Evaluating and optimizing a method for using cotton-pads to monitor for fluorescent compounds in urban water systems

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ABSTRACT

Sewage misconnections and storm drain outflows can dump pollutant-runoff, which may include detergents, into watersheds. With drought concerns in California, properly managing water chemistry is necessary. Community members need to become the scientists and stewards of their local streams. However, some communities may not be able to afford current chemical kit testing methods. Using a low-cost cotton-pad, I enhanced a procedure to assess detergent levels in streams. The findings suggest a useful method to create a viable calibration, an optimal submersion in-field time of two days, an optimal in-lab submersion time of 1 hour, the ideal light being a handheld ultraviolet light that fluoresces in the 375-395nm range and zip-tying to protrusions was best for fixing. With additional implementation and a comparison to modern testing methods, my findings suggest that an inexpensive, easily-accessible detergent test kit can effectively be calibrated. Such a test can be used preliminarily to detect existing point-source detergent sources. If the low-cost cotton-pad testing kit provides positive results for the potential presence of detergents, then common methods should be considered. Environmental groups can add the testing recommendations to their catalogue, making them more effective in their duty to resolve water quality concerns within communities.

KEYWORDS

watersheds, creeks, water quality, detergents, optical brighteners, pollution.

INTRODUCTION

Watersheds play a vital role in sustaining ecological systems. Environmental scientists use watershed analysis to determine the current water quality of an ecosystem (Tanaka 1999). To evaluate the relative status of a watershed, one can measure the quality of water within its streams**.** Currently, our watersheds are at risk due to urban degradation, which can harm water chemistry, hydrology, biotic life, and ecosystem processes (Walsh et al. 2005). If the water quality is poor based on any of these factors, it may negatively affect the ecosystem, including the health of the public.

Chemical runoff persists in urban streams. However, common detection methods are typically inaccessible and expensive to citizens who want to monitor water quality in their communities (Hyder et al. 2015). Additionally, determining which chemical tests are necessary, can be unclear. For example, to detect copper levels in streams requires the use of multiple water test kit refills as one kit is not sufficient to test an entire stream. A fluorometer, which measures instantaneous detergent fluorescence levels, costs anywhere from $500 to $2000. Stormwater kits, which are used to monitor storm sewer outflows and industrial discharge, typically test for detergents, chlorine, copper, phenols, pH, and dissolved oxygen. For example, a La Motte Stormwater Test Kit uses detergent tests to provide distinct results (in ppm) but the kit costs $495 and refills are around $50 each. The required reagents in such kits are often used up quickly as a large volume of reagent is required per each water sample test. Furthermore, ordering a refill from their perspective chemical test kit companies can be a slow process. Similarly, sending in a water sample to a lab for testing is another option and heavy metals testing can cost around $120. However, when multiple sample-tests are necessary, as is with stream monitoring, these options because less efficient. With local communities as stewards of urban streams, an easily accessible method to test for the presence of chemicals or poor water quality is necessary.

Monitoring for optical brighteners (OBs) as indicators of sewage misconnection discharge, a form of improperly connected sewage piping, is a cost-effective way to determine water quality (Chandler and Lerner 2015). Optical brighteners, which fluoresce under ultraviolet light, are used in detergents to whiten fabrics and paper and they may be found in urban streams. Although their current concentrations do not pose a direct threat to biota, their presence may suggest that fecal coliform bacteria are in the water system – a known harm to the health of the public (Tavares et al. 2008) (Hartel et al. 2007). These plumbing mistakes are usually caused by inappropriate piping of toilets, sinks, showers and household appliances, including washing machines. If these appliances have incorrectly been connected into the surfacewater sewer they may discharge detergents directly into urban rivers and streams (Burres 2011).

