Kimberg Rainwater Harvesting Monitoring Project
Water Year 2012-2013 Final Report
March 27, 2014

Overview

Nationwide, there is a substantial data gap for residential rainwater harvesting systems; municipalities do not normally regulate private installations of these systems, and homeowners do not have access to costly monitoring equipment or qualified technicians to conduct sampling and analysis. The partnership between the Kimberg family, the SFPUC, and SFDPH has provided a means to scientifically inform advances in non-potable water policy. When completed, this effort can help to inform policy makers about the potential for harvested rainwater to replace potable water for other household uses, such as dishwashers. Initiatives such as the Kimberg Rainwater Harvesting Monitoring Project inform the evolution of rainwater harvesting technologies for our unique climatic characteristics so that San Franciscans can design the most efficient, safe and cost-effective rainwater harvesting systems to meet further needs.

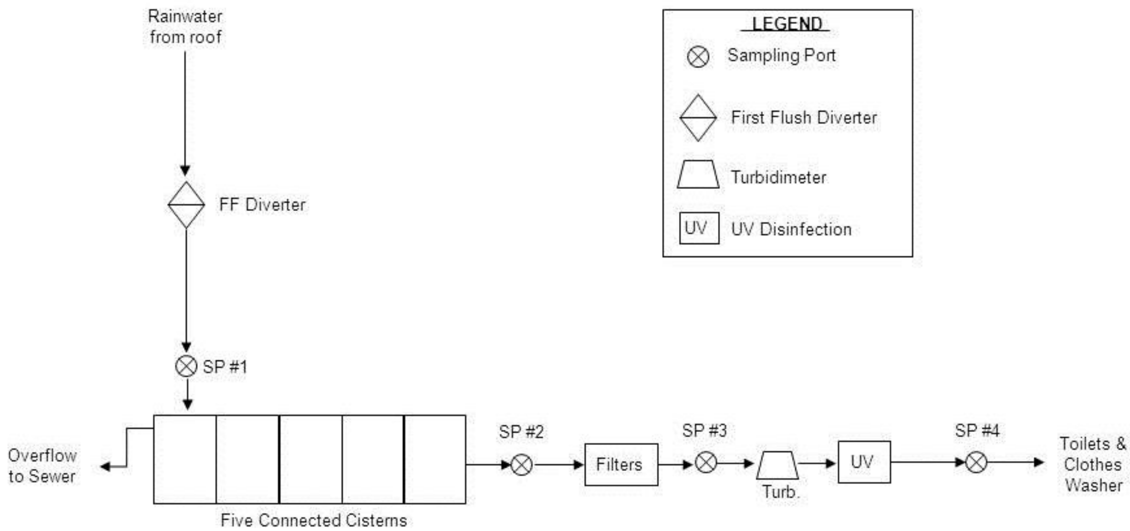
The Kimberg Rainwater Harvesting System was installed in 2009 by the homeowner in the Noe Valley neighborhood of San Francisco. The system collects rainfall from a 1,100 square foot (sf) rooftop, treats the water via settling, filtration and Ultraviolet (UV) irradiation, then distributes treated water to interior plumbing fixtures (toilets and laundry machine) and to an exterior hose bib. A series of five cisterns provides 2,500 gallons of storage (Figure 1). In 2012, the San Francisco Public Utilities Commission (SFPUC) and the San Francisco Department of Public Health (SFDPH) partnered with the owner to implement water quality monitoring of the rainwater harvesting system with the goals of: (1) assessing the quality of water provided by this type of system in San Francisco (2) quantifying potable water savings and (3) quantifying the rainwater diversion from San Francisco's combined sewer system (CSS). The results of the first year of this monitoring program are described in this report.

Understanding the water quality results from this water sampling project requires a determination of appropriate threshold levels of contaminants to which results may be compared. Although the treated rainwater at the Kimberg Project was within the allowable limits for non-potable reuse of rainwater as laid out in the SFDPH Director's *Rules and Regulations Regarding the Operation of Alternate Water Source Systems,* the DPH Rules are not applicable to residential projects (SFDPH 2014). Nonetheless they are a useful tool for assessing the performance of this system. The rainwater harvesting system prevented approximately 11,800 gal of stormwater from entering San Francisco's CSS during the 2012-2013 water year.

