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Greywater management in the Monteverde Zone: Perceptions, challenges, and solutions

Greywater Management in the Monteverde Zone:
Perceptions, Challenges and Solutions

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Abstract
Greywater is the wastewater produced by kitchen sinks, bathroom sinks, showers and laundries. In Monteverde, Costa Rica, it is a popular practice to discharge untreated greywater into the local surroundings. However, there has been a growing awareness about the negative environmental impacts, an increasing concern in regards to public health risks, and a push for better greywater management strategies in the region. Over a six-week period, a research team, with collaboration and support from the University of South Florida, the Monteverde Institute, and the National Science Foundation implemented various anthropological and engineering methods to assess the perceptions and characteristics of greywater in the area. A greywater treatment system was also partially reconstructed at the Monteverde Institute, including two biogardens. The research team completed one biogarden and further construction and maintenance information was provided to the institute in order to aid in its completion and future care. Both the Monteverde Institute and research team hope the biogarden will serve as an educational resource for the greater Monteverde community. Lastly, the research team worked with a local and recently formed water commission in identifying zones of risk for greywater discharge in the Monteverde Zone, as well as established relationships with residents of a neighborhood to potentially serve as a pilot site for implementation of a community greywater treatment system. In addition to this report, a technical report regarding the design of the biogarden at the Monteverde Institute and a executive summary for the water commission with three suggestions for the future have been created. In response to the need to address pressing greywater issues, the research team hopes this study and its results serve as a platform for future investigations regarding greywater management in the Monteverde Zone.

Introduction

Greywater is the wastewater produced by bathroom sinks, showers and laundries. In Costa Rica, local regulations also categorize residual kitchen sink water as greywater effluent (Marin Araya & Ramirez, n.d.). Septic water, produced by toilets, is known as blackwater and requires a different form of treatment due to its chemical composition and association with fecal matter (Dixon, 1999). Unlike in the United States where the majority of grey and black residual waters are treated jointly, Costa Rica's plumbing schematics usually separate the two types of wastewater; and while most houses in Costa Rica have septic systems for blackwater treatment, greywater treatment options are less common (Dallas, 2004). Therefore, untreated greywater discharged from the home has potential environmental and human health risks, ones that demand attention and consideration (Marín Araya & Ramírez, n.d.). The ultimate goal of this research project is to explore greywater challenges and possible treatment systems in order to mitigate local environmental stresses and health risks.

Environmental and health issues associated with greywater

Untreated greywater is a source of pollution that threatens the health of the hydrologic cycle and the local environment, and can negatively impact human health as a direct consequence (Elvir, 2012). Depending on the source of greywater (i.e. kitchen sink or laundry), this form of effluent contains a variety of chemicals, food residuals, nutrients, and pathogens that each present various potential health implications (Moncada Corrales, 2011). Environmental risks of greywater include oxygen depletion and eutrophication of nearby water sources, as well alterations in surrounding soil composition (Morel & Diener, 2006).

It is difficult to fully realize the extent of untreated greywater impacts on the environment, as one must first consider how the hydrologic cycle functions within the local watershed, as well as the local activities of both businesses and households that characterize the greywater. Greywater discharge not only impacts the health of its final destination, but also impacts water and infrastructural resources as it travels (Morel & Diener, 2006). For example, untreated greywater discharged into streets often erodes and damages surrounding infrastructure, such as roads, banks, ponds, and presents an unpleasant odor (Morel & Diener, 2006). This wide variety of environmental hazards demands attention in order to protect the vitality of local watersheds and environmental quality, and by extension, the health of local residents and the entire ecosystem.

Human health is intrinsically related to the health of the surrounding environment. It is difficult to directly link the discharge of greywater to episodes of disease or health, (Dallas, 2005) so negative health impacts in humans tend to be thought of in terms of public risks. Surface pounding from greywater runoff has been identified as the single greatest risk, as it poses a breeding ground for various pathogenic and waterborne disease vectors, such as bacteria, parasites, and mosquitoes (Dallas, 2005; Esclamado, 2006). Furthermore, untreated greywater increases the risk of humans coming into contact with harmful pathogens or viruses through exposure to occasional fecal matter, or via ingestion of raw foods exposed to greywater effluent (Morel & Diener, 2006).

The severity of risks associated with untreated greywater depends on local practices, available infrastructure, and initiatives to mitigate impacts (Morel & Diener, 2006). Thus, in order to appropriately manage greywater and lessen the potential environmental and health impacts in the Monteverde Zone, one needs to take into consideration a combination of the local ecology and cultural norms.

Situation in Monteverde Zone

The Monteverde Zone is located at the top of the Río Guacimal watershed. Unfortunately, quantitative information regarding groundwater resources in this watershed is virtually non-existent (Welch, 2008). Despite legislative action aimed at preventing the pollution of Costa Rica's waterways, concerns have been raised in recent years over the continued contamination of water sources downstream from the Monteverde Zone, as well as its immediate vicinities.