The involvement of community members in water quality management accelerates the path towards remediation. As we rely more on the information acquired from citizen science, a detailed protocol with data-collection and monitoring suggestions becomes necessary (Hyder et al. 2015). Traditional detergent tests such as those included in the aforementioned stormwater montoring kits are precise in detecting detergent levels, but the cost of test kits are prohibitive for widely screening urban streams. Sargent and Castonguay (1998) described in detail the method of using cotton-pads to test for detergents from sewage misconnections in streams. Chandler and Lerner (2015) used cotton-pads to detect point source pollution in Scheffield, England; this method holds wide promise. An affordable test uses an unused cotton-sanitary pad, such as commercially available tampons, and an ultraviolet light. A cotton-pad is placed into a stream for a period of time, removed, dried, and observed underneath an ultraviolet light. By measuring fluorescence levels of this improvised test device, communities may be better able to understand the contamination level of a community's urban stream. A goal is to acquire this knowledge by using a rather simple and economical test, like the one implemented by Chandler and Lerner (2015) and others. However, variability in the research currently exists as all consumer detergent concentrations differ, access to measuring equipment that disperses microliter amounts of detergents can become complicated, and tools used to measure the amount of stream water necessary for in-lab concentration testing - as recommended in previous research – is convoluted. These obstacles currently make it difficult for a community group to implement them. Monitoring optical brighteners also serves as a surrogate to detect fecal contamination from homes and incorrect plumbing. However, a universal low-cost solution for detecting fecal coliform contamination has not yet been optimized or calibrated for use by community groups for monitoring their water systems. With the well-being of communities in mind, this research attempts to refine tools and empower community members and local environmental groups to confidently test for these substances (Savan et al. 2003).

In this study I adapt Chandler and Lerner's (2015) low-cost monitoring method for optical brighteners and optimize the method for use by community monitoring groups. Although a low-cost test would not be able to detect detergents as precisely as commercially-available tests, it may be fine-tuned to become useful as a preliminary test. In adapting their method, I determine how a low-cost method to test for optical brighteners compares to chemical test kits to quantify surfactants. I describe a set of step-by-step approach that can be used to detect optical brighteners in urban streams. I determine the ideal set of standard concentrations that can be used for reference, I find the best way to fix the cotton-pad in a stream, I find the sampling procedures for the comparison of fluorescence levels of difference household detergents and I define the water exposure time. I field tested this approach in two urban streams in the East Bay region of San Francisco in Berkeley, California.

METHODS

Research Approach and Justification

The method that has been used has been derived from Chandler and Lerner (2015); the cotton-pad tampons are used as a passive, water-chemistry sampler testing method that requires diffusion onto a cotton absorbent. However, the type of cotton-pad, detergent brands and detailed methods for creating a dilution is not provided by Chandler and Lerner (2015). In the laboratory, I tested household detergents on cotton-pads and observed them under ultraviolet light. I also created a calibration standard.

Lab Calibration of Detergent Standards

To create a necessary standard calibration, I made a series of dilutions of a non-concentrated, non-high efficiency household laundry detergent, Liquid Tide Original Scent (Procter and Gamble), and I measured the fluorescence and compared it to a detergent reagent task in a stormwater kit.

For my standards, I used ratios that were selected based around the typical laundry detergent greywater output given by Chandler and Lerner (2015) and preliminary in-lab pilot studies. I acquired plastic paint mixing 2L buckets from a local hardware store. The buckets were graduated;

however, any demarcated container could have been used. You can use a graduated container to determine a known amount of liquid and transfer it to the container of your choosing, you can then mark this new container with graduations for future use. I also used a 1ml dropper that had markings at 0.25 ml, 0.5ml, 0.75ml and 1ml. I thoroughly rinsed the container with water after each use. I created three different ratios, (1) 0.5ml in 1L creating a 5 X 10^-4 liter concentration in water, (2) 1ml in 1L creating a 1 X 10^-3 liter concentration, and (3) 2ml in 1L creating a 2 X 10^-3 liter concentration (Table 1). To divide these standards, I initially pipetted 2ml of Tide in 1L of water. Then I removed half of the total liquid and replaced it with water, creating a 1ml of Tide in 1L of water solution. I repeated this again to create the .5ml of Tide in 1L of water solution, resulting in a spectrum of standards levels.

Ratio Number	**Liter Concentration**	**Making Procedure**
1	5 X 10^-4 liter	0.5ml detergent in 1L water
2	1 X 10^-3 liter	1ml detergent in 1L water
3	2 X 10^-3 liter	2ml detergent in 1L water

Table 1. Three concentrations created for in-lab calibration and the solution mixture to create them.

