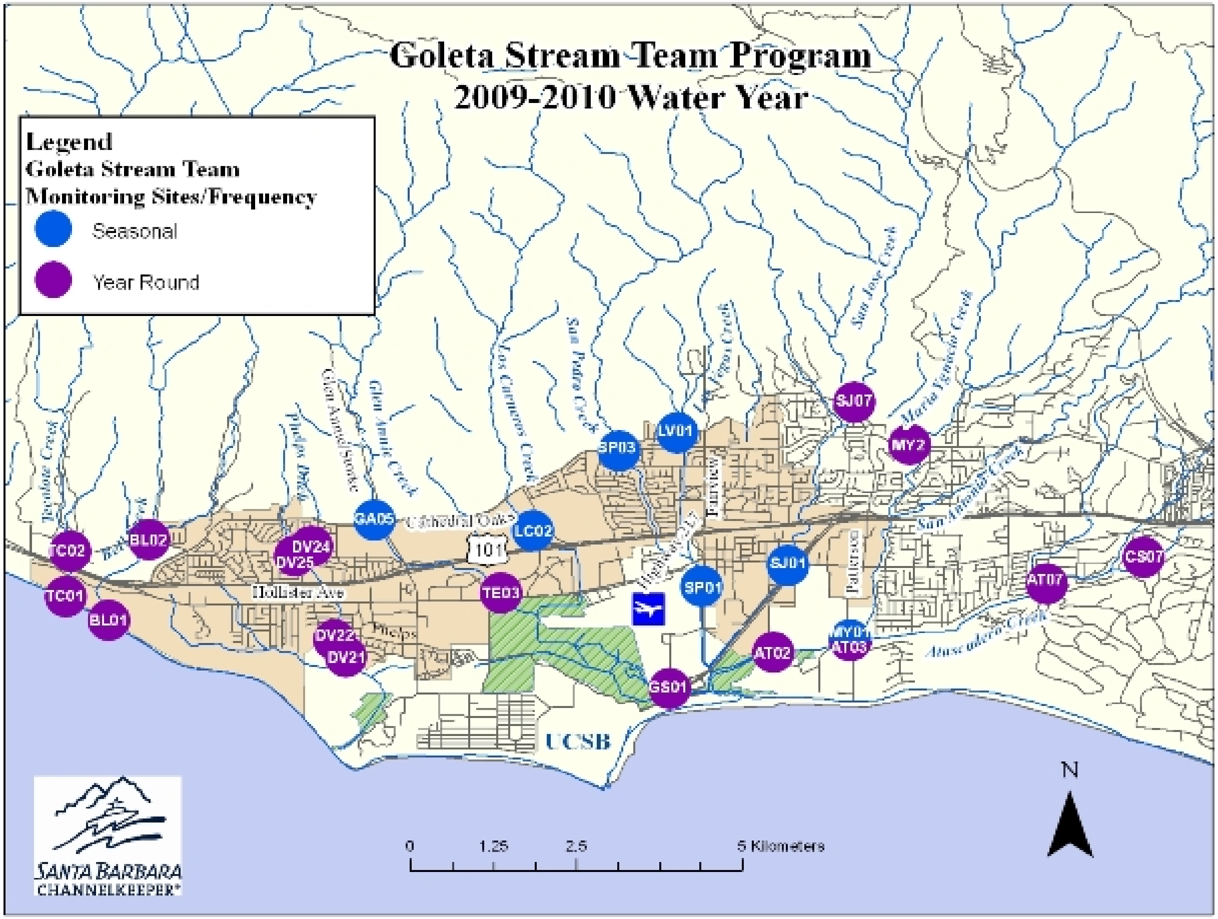

Figure 1: Goleta Stream Team Monitoring Sites

Methodology

Sampling - The project involved several types of sampling: Stream Team sampling, "time-lapse" sampling, and point source sampling.

Stream Team volunteers collected samples at monitoring locations monthly from August to November 2009 for this project. Since exposure to UV light can cause optical brightener chemicals to degrade, samples were collected in 60 ml foil-wrapped amber glass bottles to eliminate exposure to sunlight. Collected samples were transported in an ice chest and refrigerated until they could be analyzed.

Ten Stream Team monitoring sites underwent subsequent eight-hour time-lapse sampling. Time-lapse sampling involved the collection of one sample per hour for four hours in the morning and four hours in the afternoon. This time frame was chosen to best capture the interval when detergents were most likely to be discharged into the sanitary sewer system.