The Monteverde Zone gained municipal status in 2001; however, sufficient legal enforcement has yet to be strongly established (Welsch, 2008). As a result, bringing central control over an area that has been typically marginalized by distant administrative centers has generated significant controversy (Greenbook, Welsch, 2008). A study done by S. Hardwood (2002) indicated that a large amount of households in the Monteverde region lack any form of greywater treatment; of 512 households surveyed, 97.8% discharged their greywater directly into the streets without any form of treatment (Dallas, 2005). In addition, Monteverde is characterized by a wet season and a dry season. Theoretically, the greater dilution of greywater by rain during the wet season should result in decreased bacterial concentration, somewhat lessening the potential risks associated with greywater discharge (Dallas, 2005). In this region, however, the wet season brings a dramatic increase in bacterial concentrations due to the flooding of inadequately designed septic systems (Dallas, 2005). Contamination from the septic systems then merges with untreated greywater in the local waterways, creating a health risk for the immediate community, as well as those located further downriver. The wastewater problems are largely due to unregulated growth, and though construction codes are in place, unplanned residential development and insufficient enforcement of construction codes continue to be critical problems. These two factors challenge the enforcement of environmental regulations, and many judicial cases regarding the improper discharge of wastewater remain unresolved (Water Forum 2, 2014).

In a region where access to clean drinking water and a healthy environment is a constitutional right, the increasing visibility and unpleasant odor produced by greywater has elicited community concerns for the future of Monteverde (Water Forum 1, 2014). In addition, the interest in preserving the local economic vitality reliant upon ecotourism has prompted the creation of a water commission in order to regulate the discharge of wastewater into the environment (Water Forum 1, 2014). During a water forum hosted at the Monteverde Institute on June 16, 2014, it was expressed that the two greatest barriers to greywater treatment are the existing infrastructure and cultural perceptions in the region. Lack of available space makes it difficult to construct a centralized water treatment facility, and gaps in local understanding of greywater discharge challenge the development of decentralized solutions (Water forum 1, 2014). Improved greywater regulation offers the opportunity to explore greywater reuse options, potentially reducing a household or community's dependence on potable water sources for certain types of irrigation or household cleaning practices (Marín Araya & Ramírez, n.d.).

Objective/Goals

The objective of this project is to address greywater issues in the Monteverde Zone by partnering with local organizations in the assessment of community perceptions and the construction of a community model of a greywater treatment system. The goals of this project are thus three fold. In order to design a sustainable treatment system, a thorough understanding of local perceptions and resources is essential. Therefore, Goal 1 has been designed to gauge perceptions in the Monteverde Zone regarding greywater issues, awareness, and existing treatment options. In an effort to construct an example for community education and awareness, Goal 2 focuses on reconstructing a biogarden at the Monteverde Institute, a local educational organization and leader. Ultimately, this biogarden will serve as an example for future greywater treatment efforts in the Zone. Goal 3, developed to fuse the anthropological and technical aspects of project design, focuses on working with local environmental, governmental, and health organizations to assess "Zones of risk", or greywater issue hotspots in the Monteverde Zone, as well as initiate a community-directed pilot model.

Methods

This investigation utilized a mixed-methods approach, incorporating qualitative and quantitative techniques commonly used in the fields of Anthropology, Engineering and Statistics. Quantitative techniques included two surveys designed to assess the perceptions of greywater. These were administered to participants at a health day in a small farming community, as well as administered door to door in a particular neighborhood of interest. A free listing method that inquired information about the composition of greywater was administered at a local Saturday market and with student's homestay families. Standard Methods laboratory tests included total Suspended Solids/Volatile Suspended Solids, Total Coliform, pH, and Biological Oxygen Demand as measures to assess the quality of greywater effluent. Lab method data can be found in a technical report provided to the Monteverde Institute, accessible through their online digital collections library. Qualitative techniques included three semi-structured interviews, two focus groups, three hotel visits, tours of two water treatment plants, and six weeks of participant observation. Qualitative notes were coded and analyzed in Atlas.TI (version 7.0), as well as manually through Microsoft Word. All quantitative statistical analysis was conducted in SAS (version 9.3). Engineering plans were designed in Sketchup Make, and investigative guidance was provided by program professors, as well as local community advisors and environmental engineering expertise from the Asociación Centroamericana Para la Economía, la Salud y el Ambiente (ACEPESA).

Quantitative Results

Freelisting

A total of n=49 people were asked to list the items that go down kitchen and bathroom sinks, showers, and laundry drains in the Monteverde area *(Site form in appendix).* The sample consisted of students' homestay families and community members at a local Saturday market. The number of items listed were normally distributed with a mean of 6 and a standard deviation of 2 *(Figure 1 Appendix B)* and a total list of 114 different items were compiled.