I then soaked U by Kotex Security Plus (medium absorbency) Kimberly-Clark brand tampons in the 1L bucket for 30 minutes. I fixed the cotton-pads by taping them to the side of the bucket, allowing them to remain suspended a few inches underwater. However, I did not disturb the water. I used a LaMotte StormWatch Drain Monitoring Model SD Detection Kit (order code: 7446-01) ‘Detergents Test’ to measure the detergent levels in my detergent dilutions standards by chemically testing the water to determine the concentrations. The LaMotte test values were then compared to the cotton-pad ultraviolet fluorescence calibration.

To properly illuminate the cotton-pads I used a battery-powered UV handheld ultraviolet light that fluoresces in the 375nm-395nm range that I purchased at my local Ace Hardware Store (Figure 1). A similar light can be purchased from Amazon for about $10. I held the light directly overhead about 4 feet from the pads so that all the pads are equally under the light emitted from the handheld light. To compare the fluorescence, I would visually notice a difference and then take multiple photographs, choosing the best one that clearly captures this difference.

Figure 1. Samplers that were illuminated with a non-branded 375nm-395nm UV handheld light from a local hardware store to detect fluorescence a. Non-Fluorescing cotton-pad sampler (left, entire cotton-pad does not fluoresce) b. Fluorescing cotton pad sampler (right, entire cotton-pad does fluoresce).

Field Procedure

After creating the standards, I tested three different field setups to secure the cotton-pads in streams. The first method is to fix a cotton-pads to a rock, with a zip-tie attached to the string, and to let it sit in the running stream water. A second method is to zip-tie the cotton-pad to a drain and to let it sit in the running stream. The third method is to place a metal rod (e.g. rebar) in the stream and zip-tie a cotton-pad to it. I left the cotton-pads in for 1 hour, 1 day, 2 days and 3 days (as recommended by Chandler and Lerner 2015) to note any physical differences in the cotton-pad results due to exposure time (Figure 2). I used those exposures to determine if submersion time is an important factor for detecting for OBs.

Figure 2. A lightly soiled cotton-pad after two days, fixed underneath a rock.

Strawberry Creek and Codornices Creek Field Test

I tested for OBs in the field using the optimized cotton-pad assessment in two streams in the San Francisco Easy Bay Region in Berkeley, CA. Codornices Creek, is a 4.7 km daylighted natural, open channel that travels through an urban residential area. This daylighted section of the stream makes this creek easily accessible by the public and could lead to heightened surfactant levels. Strawberry Creek, is a 6.4 km stream that travels mostly inside a culvert but is surface level through the U.C. Berkeley campus and Strawberry Creek Park in the city of Berkeley. Persistent sewage has been found in Strawberry Creek (Charbonneau and Resh 1992). Leaking pipes and sewage misconnections have deemed this stream as a chronic problem for health (Hans and Maranzana 2006). Hans and Maranzana (2006) considered the greatest threats to the stream to be sudden discharge of polluted urban stormwater runoff.

I selected 5 sites from each stream that were equidistant downstream towards the Bay and submerged my cotton-pad in for a total of 10 sites. I fixed the cotton-pads (1) underneath rocks (with the string fastened to a zip-tie), (2) zip-tied to protrusions, such as roots or permanent structures, and (3) zip-tied to rebar fixtures at each site. I submerged cotton-pads for 1 day, 2 days and three days (returning daily and recording visual results). I then dried the pads only after the 3-day period and measured the levels of fluorescence under UV light compared to the three calibration standards (low, medium, high). I also compared the field samples to detergent concentrations using the results acquired by the LaMotte Stormwater detergent test. This test helped me determine how precise the standard test is to the actual detergent concentration in the streams. I also noted the physical state (soiled, cotton intact) of each cotton-pad after submersion. I collected 3 water samples from each creek totaling 6 samples to test with the 'Detergents' portion of the LaMotte StormWatch test.

RESULTS

Detergent Standards

I noticed a difference in the fluorescence levels of the three cotton pads after creating the Tide in-lab calibration (Figure 3). The difference between 2 ml in 1L from the other two was clear in terms of brightness: the 2ml in 1L, which contained a higher detergent level, fluoresced more. However, telling the difference between 0.5ml in 1L and 1ml in 1L could be tough, but the 1ml in 1L does fluoresce more than the half concentration under ultraviolet light. When compared to my LaMotte Test a higher concentration did mean more fluorescence as .5ml in 1L contained 0-0.1 ppm of detergents, the 1ml in 1L contained 0.2-0.3 ppm of detergents and the 2ml in 1L contained 0.6-0.7ppm per of detergents (Table 2). Based on the dilutions, this was within the expected range.