Additional monitoring sites were selected as candidates for surveys to investigate the presence of upstream point sources of optical brighteners. Project personnel walked accessible portions of creeks upstream of Stream Team monitoring sites in search of visible outfalls of water flowing into the stream. Samples from these outfalls were collected and analyzed. On occasion, project field personnel collected additional samples during these surveys from the stream itself.

Laboratory and Analytical Procedures – Project personnel followed calibration and analytical analysis procedures outlined in the State Water Resource Control Board's (SWRCB) Standard Operating Procedure for Measuring Optic Brighteners in Ambient Water Samples Using a Fluorometer (Burres 2009). These procedures were developed by the SWRCB's Surface Water Ambient Monitoring Program and are adapted from Cao et al. 2009 (**Figure 2**). Samples were analyzed using an Aquafluor™ Handheld Fluorometer manufactured by Turner Designs according to instructions outlined in the Turner Designs instruction manual.

Calibration Solution Preparation and Calibration Procedures:

1. Prepared a diluted stock solution by mixing 0.5 ml Tide 2X Front Loader laundry detergent with one liter of distilled water.
2. Prepared calibration solution by mixing 2.5 ml the diluted stock solution with 22.5 ml distilled water.
3. Used 3 ml of calibration solution to calibrate the fluorometer to 100 Relative Fluorescence Units (RFUs) as specified in the Aquafuor™ Handheld Fluorometer user manual.
4. On each testing day, the calibration solution was used to test fluorometer calibration. If fluorometer results were off by more than +/- 10% of 100 RFUs, the fluorometer was re-calibrated.

Analytical Procedures:

1. Three replicates of each sample were created by placing 3 ml of the sample into three labeled cuvettes.
2. Initial fluorescence of each replicate was measured and recorded using the fluorometer. If the initial fluorescence was less than 10 RFUs, then the sample was considered negative.
3. If the initial fluorescence was greater or equal to 10 RFUs, the replicate was exposed directly to UV light for five minutes using a 6W, 365nm UV lamp.
4. After five minutes of UV light exposure, fluorescence was again measured.
5. If the percent decrease in florescence after five minutes of UV exposure was less than 8%, the sample was considered negative. If the percent decrease was greater than 30%, the sample was considered positive. If the percent decrease was between 8% and 30%, then the cuvettes were exposed to five additional minutes of UV light (10 minutes total).
6. After an additional five minutes of UV light exposure, fluorescence was again measured.
7. The ratio of percent reduction in fluorescence after 10 minutes UV exposure over the percent reduction after 5 minutes of exposure was calculated

8. If the calculated ration was greater than 1.5, the replicate was considered positive. If the ratio was less than 1.5, the replicate was considered negative.

   [(X-Y)/X] / [(Y-Z)/Y] >= 1.5 than positive, otherwise negative.
   X=initial reading
   Y= reading after five minutes of UV exposure
   Z= reading after ten minutes of UV exposure

9. If all three replicates had positive results, then the sample was declared positive. If only one or two of the replicates had positive results, then the sample was declared undetermined. If all replicates had negative results, then the sample was declared negative.

Note regarding analytical procedural error: The analytical procedure described above was not strictly followed for a small number of samples. On 16 out of 438 samples analyzed, project personnel erroneously failed to proceed with additional UV treatment when the UV decrease fell within 8 and 30 percent. Replicates on which this occurred are flagged in the database included in Appendix A. When this error occurred, we assumed that the replicate was "Negative" resulting in a final sample result of either "Negative" or "Undetermined." This eliminated the chance for false-positive results to occur due to procedural error.

Results

During the project, 438 replicates from 146 stream samples were analyzed for optical brighteners. Sample results are included in **Appendix B**. A summary of the results is presented below in three sections: Stream Team sampling results; time-lapse sampling results; and stream survey sampling results.

Stream Team Sampling Optical Brightener Results – Results from samples collected during monthly Stream Team events are illustrated in **Figure 3**. Not every sampling location was sampled during each event. Some locations were often dry and many creeks were only sampled during the November sampling event, after seasonal rainfall produced stream flow.

