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LONG-TERM STUDY ON LANDSCAPE IRRIGATION USING HOUSEHOLD GRAYWATER - EXPERIMENTAL STUDY

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EXECUTIVE SUMMARY

As water supply becomes more limited throughout the world, there is a growing interest for innovative approaches to sustainable water resources. One approach that is gaining popularity is household graywater reuse for residential landscape irrigation. However, there are potential risks associated with this approach, and those risks are largely unquantified. Application of graywater may result in increased levels of pathogens in surface soil, negative impacts to soil quality, potential groundwater contamination, or negative impacts to plant health. Graywater irrigation systems offer many benefits, however the use of such systems has not become widespread due to concerns about safety issues. While some states have begun to regulate the practice of graywater reuse for residential landscape, little guidance based on scientific data has been provided for the safe operation of graywater irrigation systems. Limited scientific data is available on the fate of graywater chemical and microbiological constituents and the effect of these constituents on plant health after graywater is applied for irrigation. The objective of this research project was to elucidate information on the fate and occurrence of graywater constituents and their potential impacts on soil quality, groundwater quality, and plant and human health as a result of its application for residential landscape irrigation.

Experimental studies were conducted in three parts: existing household systems, new household systems, and greenhouse studies. Field studies were conducted on both households with existing systems and households with newly installed systems. Four households were selected in AZ, CA, CO, and TX where graywater was applied for more than five years. In addition, new graywater irrigation systems were installed at three households (AZ, CA, and CO). Baseline samples were collected at the households with newly installed systems prior to initiation of graywater irrigation. Households with newly installed systems were monitored for two to four years. At all households studied, soil samples were collected in areas irrigated with graywater and in a control area with similar vegetation irrigated with a source of freshwater. Plant health was monitored in addition to analysis of tissues to evaluate impacts to plant health. In addition to the field studies, a greenhouse experiment was conducted to evaluate the impact of graywater application to plants and to monitor leachate from graywater irrigated soils.

Results from the field study on existing and new household systems showed that most plants are healthy under long-term graywater irrigation. Among 22 plant species evaluated, the research team only observed three species (avocado, lemon tree, and Scotch pine) that were sensitive and showed reduced growth, or leaf burning, or reduced fruit production under graywater irrigation. Graywater irrigation was found to significantly increase sodium in households with graywater systems in place for more than five years ($P \leq 0.05$), however not to levels of concern for plant health or soil quality. Graywater irrigation was also found to significantly increase surfactants in soil at households with graywater reuse systems in place for more than five years. In addition, soil collected from households with newly installed graywater systems had significantly higher surfactant concentration than control areas irrigated with graywater ($P \leq 0.05$). Surfactant concentration did not continually increase with duration of graywater irrigation. The antimicrobials triclosan and triclocarban were detected in graywater irrigated areas, but not freshwater irrigated areas. These constituents were only detected in

surface soil samples and are not easily transported through soil. Graywater has the potential to contaminate the environment with human-associated fecal organisms, including *E. coli* and enterococci. In this study, however, the research team found no strong, consistent effect of graywater on numbers of *E. coli* or enterococci in soil. Contamination was inconsistent and depended on the household, sampling date, and depth of soil sampled. In addition, *E. coli* and enterococci were detected in freshwater-irrigated soils, indicating sources other than graywater for fecal indicators detected in the environment. Of note is that these organisms can grow in the environment.

The objective of the greenhouse study was to evaluate the potential for graywater constituents to leach through soil and contaminate groundwater. There is a potential for salts, and in particular nitrogen (N) and boron (B) salts to leach through soil when graywater is applied for irrigation. A portion of the applied N is taken up by plants, but leaching of N was still observed. Leaching of N was lower in columns planted with grass compared to shrubs. Of note is that nitrate measured in graywater is well below the National Primary Drinking Water Standard limit of 10 mg L^{-1}. While a low percentage of surfactants added to greenhouse columns leached through 50 cm, leaching did increase with the duration of the study (17 months). More research is required to determine if leaching of surfactants would continue to increase over time. More than 90% of applied surfactants were determined to be biodegraded in planted columns. Due to the much greater nutrient content in the synthetic graywater for the greenhouse study, synthetic graywater-irrigated plants exhibited greater plant biomass and enhanced density, color, and quality when compared to potable water irrigated plants. No visual symptoms of toxic effects were observed in the greenhouse study. It is thus implied that surfactant accumulation in planted column soil did not result in phytoxicity. Graywater irrigation resulted in higher infiltration rates in columns compared to potable water irrigated columns.

No major concerns were identified in this study that would render reuse of graywater following best management practices unsafe for growing garden plants. Considering human health, the state of Arizona has set the standard for graywater irrigation best management practices (http://www.azdeq.gov/environ/water/permits/download/graybro.pdf) and these practices are recommended in many states. Graywater does contain pathogens and human contact with graywater should be avoided. Graywater should be applied through drip irrigation with a protective layer of mulch above emitters. In some states, subsurface irrigation systems are required. One such system was studied as part of this research. There was no indication that a subsurface irrigation system resulted in lower indicator organisms compared to surface irrigation systems studied here. In general, the source of indicator organisms was difficult to determine since they were found in areas irrigated with freshwater (control). However, because indicator organisms were detected in graywater irrigated areas, it is recommended that human contact with graywater irrigated areas be avoided. Placing a mulch layer over drip emitters where graywater is applied appears to be a good control to minimize human contact with graywater irrigated soil. The research team found that most plants were healthy under long-term (more than 5 years) graywater irrigation. However, avocado, lemon tree, and Scotch pine are sensitive to graywater irrigation and not recommended when graywater is the only source of irrigation water. Results from the greenhouse study showed that N present in graywater was beneficial for plant growth. Supplemental fertilizer can be reduced or eliminated where graywater is applied for irrigation.

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