The prevalence of each item was estimated by the proportion of people who listed that particular item. The cultural saliency of each item was estimated by the mean of the item's individual saliencies, which were calculated under the assumption that people tend to list items in order of familiarity. A wide range of items was reported, including *moneda* (coins) and *diesel* (diesel/gasoline). An initial examination of the raw data (*Figure 1 Appendix B*) suggested *jabon*, *grasa,* and *cloro* (soap, grease, and bleach) are the most culturally salient and prevalent greywater content items. All items pertaining to food leftovers - including *'comida', 'sobras de comida', 'residuos de comida', 'restos de comida', 'desechos de comida', 'comida mala', 'desperdicios de comida*' - were combined into one item, '*comida*' (food), and used to recalculate saliency and prevalence. These results further suggested that food is also a dominant item in this domain (Figure 2 Appendix B). While additional grouping and pile sorting of items was possible (ex. combining different types of jabon/soap), it was deemed unnecessary.

Surveys

A total of n=19 people were surveyed. The sample was mostly female (78%) ranging from 18 to 85 years of age (mean=47, std=19). The majority (68%) of the sample resided in a rural (as opposed to urban) area, and the number of people per household ranged from one to ten (mean=3.5, std=2.1). Income was assessed in five intervals, of which 46% earned less than 150.000 colones a month, 15% earned between 150.000 and 258.000 colones per month, 31% earned between 259.000 and 350.000 colones per month, none earned between 351.000 and 450.000 per month and 8% earned over 450.000 colones per month. Age was divided into three groups, less than 30, between 30 and 50, and over 50, (containing 21%, 47%, and 32% of the sample, respectively). Due to the small sample size, Fishers exact table probabilities were used to test two-way associations. Demographic information is summarized in Tables 1 and 2 of Appendix B

About half (47%) of the people surveyed knew the difference between greywater and blackwater. This knowledge did not vary be age (p-value = 0.16), gender (p-value =0.28), or residence (p-value=0.37). However, there was a significant difference (p-value=.042) between income levels, which suggested higher incomes were more likely to have greater knowledge of the difference between greywater and blackwater (Table 3 Appendix B). We provided a definition of greywater for each participant after asking this question.

Seven (47%) of the people surveyed had greywater treatment systems; one had a grease trap only, four had a rock drainage only, two had both a grease trap and a rock drainage, and none of the individuals surveyed had tire drainage systems. Whether or not they had a greywater treatment system did not depend on age (p-value=0.13), gender (p-value=0.43), residence (p-value=0.43) or income (p-value=0.15). It should be noted that three people were renters and did not know whether or not they had greywater treatment systems, so they were excluded from the analysis of this question.

Over three quarters of the sample (78%) did not use biodegradable soap. Whether or not they used biodegradable soap did not appear to differ by gender (p-value=.45) or income (p-value=0.18). It was observed that none of the people living in urban neighborhoods used biodegradable soap, while approximately half of the people in a rural neighborhood reportedly did. This association, however, was not statistically significant (p-value=0.16; Table 4 Appendix B) There was, however, a marginal significance (p-value=0.07) by age that suggested younger age groups were more likely to use biodegradable soap than the older age groups (Table 5 Appendix B).

Using a five point likert scale on the situation of greywater in Monteverde, none thought it was 'Very bad', five (26%) thought it was 'bad', three (16 %) though it was more or less acceptable, five (26%) thought it was 'good', two (11%) thought it was 'very good', and 4 (21%) had no opinion (Table 6 Appendix B). After removing people who had 'No opinion', independent cumulative logit models were used to test the relationship of the likert responses with age, gender, residence, and income separately. There were no apparent differences in response probabilities between gender (p-value=0.43), residence (p-value=0.89) or income (p-value=0.98). It did appear, however, that people aged 30-50 were more likely to report negative ratings than those below 30 or over 50 (Figure 4 Appendix B), however, due to the small sample size, this information was not statistically significant (p-value=0.30).

Using a five point likert scale on 'The greywater from my home affects my neighborhood', ten (77%) completely disagreed, none somewhat disagreed, one (8%) neither agreed nor disagreed, two

(15%) somewhat agreed and none strongly agreed (Table 6 Appendix B). There were no differences in response probabilities detected between age group (p-value=0.47), gender (p-value=0.25) or income (p-value=0.88) groups by cumulative logit models.

Finally, almost all (89 %) of the people surveyed were interested in learning more about greywater treatment systems. Because only two people responded that they were not interested, this question was not tested for differences in response probabilities. A summary of the yes/no survey questions can be found in Table 8 of Appendix B, a summary of the Fisher's Exact p-values in Table 9 of Appendix B, and a summary of Wald statistic p-values in Table 10 of Appendix B.

Qualitative Results

Freelisting

"Cuales son las cosas que bajan por los drenajes de los lavaplatos, lavamanos, la ducha y las lavanderías de por aca?"

The aforementioned question was intended to gauge individual perceptions and knowledge about the composition of untreated greywater in the Monteverde Zone. By having respondents identify the types of contaminants that end up in their streets, it served as an educational tool that elicited a conversation regarding soil and water contamination, as well as implications for human health. The saliency results were ultimately used to tailor some of the questions in the anonymous survey, serving as a basis for further investigation.