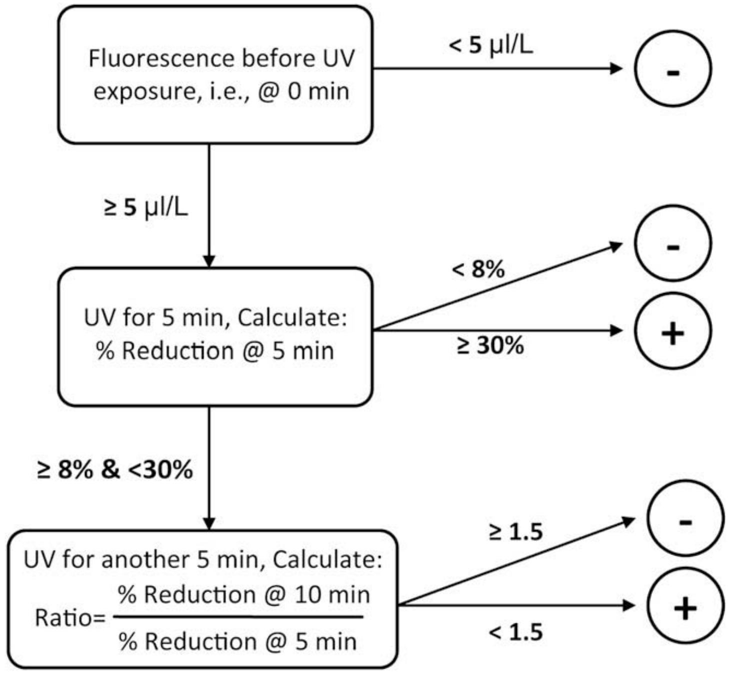

Figure 2: Analytical Procedure Decision Tree. Figure excerpted from Cao (2008)

San Jose Creek at Patterson (SJ1), Phelps Ditch at Evergreen Open Space (DV25), and Atascadero Creek at Patterson (AT2) tested positive for optical brighteners during the October sampling event. SJ1 also tested positive in September. Phelps Ditch at Phelps Road and Evergreen Open Space (DV22, DV25) resulted in "undetermined" results during the August sampling event. Tecolote Creek at Vereda del Padre (TC2), San Pedro at La Goleta (SP3) and San Jose Creek at Patterson (SJ2) also resulted in "undetermined" results during the November sampling event. Samples from all remaining sites tested negative for optical brighteners.

Stream Team sites are also tested for the presence of *Escherichia coli* (*E. coli*), a fecal indicator bacteria. Most samples collected throughout the duration of this project contained concentrations of *E. coli* that exceeded the *E. coli* limit (235 MPN) established by the US EPA for "full body contact" recreation in freshwater (EPA 2002). Generally, however, there was a poor correlation between the presence of optical brighteners and elevated indicator bacteria concentrations. Of the four Stream Team samples that tested positive for optical brightners, two contained *E. coli* concentrations below the EPA standard. The other two samples, unfortunately, did not have contemporaneous indicator bacteria results due to sampler error. Four out of six of the Stream Team samples that resulted in "undetermined" optical brightener results exceeded the EPA standard. Twenty-four of 39 samples that had negative optical brightener results exceeded the EPA standard.

Stream Team Sampling Optical Brightener Results

OB Result: Negative (blue) / Undetermined (yellow) / Positive (orange)

<------------ Number in cell indicates E. coli concentration in MPN for contemporaneous indicator bacteria sample

Site	Date	OB Result	
AT1	9/13/2009	Negative	776
AT1	10/4/2009	Negative	1109
AT1	11/10/2009	Negative	350
AT2	9/13/2009	Negative	10
AT2	10/4/2009	Negative	265
AT2	11/10/2009	Negative	554
AT3	9/13/2009	Negative	281
AT3	10/4/2009	Positive	63
AT3	11/10/2009	Negative	52
BL1	8/3/2009	Negative	7701
BL1	9/13/2009	Negative	3255
BL1	10/4/2009	Negative	107
BL2	11/10/2009	Negative	199
CG1	9/13/2009	Negative	1017
CG1	10/4/2009	Negative	2602
CG1	11/10/2009	Negative	529
DV21	8/3/2009	Negative	637
DV21	9/13/2009	Negative	657
DV21	11/10/2009	Negative	1989
DV22	8/3/2009	Undetermined	450
DV22	9/13/2009	Negative	246
DV22	10/4/2009	Negative	1106
DV22	11/10/2009	Undetermined	3441
DV24	8/3/2009	Negative	3840
DV24	9/13/2009	Negative	512
DV24	10/4/2009	Negative	1616
DV25	8/3/2009	Undetermined	1220
DV25	9/13/2009	Negative	<10
DV25	10/4/2009	Positive	<10
GA1	9/13/2009	Negative	350
GA1	10/4/2009	Negative	265
GA1	11/10/2009	Negative	1081
GA2	11/10/2009	Negative	472
GS1	9/13/2009	Negative	14
GS1	10/4/2009	Negative	122
GS1	11/10/2009	Negative	<10
LC2	11/10/2009	Negative	6
MY1	11/10/2009	Negative	NS
MY02	9/13/2009	Negative	6
MY02	10/4/2009	Negative	2
SJ1	9/13/2009	Positive	NS
SJ1	10/4/2009	Positive	NS
SJ2	11/10/2009	Undetermined	160
SP1	11/10/2009	Negative	41
SP3	11/10/2009	Undetermined	538
TC1	8/3/2009	Negative	9930
TC1	9/13/2009	Negative	85
TC1	10/4/2009	Negative	148
TC2	11/10/2009	Undetermined	98