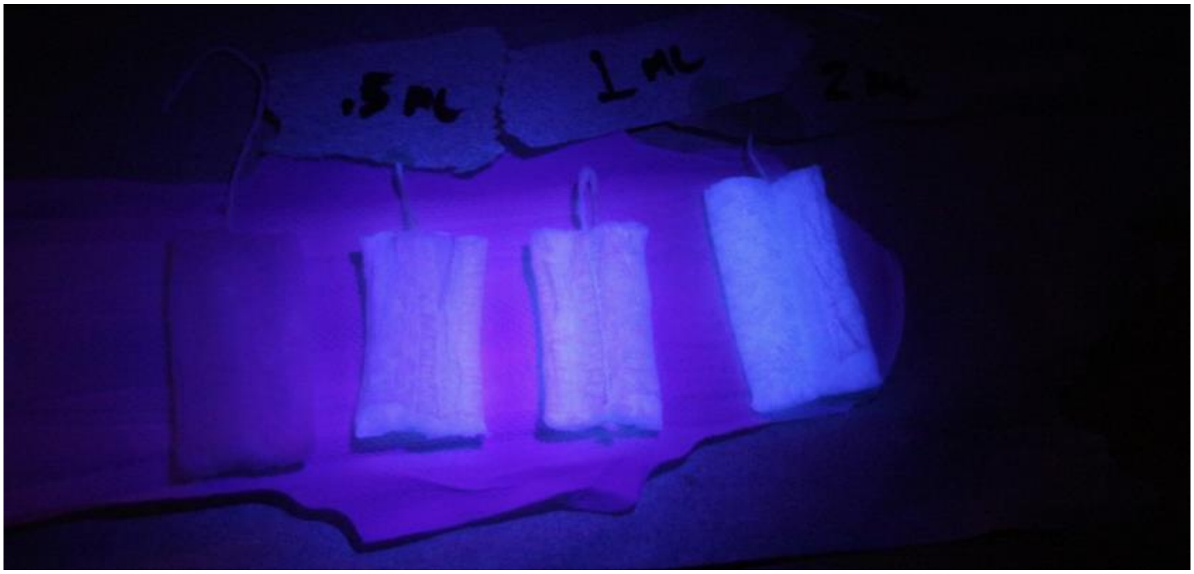

Figure 3. Tampons fluorescence levels for 3 dilutions. The calibration with a cotton tampon soaked in water without Tide, a cotton tampon soaked in .5ml Tide in 1 L (low fluorescence), a cotton tampon soaked in 1ml Tide in 1L (medium fluorescence), and a tampon soaked in 2 ml in L Tide in 1L (high fluorescence) (from left to right).

Detergent Dilution Concentration	**LaMotte Detergent Test (ppm)**	**Cotton-Pad Fluorescence Grade**
5 X 10^-4 liter	0 < X < 0.1	Low
1 X 10^-3 liter	0.2 < X < 0.3	Medium
2 X 10^-3 liter	0.6 < X < 0.7	High

Table 2. Calibration with LaMotte detergent levels in ppm against fluorescence grade levels of the cotton-pad test. Grades selected based on relative fluorescence (refer to Figure 3 for clarification).

Field Procedure

I initially used a total of 30 cotton-pads - three cotton-pads at each site. At first, I did not properly tighten the cotton-pad at the selected sites and a few were gone when I returned (Figure 4). I replaced the thirty initial cotton-pads and used zip-ties and the maximized fixing methods to solve this problem; none of the pads were lost after zip-tying the pads. This could be a result of the zip-tie adding additional weight and rigor to the string of the cotton-pad.

The optimized three fixing methods are as follows. If placed underneath a rock (with a zip-tie attached to the string), the cotton-pad was least soiled throughout a three-day period, but most rocks prevented continuous water flow through the cotton-pad. If the cotton-pad was zip-tied to protrusions, such as branches or metal piping, the pad will stay afloat and is medium soiled. If a rod is hammered into the soil at the center point of the stream and the cotton-pad is fixed to the rod, the cotton-pad will become too soiled to gather data from it. After analysis, fixing the cotton-pad to a protrusion half-way between the center and the side of the stream is best. According to the data collected, two days is more ideal that three; by the third day, the cotton-pad is too soiled to determine fluorescence (Figure 5). One day may also be effective, but may not maximize the sampling of total detergents in a stream. The results overall were consistent.