Methods

E.Coli & Lead

Water grab samples were collected twice a month from four sampling ports (SPs) within the system during the wet season of 2012-13 (November 2012 – April 2013), as well as one sampling in May 2013. Grab samples were analyzed for E Coli. (MPN/100mL) and lead (µg/L). SP 1 is located below the first flush diverter, before the inlet into the cisterns. SP 2 is located below the outlet of the final cistern, after the water has moved through the 5 cisterns, but before the water is filtered. Particulates are allowed to settle from the rainwater within the cisterns between SP 1 and SP 2, preventing clogging of downstream pipes and improving water quality at a low cost (Bellingham 2012). SP 3 is located after two filters – A 50 micron filter followed by a 25 micron filter. SP 4 is located after the UV treatment system and allows for sampling of the treated rainwater right before it enters the house (Figure 1). E Coli. was sampled at SP 1, 2, 3, and 4; while lead was sampled at SP 1 and 4, totaling six samples per visit (except for May, when there was not enough water in the tanks for samples at SP2).



E Coli.	Lead
Sampled at: SP 1, 2, 3, and 4	Sampled at: SP 1 and 4

Figure 1. Kimberg rainwater harvesting system water sampling port diagram.

Turbidity

Turbidity (NTU) was continuously measured (15 minute intervals) with a turbidimeter from November 14, 2012 – August 13, 2013. The turbidimeter is located after filtration but before disinfection (Figure 1).

Water Use

Rainwater volume in gallons (gal) was measured with two water meters: one located before the filters (to measure use by the house) and another located in the overflow pipe (to measure overflow into the CSS). The volume of rainwater draining from the rooftop and into the system is equal to the sum of the two measured volumes. The overflow water meter was not functioning properly until January 7, 2013. Therefore, overflow estimates for the period prior to January 7, 2013, may be low. In addition, in December 2012 it was determined that the water meter measuring the volume of treated rainwater flow into the house was overestimating volume due to re-circulation of water for the turbidimeter (which requires constant flow to take accurate measurements). Because these measurements were unreliable, total water use for the 2012-13 water year was calculated using the rooftop capture area of 1,100 sf and a rainfall capture efficiency of 85%. Rainfall at the site was estimated to be the average of SFPUC Rain Gages #25 at Mission Education Center and #26 at Hilltop High School, located 0.7 miles south-west and 0.9 miles easy from the residence, respectively).

Results

The maximum and minimum concentrations of each measured parameter can be found in Table 1. Turbidity levels at SP4 (the final sampling port before the water enters the house for use) was consistently below 5 NTU; E Coli. at SP4 did not exceed 1 MPN/100mL. At SP4, lead levels in the treated rainwater ranged from 1.55 to 314.88 ug/L.

Table 1. Mean, maximum and minimum concentrations of measured water quality parameters.

	E Coli (MPN/100mL)				**Lead (µg/L)**		**Turbidimeter Reading (NTU)**
	SP 1	**SP 2**	**SP 3**	**SP 4**	**SP1**	**SP4**	
Max	16	4	1	<1	9.35	314.88	0.69
Min	<1	<1	<1	<1	0.91	1.55	0.08
Mean	2.82	0.70	0.30	<1	4.01	43.52	0.19

E Coli. and Lead

Most samples taken at SP 2 had substantially less E Coli. than seen at SP1. At SP1 44% of samples detected <1 MPN/100mL, which increased to 75% at SP2, with particulate settling within tanks as the only treatment method. After UV disinfection, 100% of samples taken at SP4 detected <1 MPN/100mL (Figure 2-c).

Lead concentrations in SP 4 samples were highest in the first sample that was taken (November 2012); this result was likely due to soldering that was performed as part of water meter and turbidimeter installation. Lead concentrations steadily decreased over time and were lower than the influent lead levels by May 2013 (Figure 2-d).