Figure 3: Stream Team Monitoring Sites Optical Brightener Results

Time-Lapse Sampling Optical Brightener Results – Ten Goleta creeks were sampled each hour for four hours in the morning and four hours in the afternoon. Results varied over time at each creek and are illustrated in **Figure 4**.

Samples from two creeks tested positive for optical brighteners:

- Atascadero Creek at Patterson (AT2) was sampled on August 16th. Samples collected at 8:17 AM and 9:17 AM resulted in positive detections. All other samples from Atascadero Creek on this day were "undetermined."
- San Pedro Creek at Cathedral Oaks (SP3) was sampled on November 15th. Samples collected at 9:00 AM, 10:00 AM, 11:00 AM, 4:00 PM, 5:00 PM, and 6:00 PM resulted in positive detections. Two additional samples, collected at 11:00 AM and 3:00 PM, were "undetermined."

Time-lapse samples at four of the monitoring sites all tested negative for optical brighteners: Phelps Ditch at Phelps Road (DV22), San Jose Creek at Hollister Avenue (SJ1), San Pedro Creek near Hollister Avenue (SP1), and Tecolote Lagoon (TC1). The remaining four monitoring sites had a mixture of negative and “undetermined” results: Cieneguitas Creek at Nogal (CG1), Phelps Ditch at Evergreen Open Space (DV25), Glen Annie Creek at Hollister Avenue (GA1), and San Jose Creek at Patterson (SJ2).