Surveys

As stated above, out of the nineteen individuals surveyed, a little less than half of the sample size had an adequate understanding of greywater and blackwater differences. The only significant demographic association seemed to be in regards to socio economic status, where a higher income level could be associated with a greater knowledge of greywater composition and its negative impacts. Over half of the individuals surveyed indicated that they had no form of greywater treatment system, implying that their greywater flowed directly into the streets. When asked the reasoning behind their lack of greywater treatment, respondents cited cost and space as the two greatest barriers to treatment system construction. One individual expressed awareness of water discharge regulations, but cited lack of municipal enforcement as an inhibitor to greywater treatment. Three of the individuals surveyed were renters and expressed that they had no knowledge of whether or not a treatment system existed for their homes.

While approximately ¼ of the individuals interviewed acknowledged the greywater situation in the Monteverde Zone to be “bad,” an overwhelming majority felt that their greywater had no negative impacts on their respective community. Some even expressed that the greywater situation in the Zone was good, or fairly acceptable. These results are significant in understanding the perceptions of greywater impact in the community and the potential barriers to the implementation of an overall solution. While further research is necessary, if future surveys yield the same results, an educational campaign may be necessary prior to the implementation of a treatment system.

Focus Groups

Two focus groups were conducted as part of qualitative data acquisition. The first centered on the general impacts of greywater in the Monteverde Zone. It was conducted at the Monteverde Institute and the participants were recruited by MVI staff. Two of the individuals from the first focus group were residents of an "at risk" zone and expressed concerns over greywater contamination in their neighborhood. We confirmed that the greywater situation in this neighborhood was fairly critical through a site visit, first by walking through the neighborhood ourselves and then with the guidance of a community member that took us directly to the areas of most concern. We determined this would be an appropriate site to hold another focus group centered on finding community based solutions, and in hopes of finding a pilot site for an exemplary model of a multiple house greywater treatment system.

Discussion

Community Perceptions

The estimated 53% of people with no form of greywater treatment system from this survey contrasts from the 97.8% of people that Hardwood (2002) estimated. This is due to the consequences of convenience sampling; due to selection bias, the survey is not necessarily representative of the

Monteverde zone. The survey will need to be administered in more neighborhoods and a larger sample size is necessary to make further inferences. Other trends indicated by the survey included a higher prevalence of biodegradable soap use in rural over urban areas and more knowledge of the difference between greywater and black water in higher income groups. Though statistical techniques were employed to combat the small sample size, the data was sparse and the study was still severely underpowered. It is possible that other significant associations exist but were not able to be detected, particularly within the likert scale response survey questions. We recognize that no real conclusions can be inferred from our survey results, but it was none the less exciting to see a hint of a shift in greywater management strategies, as well as the 89% of people interested in learning more about greywater treatment systems backed by an overwhelming amount of qualitative support from interviews and focus groups.

In contrast, the freelisting results from this project were derived from a sufficient sample size, consisting of individuals from the local farmers market and the Public Health program's homestay families. Because of this, the sample was not as subject to selection bias as the health day participants and the surveys conducted at a particular neighborhood of interest. The results provided a useful reflection of household activities that contribute to composition of greywater, because the main characteristics of greywater strongly depend on the most culturally salient items going down the drains. In the Monteverde Zone, the most culturally salient items were *comida* (food), *jabón* (soap), *grasas* (greases/oils), and *cloro* (bleach). The physical and chemical characteristics of these items are important considerations when evaluating greywater challenges and potential solutions.

The chemical parameters, including sodium, boron, and phosphate concentrations, and alkalinity of soaps determine the level of risk to the surrounding environment (Morel & Diener, 2006). Though the salinity of greywater is normally not problematic, it can become a hazard when greywater is reused for irrigation and there may be long-term impacts of salt loading on the soil, especially when in combination with high sodium laundry detergents (Morel and Diener, 2006). The sodium hazard is indicated as sodium absorption ratio (SAR) and the detrimental effects are specific to the soil's physical properties

(Morel and Diener, 2006). The sodium hazard can best be avoided by using low sodium products (Morel and Diener, 2006), but would likely require many Monteverde residents to use alternative cleaning products. Availability, price and custom were cited as the primary reasons for the underutilization of biodegradable soaps. Creating a local industry that sells affordable biodegradable soaps was cited as a potential solution, and some future efforts in reducing greywater impact should focus on exploring this option further.

Routine maintenance was another issue that was noted in our qualitative data. When asked how often they cleaned out their grease traps, most respondents expressed that it was somewhere between every six months to once per year. Generally, a grease trap is not cleaned unless there is some type of blockage or clog, in which case it becomes necessary to open up the trap and remove excess grease and residual solids. From local interviews and participant observation, food residuals and greases are understood to largely determine the frequency of pretreatment system maintenance. Rice, beans, and small pieces of meat and vegetables, which are commonly consumed in Costa Rica, often clog sink drains, as well as grease traps. When considering greywater treatment options, such as grease traps or rock drainage systems, the ability and willingness to maintain the system on a regular basis must be taken into account in order to optimize function.