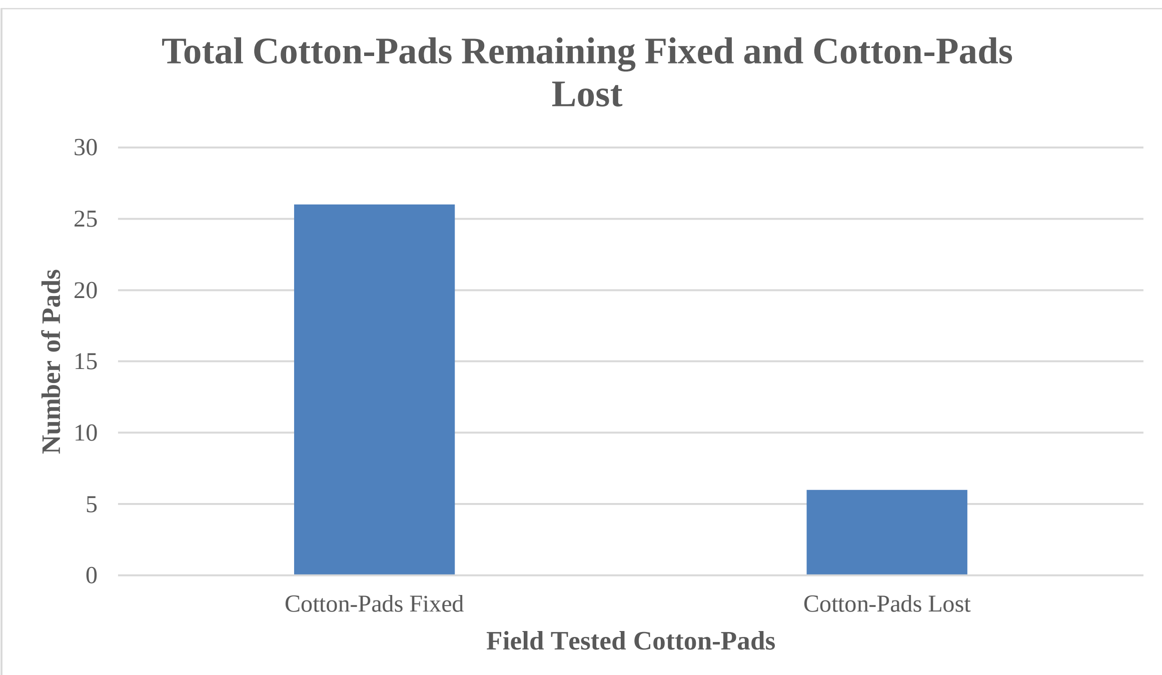

Figure 4. A total of 30 cotton-pads fixed in the field and 6 were lost. All 6 lost cotton-pads were replaced to complete the in-field research portion of the project.