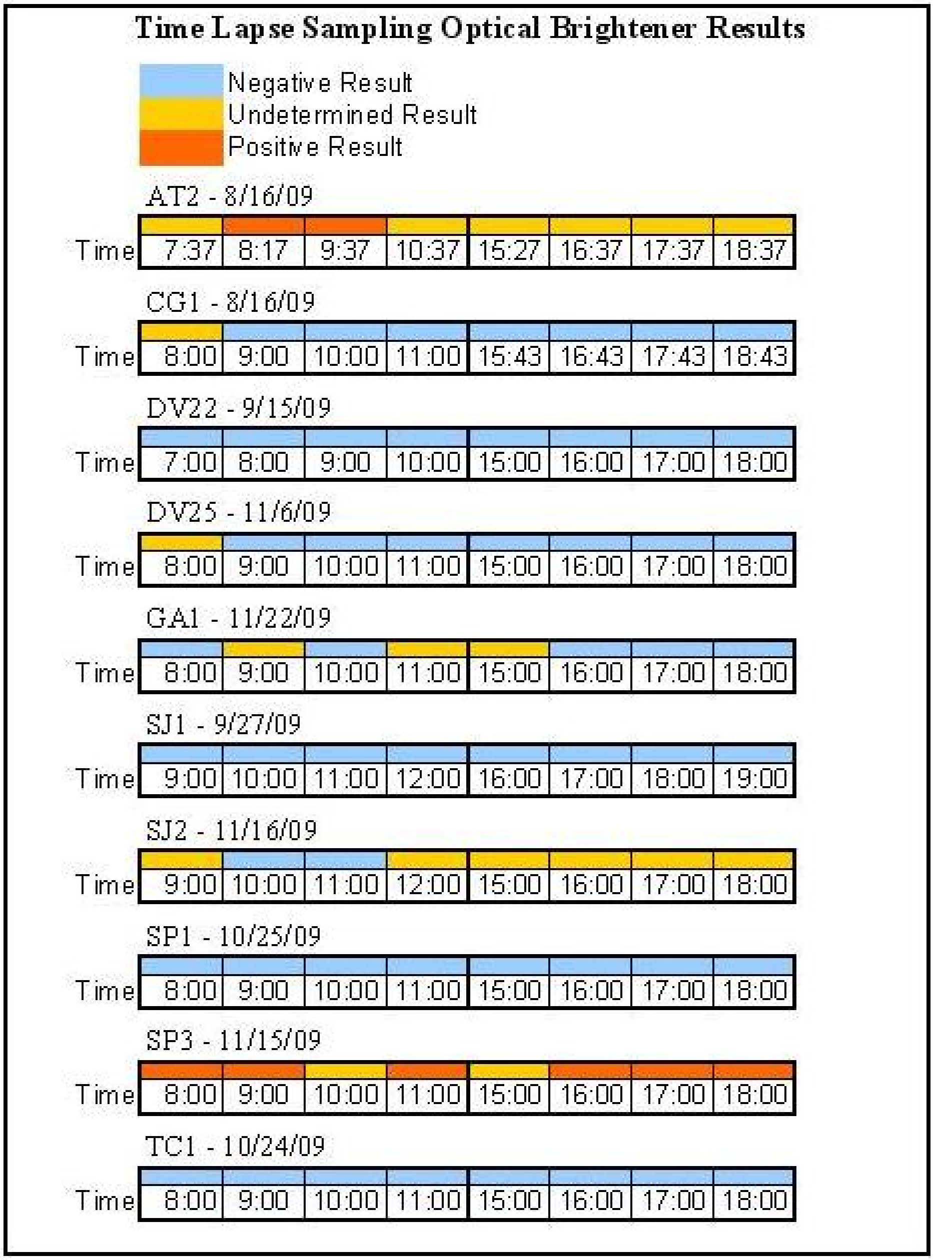

Figure 4: Time-lapse sampling optical brightener results

Stream Survey Sampling Optical Brightener Results – Three creeks were chosen for additional surveying and sampling based on the Stream Team and time-lapse sample results.

- San Jose Creek upstream of site SJ1 was surveyed on November 14th. One flowing concrete pipe located approximately 100 meters upstream was identified and sampled (SJ1-A). The creek was dry upstream of the SJ1-A culvert. The culvert sample tested negative for optical brighteners.
- Atascadero Creek was also surveyed on November 14th. Three flowing outfalls were identified and sampled (AT2-A, AT3-A, and AT3-B). One sample (AT3-A), collected from a concrete pipe located approximately 100 meters upstream of AT3, tested "undetermined" for optical brighteners. Both other samples were negative.
- San Pedro Creek upstream of site SP3 was surveyed on November 21st. Although no flowing outfalls were identified, five samples were collected from the stream at approximate intervals of 200 meters (SP3-A through SP3- E). An additional sample was collected at SP3 itself. SP3 and SP3-E tested positive for optical brighteners. All other samples were negative or "undetermined."

Discussion

Result Distribution - This study was successful in fulfilling its first objective, which was to monitor local Goleta streams for the presence of optical brighteners. Based on the analytical procedure recommended by the State Water Resources Control Board, optical brighteners were detected in multiple locations throughout the study area, including Atascadero Creek, Phelps Ditch, San Jose Creek, and San Pedro Creeks. These results strongly indicate that wastewater is entering these streams from either surface water discharges or groundwater seepage. Glen Annie Creek and Cieneguitas Creek samples generated "undetermined" results. Additional monitoring of these creeks may result in detection of optical brighteners.

Result Variability - Detections of optical brighteners varied significantly at each location over time. Only Atascadero and San Jose Creeks tested positive for optical brighteners on more than one sampling date, although San Pedro Creek did test positive on one date and "undetermined" on another. Both Atascadero Creek and San Pedro Creek tested positive repeatedly throughout day-long time-lapse sampling. Variability in sample results could depend on multiple factors, including the episodic nature of wastewater discharges. Rising and falling groundwater levels due to precipitation patterns could also influence the transport of optical brighteners from septic fields to surface waters. Boving et al. (2004) found that dissolved organic substances transported to surface waters following rain storms can also interfere with fluorometric detection and mask the presence of optical brighteners, although the UV exposure method used in this project should have minimized this type of interference. There is also an unquantified margin of error inherent in the analytical method used, as evidenced by the frequent occurrence of "undetermined" results when replicate samples tested both positive and negative. It is interesting to note that no site sampled during the time-lapse phase of sampling produced both positive and negative results throughout the course of a single day.