The focus groups conducted during the study directed attention to the environmental and human health risks of untreated greywater. During the first focus group, a local farmer expressed concerns of failing environmental health due to greywater discharge. He provided an anecdote about an occasion where many of his ducks began dying due to the consumption of water from a downstream pond; the pond was contaminated with household soaps, which he asserted was the source of the problem. Another resident noted the declining health of pine trees near her house's greywater effluent pipe. Overall, several participants associated environmental degradation with future human health complications, agreeing that greywater eventually contaminates local and downstream drinking water, and associating the term *"todo malo"* ("all bad") with the term "greywater."

Focus group participants expressed a clear interest in addressing the greywater challenges in their community through individual or communal treatment systems. A major theme that emerged from the discussions was a lack of information and knowledge about greywater issues and treatment options. Participants of the second focus group listed a lack of individual responsibility and education, a lack of space and technical knowledge, as well as the difficulties in community cooperation and environmental consciousness as some of the barriers to creating a community based solution to greywater problems. When asked what types of things would help overcome these challenges and facilitate the creation of a greywater treatment system, the overarching theme seemed to be governmental involvement. They acknowledged that the first steps would need to include educational measures, but ultimately, they concluded that governmental agencies and financial consequences demand a certain level of adherence and respect, and would be the main influencing factor in community cooperation.

Reconstruction of Biogarden and Community Alliances

In his book, *Green Encounters: Shaping and Contesting Environmentalism in Rural Costa Rica,* Luis Vivanco expressed the importance of local pilot projects as educational examples, stating that “If a project can be shown to be successful, donors...are more likely to send money, technical experts are more likely to offer technical assistance...people begin to refer to it as a “model” for other places...” (Vivanco, 2007:184). As stated before, this study involved collaborating with the Monteverde Institute (MVI) to reconstruct a biogarden that failed due in part to maintenance issues, as well as design failures. Under the mission statement of MVI, they hope the renovation of the biogarden will serve as an example for one type of decentralized, community-centered greywater treatment solution.

The design of this particular biogarden was developed with the advice of ACEPESA, a Costa Rican organization dedicated to community-focused environmental engineering solutions. Their designs were adopted to meet the consumption and maintenance demands of the site. Due to time limitations, the research team was only able to complete half of the construction, as the length of the biogarden was too long and had to be divided into two separate biogardens. In order to make future maintenance of the garden easier, however, the construction design, lab results and a rewritten maintenance manual were provided to the Institute, including the steps for further construction and lab testing.

Alliances and Community Cooperation

As a well-known and well-respected educational institution in the Monteverde Zone, the Monteverde Institute has many connections with other local leadership institutions. During the course of this study, they facilitated the formation of the *Comisión de Aguas* (Water Commission) in the Monteverde Zone. This commission is interested in identifying “at risk zones”, or hot spots of greywater issues in the region, in order to focus their efforts on the most pressing situations. Research methods and results of this investigation were organized into an executive summary, which was provided to the Water Commission to aid in future efforts. In the spirit of Goal 3 for this investigation, a pilot community in a more trafficked location, such as one of the “at risk zones” identified by the Water Commission, would be ideal. A project which empowers a community to take initiative in solving its own greywater challenges has much more potential to “plant a seed” in regards to the importance of addressing greywater issues in the Monteverde Zone; a community centered solution also has the ability to multiply the possibilities for the construction of other locally responsive and transformative initiatives. Initial steps were taken during this investigation to facilitate the development of such as project; however, future steps will fall under the guidance of the Water Commission and other partner educational institutions.

Limitations and Recommendations

A major necessity for future planning is improved collection and dissemination of consistent data sets. Improved accessibility of information and reliable statistics will make public decision-making processes and future research more adequate and efficient (Welsh, 2008). Due to time and resource limitations, this study relied on convenience sampling and suffered from a small sample size. The results obtained in this study cannot be extrapolated to the larger Monteverde zone. However, a block randomization technique can be used to select a representative sample from the target populations in Monteverde, from which properly conducted surveys can obtain more reliable and accurate results. This task would likely fall under the supervision of the Water Commission and their efforts to identify 'at risk zones'. In lieu of data collection and analysis, which can be a lengthy and time consuming process, the authors suggest that surveying hotels in close proximity to residential homes may provide a good starting point for identifying greywater ' risk zones'. Not only have hotels been shown to use three to thirteen times the wastewater than equivalent domestic use (Dallas, 2005), but hotels may have staff which could help develop successful maintenance plans.

The greater community of the Monteverde Zone has also expressed interest in more effective organization, oversight, and support from the local government and water management authorities. A previous investigation in 2008 by the University of South Florida cited the need for improved coordination between the community and local organizations (USF, 2008). The creation of the local Water Commission will facilitate achieving this goal.

Incentives for the Future

Monteverde is a region known and loved for its rich biodiversity and history of sustainably-minded ecotourism, yet, as a local resident expressed during a community meeting, *“Hay dos caras de Monteverde – una linda, una no tan linda,” or, “Monteverde has two faces, a beautiful face and a not-so-beautiful face*” (Water Forum 1, 2014). The “not-so-beautiful face” refers to the environmental and health consequences of recent infrastructural and touristic expansions. Another community leader stated that economics are what everybody has in their best interests. Several studies have attempted to link the unattractive odors and appearances of untreated greywater to a decrease in tourism, and hence a threat to economic stability (Ringler, 2001; Kumar, 2002). It is debatable, however, whether or not the increasing visibility of greywater will be a sufficient incentive for individual investment in greywater treatment systems (Kumar, 2002).