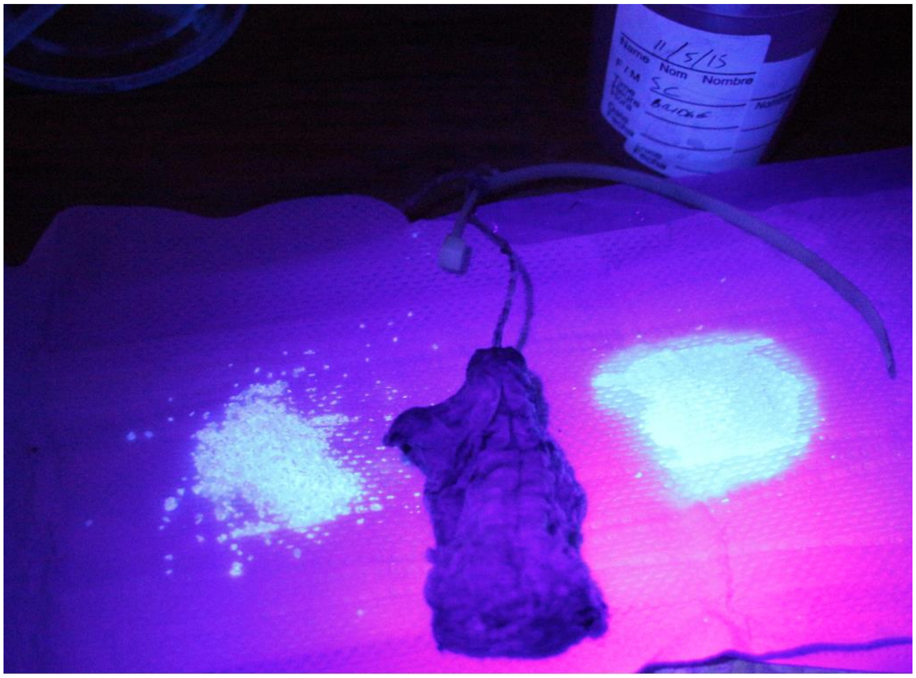

Figure 5. A soiled non-fluorescing cotton-pad after a three-day period. Fluorescing powdered Tide detergent (left) and fluorescing liquid Tide detergent (right) demonstrate the difference between fluorescing and non-fluorescing under ultraviolet light.

Field Test

The data collected from the 10 sites did not fluoresce after exposure. Figure 5 above demonstrates this difference between fluorescing and non-fluorescing. Soiling appeared to be any cotton-pad that was covered in debris, soil, and overall was discolored to a dark-brown shade. The LaMotte Test was conducted at a total of 6 sites. All detergent tests resulted in values below detectable levels (<0.1ppm).

DISCUSSION

Adapting Chandler and Lerner's research provided the framework for creating a more-cost effective and easier to use detergents test. From the research, instructions for creating a calibration, the optimum submersion time, and the ideal form of fixing were determined, however, the optical brightener levels were inconclusive in the field test research because in-stream detergent levels were too low. According to the results, this project may be best used as a preliminary kit for detecting intermittent discharge. Community members need to act as the stewards of their streams and the results of this research project provide assistive tools that can be used as effective universal guidelines.

A Low-Cost Detergent Test

An analysis of the methods provides us with valid, cost-effective applications anywhere in the world. For the in-lab exposure time, there was no difference in fluorescence between the amount of time the cotton-pads were submerged and I recommend a 1-hour exposure time to be sufficient. For the concentration dilution, Chandler and Lerner (2015) recommended a 25 microliter in 25 L concentration for the minimum concentration that can be viewed visually, however for the research to be useful to all communities, we must create more accessible dilutions. Their research article did not implement the creation of an in-lab gradient using a detergent. I used different concentrations because creating their recommended dilutions with simple equipment was not easy; one would need a pipette that disperses microliter amounts. The average dilution discharged from washing machines is 0.65ml in 1L, thus I selected the 0.5ml in 1L, the 1ml in 1L and the 2ml in 1L dilutions. The detergent gradients were produced by the dilutions of concentrations and thus, the more diluted detergents resulted in lowered detectable fluorescence.

However, differences between .5ml in 1L (a 5 X 10^-4 liter concentration) and 1ml in 1L (a 1 X 10^-3 liter concentration) were hard to detect visually. At first, I could not discern the difference with a quick glance, but with the placement of the 2ml in 1L soaked cotton-pad in between them and then looking at the photographs of the results, it became more apparent that the 1ml in 1L fluoresced more than .5ml in 1L. This may add a different cost component if quantitative fluorescence in lumens needs to be collected to discern a clear difference. In urban streams, these differences are usually small as well, again creating the potential need for necessary equipment after the preliminary visual analysis. A tool that helps differentiate between fluorescence levels under UV light, such as a fluorometer, may be necessary to confirm results (Burres 2011).