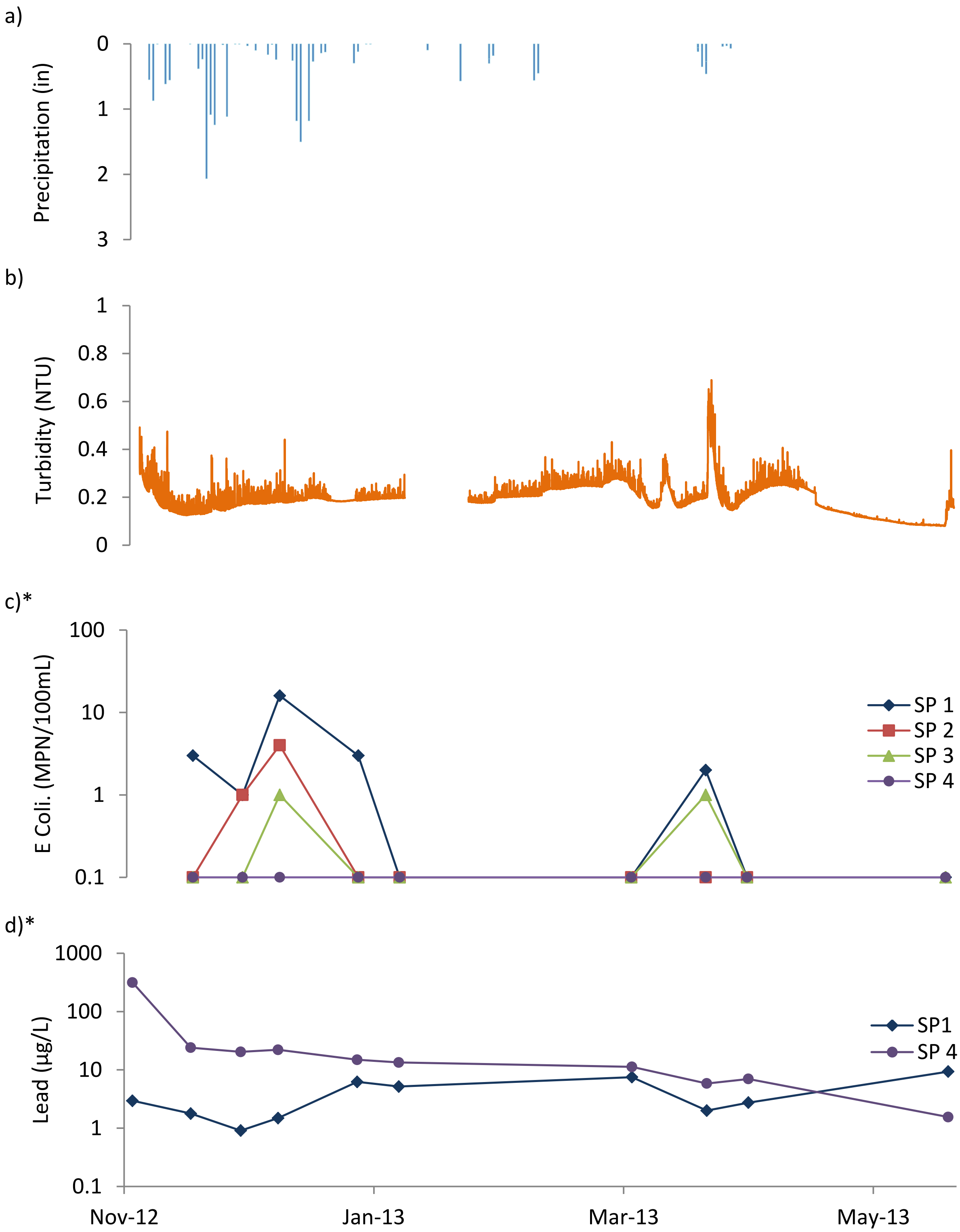
Turbidity

Turbidity typically ranged between 0.2-0.5 NTU while the system was operational during the rainy season. For the sampling period, mean turbidity was 0.19 NTU and remained well under 1 NTU for the entirety of the wet season (Figure 2-b). It should also be noted that turbidity was more than one tenth of the level required for the UV system to achieve the log(3) pathogen reduction. Data were lost for the period January 17 to February 1, 2012 due to an exceedance of the turbidimeter's data storage capacity[1].