A community leader in sustainability efforts in the Zone mentioned in an interview, “People are hesitant to touch stinky water…[and] we have disconnected ourselves from our waste...” He emphasized that action is more powerful than discussion, and asserted that Monteverde residents needed to begin to, “walk [their] speech.” The Monteverde Zone sits at a crossroads: one path on the brink of tangible, impactful results, and the other threatening to harm the health of the community - the people and the environment - detrimentally. While this study has observed the pressing need to address untreated greywater challenges and risks in the Zone, there are community members and organizations ready to work together to preserve the rich biodiversity and local pride that enriches the region. As one resident decried, *"[Hay que] meter mano por el barrio!"* In essence, we need to take action for our neighborhoods and for the protection of the environment in which we live.

Appendix A

Kitchen	Kitchen greywater contains food residues, high amounts of oil and fat, including dishwashing detergents. In addition, it occasionally contains drain cleaners and bleach. Kitchen greywater is high in nutrients and suspended solids. Dishwasher greywater may be very alkaline (due to builders), show high suspended solids and salt concentrations
Bathroom	Bathroom greywater is regarded as the least contaminated greywater source within a household. It contains soaps, shampoos, toothpaste, and other body care products. Bathroom greywater also contains shaving waste, skin, hair, body-fats, lint, and traces of urine and feces. Greywater originating from shower and bath may thus be contaminated with pathogenic microorganisms.
Laundry	Laundry greywater contains high concentrations of chemicals from soap powders (such as sodium, phosphorous, surfactants, nitrogen) as well as bleaches, suspended solids and possibly oils, paints, solvents, and non-biodegradable fibers from clothing. Laundry greywater can contain high amounts of pathogens when nappies are washed

Source: GWM

Appendix B Statistical Analysis

Figure 1: Distribution of the number of items listed in Greywater content freelisting.

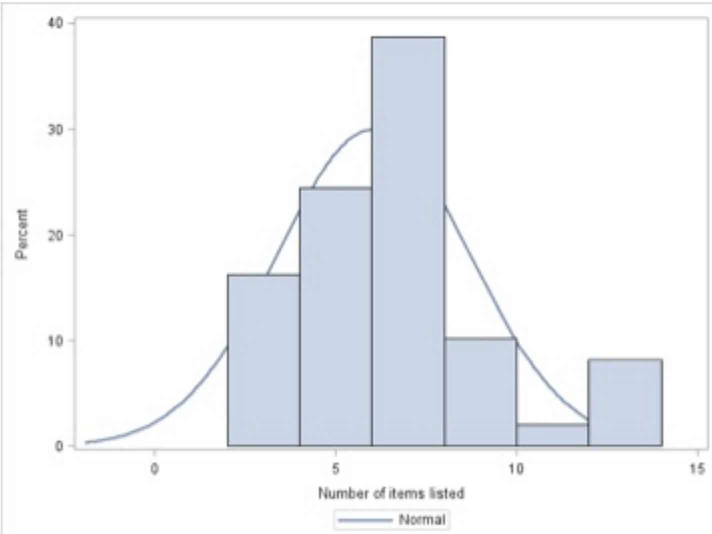

Figure 2: Raw greywater content freelisting results.