Brand name household detergents do not contain the same concentrations of detergents that fluoresce under ultraviolet light per ml; their effects on water quality differ based on their respective chemical makeups and biodegradability (Smulders et al. 2007). Currently, brands like Seventh Generation and Method are creating detergents that are organic and biodegradable. Household brands are also coming on board with their version of environmentally friendly detergents, for example Tide has created "Tide purclean," which is their first bio-based detergent. Some modern detergents are also now being described as "ultra-concentrated" and advertised as "High Efficiency." Amongst them ultraviolet fluorescence varies as they contain different OB concentrations. However, they do not all clearly state this on the packaging for the consumer to know. For example, Seventh Generation's website states that they indeed do not use 'artificial brighteners' but it is not clear if Method does or does not use them. These environmental-friendly detergents may decompose differently when they enter stream water and may vary the detected cotton-pad fluorescence levels (Amrita et al. 2010). Streams may contain less harmful detergents overall in the future because of this shift, but the cotton-pad detection test may be limited to only sensing certain detergents that fluoresce under ultraviolet light. As detergents are changing, the environmental impact will change and can render modern detection less effective. Today, typical detergents contain a chemical known as nonylphenol ethoxylate which is not entirely biodegradable. As this chemical begins to break down in water, the molecule can alter to become an endocrine disruptor (Naylor et al. 1992). Because we cannot detect such molecules using the OB method, we cannot use them as a surrogate to test for the presence of fecal coliform. These biologically harmful molecules are one reason for the shift being made towards safer detergents but such development will require changes in our testing methods.

Field study

Fixing the cotton-pad appropriately for an ideal amount of time provides more effectual results. For the in-field fixing time, there is little distinction between the length of time to leave the cotton-pad in Strawberry Creek and Codornices Creek. However, by the third day the cotton-pads were too soiled and I recommend a two-day fixing time in streams. For Chandler and Lerner (2015), they found three days to be ideal but they did not elaborate on their reason for choosing that time period. The lack of detectable fluorescence from the 10 sites provides insight into the status of both streams. Strawberry Creek was cleaned up in 1992 (Charbonneau and Resh 1992) and detergents may be below detectable levels (and sewage misconnections were already corrected). The campus may not be an ideal site for testing because it is not residential and there is little to no grey water dumping. Codornices may not be directly impacted by residential neighborhoods, contrary to what was initially expected, and thus may not be receiving a detectable detergent load and consequently sewage systems are likely functioning properly. Furthermore, foreign particles like dirt and sand may have coated the cotton-pads and block any potential fluorescence. Cutting the cotton-pad in half to observe results may have helped, however at the time of testing this was not considered. Another solution may be to collect water from the streams, submerge cotton-pads in a bucket in-lab while using a tool that constantly disturbs the water, like an agitator pump, and observe if you acquire fluorescing results without soiling. In Spain, many surfactants were successfully detected in environmental water samples with the use of an entirely different method involving solid-phase extraction (SPE) combined with liquid chromatography electrospray mass spectrometry (LC–(ESI)MS) (Gomez et al. 2011). In California, the same tests can be replicated if the water soils the cotton-pads too much however the equipment will be extremely costly and limited. Once these chemicals are detected, removing such surfactants from waste streams is arduous if not impossible (Gomez et al. 2011).

The time of the year that the data was collected may have had an impact on the fluorescence results. My research was conducted in the rainy seasons of January to March. There could be a difference in water-use and runoff during a different season due to climatic variation. The Northern Californian Mediterranean climate, which is characterized by warm, wet winters and hot, dry summers, may provide results that solely will be found in this biome (Gasith and Resh 1999). In Germany in 1959, for example, warm, dry summers caused water flow to restrict and the chemical surfactants that make up detergents such as nonyphenol ethoxylates did not biodegrade and were abundant in streams (Smulders et al. 2007). So although the field-test results did not fluoresce in the months of research, I may have better detected OBs via fluorescing cotton-pads in the summertime. The summer months may differ from the months earlier in the year due to an increase in water-saving activities that may lead to more detergents in streams. We would expect water quality to be lowest during the summer months in California due to water flow restriction. During these months, aquatic life, the animals most harmed by surfactants, will see a decrease in their numbers and an increase in malformations as certain chemicals in detergents act as endocrine disruptors (EPA 2007).

As laundry-to-lawn movements gain momentum we may see that the summertime (when people have the freest time and may take the time to conserve more water) will lead to higher detergent levels in soils and can runoff potentially to water systems (Misra et al. 2010). However, if soils are overloaded with surfactants it can be detrimental for soil chemistry conditions and plant growth may decrease (Christova-Boal et al. 1996). Additionally, laundry-to-lawn grey water may contain fecal coliform bacteria and the cotton-pad test will serve as a surrogate to potentially suggest their presence if the grey water chemicals runoff into streams. Stream flows alter throughout the seasons in the Mediterranean climate, this could impact the detergent levels in the streams as both stream flow and surface runoff are related (Gasith and Resh 1999). The time recommended for fixing may change seasonally as well.