Point Source Identification - Identification of point sources was difficult to achieve during this study. Since discharges from point sources to streams are intermittent and irregular, it was difficult for project field personnel to locate and sample such discharges in the given time frame. Access issues also made it difficult for project personnel to conduct thorough surveys of streams. Effluent from one concrete storm drain on Atascadero Creek did test “undetermined” for optical brighteners. Additional investigations of this drain are warranted since Atascadero Creek itself did test positive for optical brighteners.

San Pedro Creek - Perhaps the most definitive data indicating a potential wastewater contamination problem were collected from San Pedro Creek above Cathedral Oaks Road. San Pedro Creek samples tested positive for optical brighteners in multiple samples collected on two separate days. Based on Stream Team data, this site also exceeded EPA *E. coli* standards on five out of six sampling events since January 2009. No point source discharges were identified during surveys of San Pedro Creek. However, based on information provided by the Santa Barbara County Public Health Department, the parcels located adjacent to San Pedro Creek upstream of Cathedral Oaks Road are all utilizing septic systems. Upper San Pedro Creek is relatively rural, but aerial imagery indicates that a small number of homes and structures are located in close proximity to the creek. Given these results, additional investigations to detect the presence of faulty septic systems along upper San Pedro Creek are warranted.

Contemporaneous Indicator Bacteria Measurements - There appeared to be no correlation between the presence of optical brighteners and levels of indicator bacteria. However, due to transportation and holding time considerations, only samples collected by the Stream Team were tested for both optical brighteners and indicator bacteria. Future iterations of this type of monitoring program could be greatly improved upon by finding ways to increase the number of contemporaneous indicator bacteria samples collected. Sargent and Castonguay (1998) suggest that the presence of optical brighteners in a sample lacking evidence of bacterial loading could indicate “marginal” septic systems that partially treat wastewater by separating and improperly disposing of greywater. There are also additional sources of optical brighteners that may contaminate streams. Many car wash detergent manufacturers advertise the inclusion of “optical brightening agents” to enhance cleaning ability. Surface water runoff from residential car washing is highly likely to occur throughout the study area, and could be responsible for the detections of optical brighteners where indicator bacteria levels are minimal. While improper greywater disposal doesn’t carry the same risks of fecal contamination, greywater may contain other pollutants including detergents and phosphates that could be harmful to stream ecology. It is also possible for sewage contamination to exist in wastewater that does not contain optical brighteners. In 2008 and 2009, Channelkeeper identified two examples of such discharges that were both incidences of improperly plumbed toilets that flushed human waste directly to nearby creeks or storm drains.

Quality Control Procedures - Fluorometer calibration procedures were followed and documented throughout the duration of this project. Blank samples consisting of distilled water were also analyzed to provide additional quality control. Because all streams and monitoring sites within the study area are located downstream of human land uses, there are no ‘natural stream’ control samples to help verify the accuracy of the analytical procedures used. However, the procedure used was found to produce zero false positive results among control samples in the study conducted by Cao et al. (2009).

Recommendations

Conduct additional optical brightener monitoring - Due to the presence of optical brighteners detected in stream samples and to the relatively high number of "undetermined" sampling results, it is recommended that additional monitoring be conducted. A more regular and robust monitoring program could shed additional light on potential sources or problem areas and produce a greater statistical certainty that optical brighteners do or do not exist in given stream reaches. Additional sampling may also help interpret daily, monthly and seasonal variations in sampling results.

Investigate San Pedro Creek septic systems – Based on the study's multiple detections of optical brightener and findings of indicator bacteria standard exceedences , local agencies should coordinate with landowners along San Pedro Creek to investigate the possibility of contamination from faulty septic systems.

Conduct additional monitoring to identify sewage discharges to storm drain systems – Results from this project, including optical brightener detections and significant exceedences of State and EPA standards for indicator bacteria, warrant additional investigations to identify potential sewage discharges. Local agencies should consider investing in additional techniques to identify sewage pollution sources such as DNA-based "finger printing" or source tracking methods, continuous automated flow monitoring, and visual inspections or storm drains.

Incorporate consistent contemporaneous analysis of indicator bacteria – Despite its relatively short duration, this study could have been significantly improved if time-lapse and survey samples were analyzed for indicator bacteria. Future iterations of similar monitoring projects should incorporate consistent contemporaneous analysis of indicator bacteria.

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