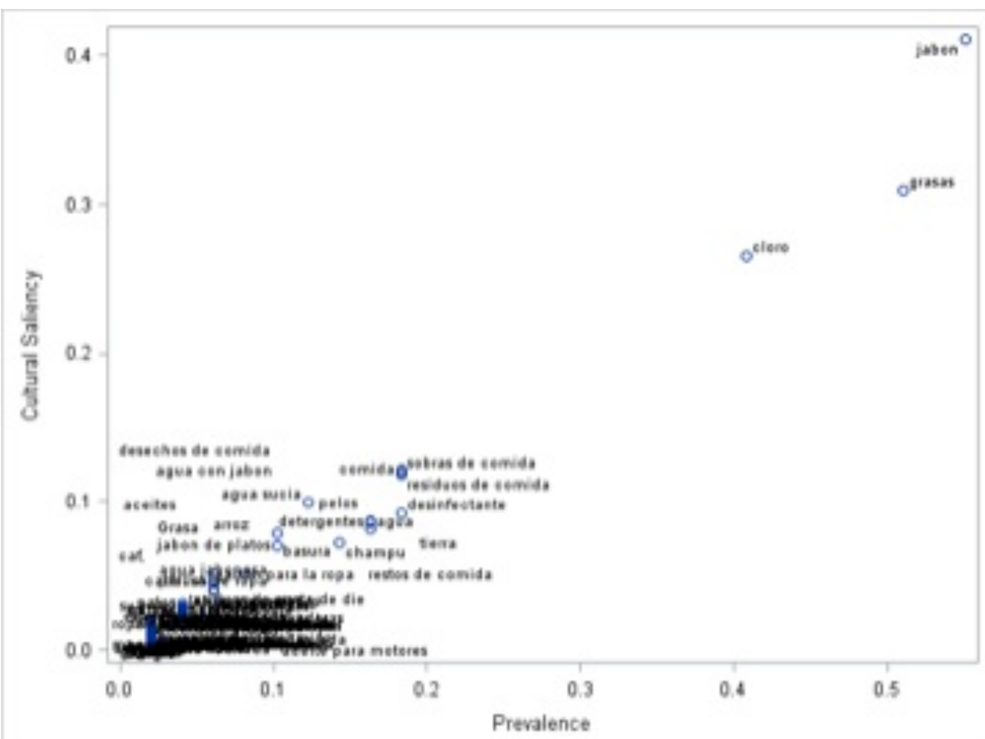

Figure 3: Grouped greywater content free listing results.

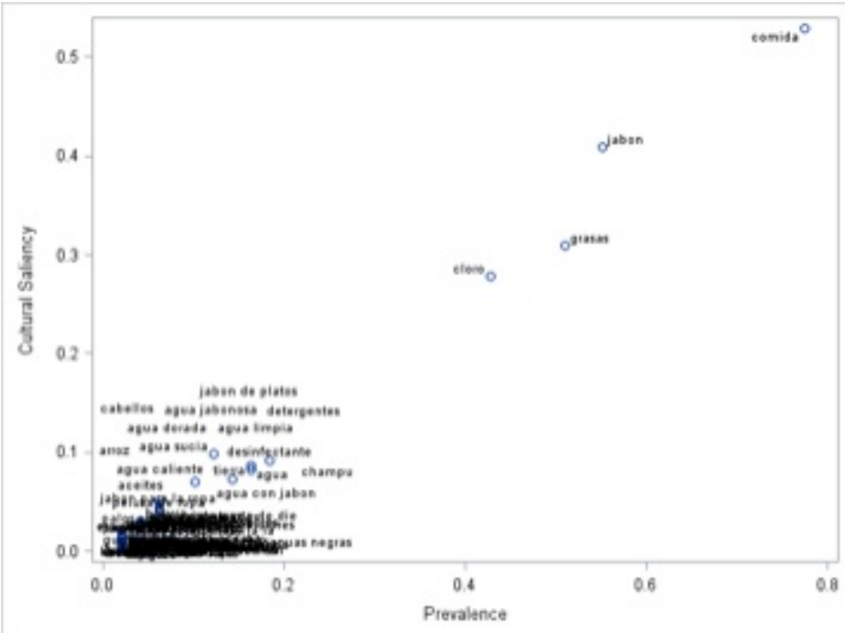

Table 1: Survey Demographics (Categorical)

Demographics	N	(%)
Gender		
Female	15	(78 %)
Male	4	(21 %)
Age		
<30	4	(21 %)
30-50	9	(47 %)
>50	6	(32 %)
Residence		
Rural	13	(68 %)
Urban	6	(32 %)
Number in household		
1-2	7	(39 %)
3-4	7	(39 %)
>5	4	(22 %)
Income		
<150	6	(46 %)
150-258	2	(15 %)
259-350	4	(31 %)
351-450	0	
>350	1	(8 %)

Table 2: Survey Demographics (Continuous)

Demographics	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**
Age	47.5	19.0	18	85
Number in Household	3.5	2.1	1	10

Table 3: Understanding the difference between greywater and blackwater by income

	Do you understand the difference between greywater and blackwater?		
Income	no	yes	Total
<150	2	4	6
150-258	1	1	2
259-350	0	4	4
351-450	0	0	0
>450	1	0	1
Total	4	9	13

Fishers Exact table probability = 0.0420

Table 4: Biodegradable soap use by residence

	Do you use biodegradable soap?		
Residence	no	yes	Total
rural	8	4	12
urban	6	0	6
Total	14	4	18

Fishers Exact table probability = 0.1618

Table 5: Biodegradable soap use by income group

	Do you use biodegradable soap?		
Age group	no	yes	Total
<30	2	2	4
30-50	7	2	9
>50	5	0	5
Total	14	4	18

Fishers Exact table probability = 0.0706

Table 6: Likert scale situation in Monteverde

How is the situation of greywater in Monteverde?	N	(%)
Very bad	0	
Bad	5	(26 %)
More or less acceptable	3	(16 %)
Good	5	(26 %)
Very good	2	(11 %)
No opinion	4	(21 %)
Total	15	

Figure 4: Response probablites for likert situation in Montevede by age group.