Community Groups: **Citizen Science and Water Quality Monitoring**

Citizen science is the collection and analysis of data relating to the natural world by members of the public. Communities rely on citizen science to act as environmental stewards that evaluate and improve a community's ecology (Bonney et al. 2009). The research conducted in-lab was successful in creating a fluorescent cotton-pad calibration that can be replicated by citizens anywhere. I was able to see the difference between a fluorescing cotton-pad versus one that was not; this simple visual analysis makes this easy and appropriate for community groups. Once I acquired all of the necessary materials and my methods were simplified, the project was easy to conduct. A community member should feel empowered with the ability to conduct a citizen science using simple tools (Savan et al. 2003). You would only need to know where you can acquire the common materials, to find the location to fix the cotton-pad and how to fix the cotton-pad. Finding a graduated bucket and cotton-tampons should not be an issue. However, purchasing a handheld ultraviolet may be hard for some communities. If handheld ultraviolet lights are available, as they sometimes are used for checking ID cards, they may also be used for this research project. Amazon also sells the handheld lights for roughly $10. Once one acquires the materials, the dilutions are straightforward; I did not encounter difficulty creating the determined dilutions. Additionally, adhering to the "Recommendations" in the following section will provide guidelines for universal use. Community groups need to pool their results on water testing methods and cost-effectiveness to create a more effective low-cost test kit (Hyder et al. 2015).

Recommendations

In Chandler and Lerner (2015) they mentioned that 0.65ml in 25 L is the typical laundry detergent amount that is released. To recreate this in the lab, a dilution of 0.5ml detergent, 1ml detergent and 2ml detergent in 1L is ideal for future replication. Emptying half of the 2ml in 1L solution and filling it with water will let you create the 1ml in 1L solution. A replication of this dilution will create the .5ml in 1L solution. From this research, it is clear that this revised OB detection method will function best as a preliminary test for detection due to the limitation of acquiring precise quantifiable results. I would recommend creating a one, two and three-day gradient for the stream that you are testing to see if there are detectable levels of detergents. If this test is positive for potential detergent presence, then the source of the pollution may be detergents and/or fecal matter. However, additional tests are necessary to determine the specifics of the pollutant. After we provide the groups with our recommendations we can then analyze their use to conduct more effective research. A table of consolidated recommendations for use by community groups is as follows (Table 3):

Concentrations for calibration	0.5ml in 1L, 1ml in 1L, and 2ml in 1L
Time (in-field)	2 days
Time (in-lab)	1 hour
Light	Handheld ultraviolet (375-395nm wavelength range)
Fixing Methods	Protrusions (zip-tied to)

Table 3. A table of concise recommendations for replication of the testing method.

In California, reducing our water use is important. Methods to reuse water can be beneficial but there are potential harms to water systems. Greywater is known to contain detergent surfactants, solids, salts, nutrients, organic matter, and pathogens all of which arise from the washing of clothes using detergents (Christova-Boal et al. 1996). The cotton-pad test can also be used to test grey water sources before dumping them onto lawns. We could pipe our laundry water into an outdoor bath-like structure, then submerge the cotton-pad in the grey laundry water for an hour. Afterwards, we can dry the cotton-pads and view them under ultraviolet light. Based on the fluorescence grade we can better quantify the amount of detergents that are being dumped onto lawns as a result of the current solutions intended to mitigate the impending drought in California.

Limitations and Future Directions

Further research should occur at various creeks with diverse climates in urban and residential neighborhoods over a longer time period. With the rise of "environmentally-friendly" detergents more research should implement tests measuring their fluorescence levels as some biodegradable or high-efficiency detergents may fluoresce less, more or not at all. Additional research worldwide will help further calibrate this low-cost method as developing countries may find even more cost efficient ways to conduct this test.

Conclusion

Cotton-pad tampons can be used as a screening method especially as a method to detect point-source pollution. Research conducted in two streams in the East Bay of San Francisco, California provided inconclusive data as no detergent fluorescence was detected. If detergents were present, the creation of standards would help make the differences in ultraviolet fluorescence detectable. Testing with different detergents, including those that state they are more sustainable, is necessary to create further calibrations and to optimize this low-cost testing method.

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