Water Use

The Kimberg household diverted an estimated 11,800 gal of rainwater to their harvesting system during the sampling period (November 2012 – April 2013), preventing it from entering San Francisco's CSS. Eighty-five gallons overflowed into the CSS when the tanks were at full capacity after January 7, 2013. Overflow water before January 7, 2013 was not accounted for, due to water meter malfunction. Harvested rainwater made up 15% of the Kimberg household's total water use during the wet season of 2012-13.

[1] In response, maintenance protocol was revised to include turbidity data download during every site visit.



* Values <1 MPN/100mL are not detectable by testing equipment and are therefore represented 0.1 MPN/100mL for graphing purposes.

Figure 2. a) Precipitation (in) and monitored water quality parameters: b) turbidity (NTU), c) E Coli. (MPN/100mL), and d) lead (µg/L). Data on charts c & d are plotted on a logarithmic scale to clearly display low value trends.

Discussion

Elevated E Coli. concentrations at SP1 during December, January, and April are likely due to deposition of animal feces on the roof between rain events, which are transported via runoff from the roof to the cisterns. The reduction in E Coli. concentrations between SP 1 and 2 supports the important role of particulate settling within the tanks for improved water quality. Further reduction in E Coli. concentrations between SP 3 and 4 indicated that the UV disinfection unit is functioning properly. Although a standard has not yet been agreed upon for the acceptable water quality for dishwashing uses, the rainwater system at the Kimberg residence produced water meeting the SFDPH Director's *Rules and Regulations Regarding the Operation of Alternate Water Source Systems* standard for E Coli for all sources and uses described within the regulation. (Figure 2-b). Future sampling will help inform policy decisions regarding residential use of treated rainwater for dishwashing[2].

Trace lead levels in the influent could be attributed to leaching from roofing materials or atmospheric deposition. As mentioned previously, the increase in lead from SP 1 to SP 4 in November 2012 was most likely due to soldering that took place while installing the monitoring equipment. This trend is also analogous to the San Francisco municipal water system, which experiences heightened lead levels after entering the home due to leaching from the premise plumbing. Even with the spike in lead concentrations due to the soldering in November, lead levels remained below 15 ppb in all three samples collected after April 1, 2013, suggesting that properly treated harvested rainwater may be a safe alternative to municipal water for low-risk domestic use such as washing machines and dishwashers.

Overall, turbidity remained very low throughout the monitoring period. Small spikes in turbidity correlated with rainfall events to some degree, but were not consistent with elevated E Coli. or lead levels. More variability and overall higher levels of daily turbidity were observed in the winter months (November-April), which could again be due to more consistent rain events transporting particulates from the roof to the cisterns. To prevent loss of turbidity data in the future, it will be downloaded during each future site visit. This will also allow technicians to complete a brief bi-weekly analysis to isolate any anomalies.

To avoid overestimation of harvested rainwater use due to the turbidimeter recirculating water, water use will be estimated based on rooftop area and total annual rainfall (as outlined in the Methods section of this report) until the turbidity monitoring is complete.

Conclusion

The Kimberg Rainwater Harvesting System produced water of high quality throughout the 2012-13 wet season. However, the 2012-13 wet season was drier than in years past and therefore the rainwater harvesting system was not subject to stressors in the event of heavier or more frequent rainfall events. Monitoring planned for the wet seasons of 2013-14 and 2014-15 will establish a more robust baseline data set. More data will allow improved assessment of trends in water quality, potable offsets, and

[2] The homeowners are interested in using harvested rainwater for dishwashing. Their dishwasher uses 5.4 gal of water per wash, which is heated to 161°F for 91 minutes, essentially sterilizing the contents of the dishwasher (NSF 2013). Disinfecting the water further at such high temperatures could be considered another form of treatment, potentially reducing health risks even further.

diversions from the CSS. In addition, this work is critical to inform recommendations for regular maintenance activities and provide a long-term measure of rainwater harvesting benefits.

References

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