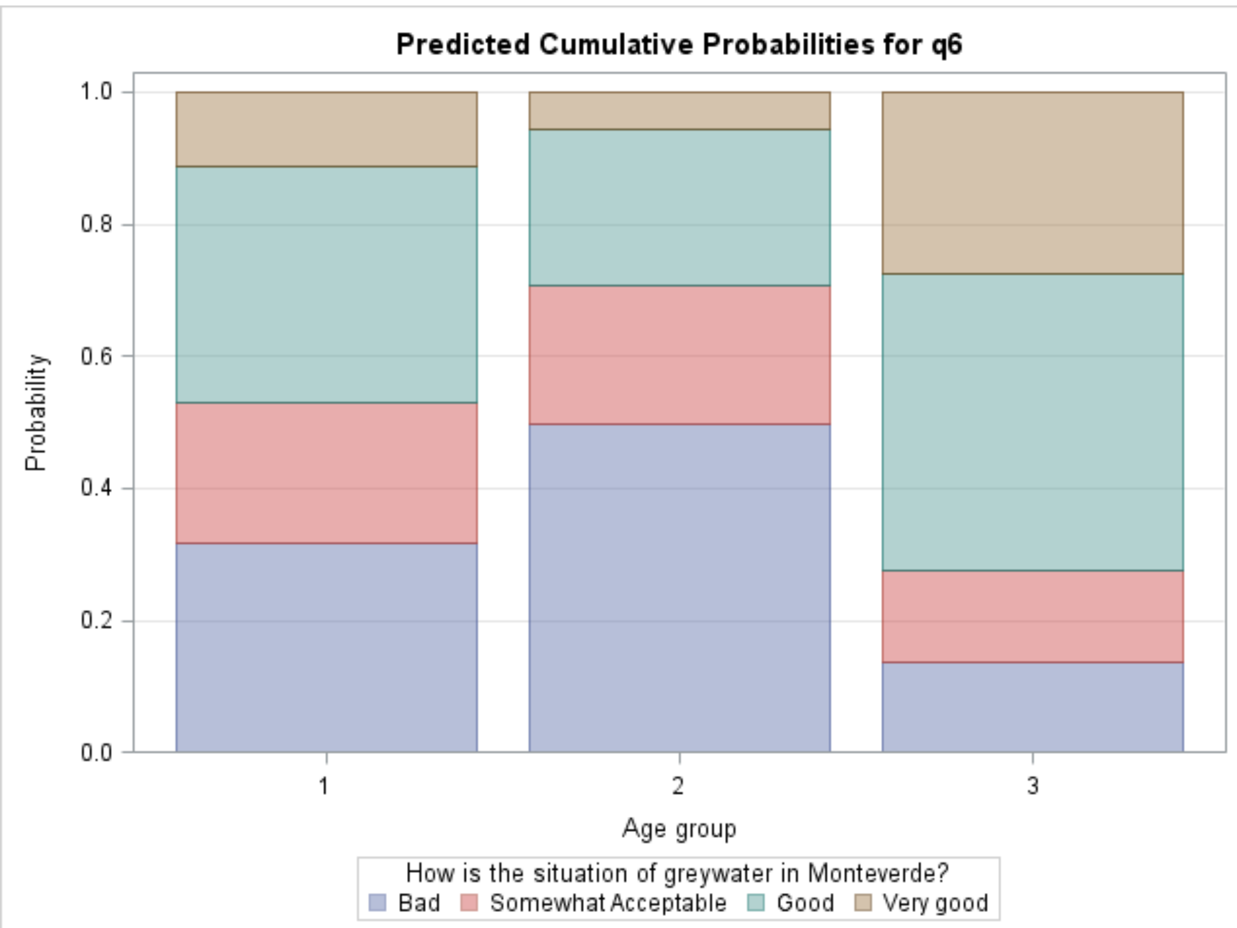

Table 7: Likert scale agreement with greywater neighborhood affect

The greywater from my home affects my neighborhood	N	(%)
Completely Disagree	10	(77 %)
Somewhat Disagree	0	
Neither Agree nor Disagree	1	(8 %)
Somewhat Agree	2	(15 %)
Completely Agree	0	
Total	13	

Table 8: Summary of yes/no survey questions

Survey Question N (%)	Yes	No	Total
Do you understand the difference between greywater and black water?	9 (47 %)	10 (53 %)	19
Do you have a greywater treatment system in your home?	7 (47 %)	8 (53 %)	15
Grease trap?	5 (71 %)	2 (29 %)	7
Rock drainage?	6 (86 %)	1(14 %)	7
Tire drainage?	0 (0 %)	7 (100 %)	7
Do you use biodegradable soap?	4 (22 %)	14 (78 %)	18
Are you interested in learning more about grey water treatment systems?	17 (89 %)	2 (11 %)	19

Table 9: Fisher's Exact table probabilities of binary survey questions by subgroups

Subgroup	Do you know the difference between greywater and blackwater?	Do you have a greywater system?	Do you use bidegradable?
Age group	0.1637	0.1305	0.0706 +
Gender	0.2786	0.4308	0.4461
Residence	0.3715	0.4308	0.1618
Income	0.0420 *	0.1429	0.1818

α:*<0.05; + <0.10;

Table 10: Wald Chi-Square probabilities of subgroup effects in cumulative logistic regression models
for likert survey questions

Subgroup	Likert scale for acceptability of greywater situation in Monteverde	Likert scale for agreement with greywater affect on community
Age group	0.304	0.4658
Gender	0.4308	0.2478

Residence	0.8945	
Income	0.9875	0.8824

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