UCLA Institute of the Environment

Everything we do now matters

Southern California Environmental Report Card - Fall 2009

GRADE B+ to B-

Graywater - A Potential Source of Water

by Yoram Cohen, Ph.D.
Professor, UCLA Department of Chemical and Biomolecular Engineering
and the Water Technology Research Center

Yoram Cohen, Ph.D.

California is facing a serious drought that prompted Governor Arnold Schwarzenegger to declare "This drought is having a devastating impact on our people, our communities, our economy and our environment… This is a crisis, just as severe as an earthquake or raging wildfire, and we must treat it with the same urgency by upgrading California's water infrastructure to ensure a clean and reliable water supply for our growing state." After three years of dry weather, and with forecasts of precipitation and snowpack below normal levels, California is preparing for the likelihood that 2010 will be a fourth year of drought [1, 2] with the State's key water reservoirs projected to be at only about 70% of their average storage. Unless precipitation leads to significant restoration of the State water supply and demand is reduced, the situation in California will become unsustainable.

WATER USE IN CALIFORNIA

The California Department of Water Resources has pursued a multifaceted approach to address the severe water shortage in California, with water conservation as a key element of its plan. Among its various elements, the approach considers reduction in water use efficiency and conservation, as well as the reclamation and reuse of municipal, industrial and agricultural wastewater streams. Various California local governments have already implemented and/or are encouraging water conservation measures, including water rationing and water reuse. The largest percentage of water consumption (77%) in California is attributed to agriculture (Figure 1) with an estimated 13% for urban residential use (both single- and multi-family). In Southern California (the South Coast Hydrologic Region), however, about 54% of the water consumption (Figure 2) is attributed to urban residential use, which accounts for the largest usage of potable water by the municipal and industrial (M&I) sector (i.e., the urban sector). Although use of water by the M&I sector in the South Coast Hydrologic Region represents a small fraction of California's total water use (~6%), the loss of even a small percentage of this potable water apportionment can have significant impact on the quality of life in urban areas. For example, in order to cope with water shortages, the Los Angeles Department of Water and Power (LADWP) has implemented a program that includes restrictions on urban irrigation, guidelines for residential water conservation, and shortage-year water price increases.

The largest percentage of water consumption in California is attributed to agriculture but in Southern California about 54% of the water consumption is attributed to urban residential use.

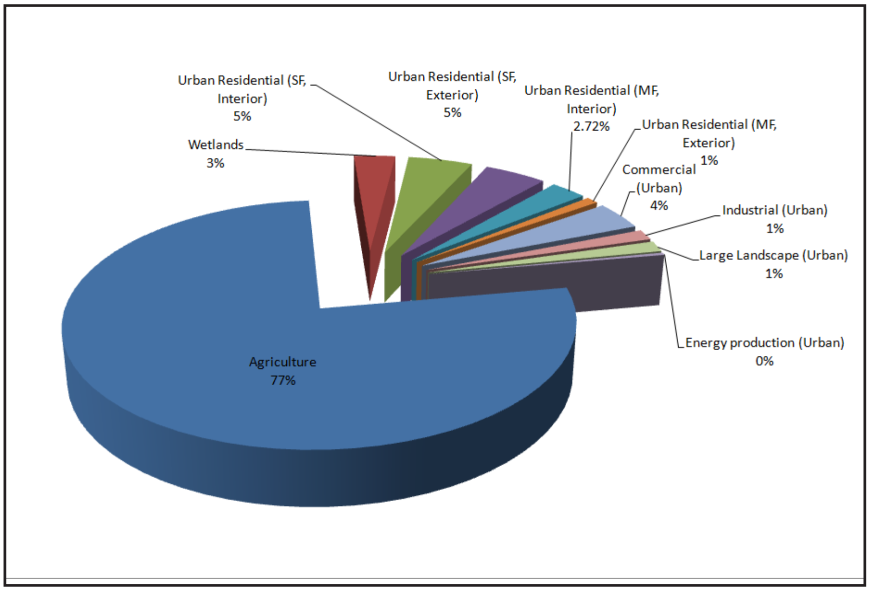

Figure 1. Freshwater use in California (Source: [3]).
Note: MF - Multifamily, SF - Single Family.

Water recycling, particularly of graywater, is now being advanced as a potential water source that could alleviate some of the water shortage pressure in Southern California.

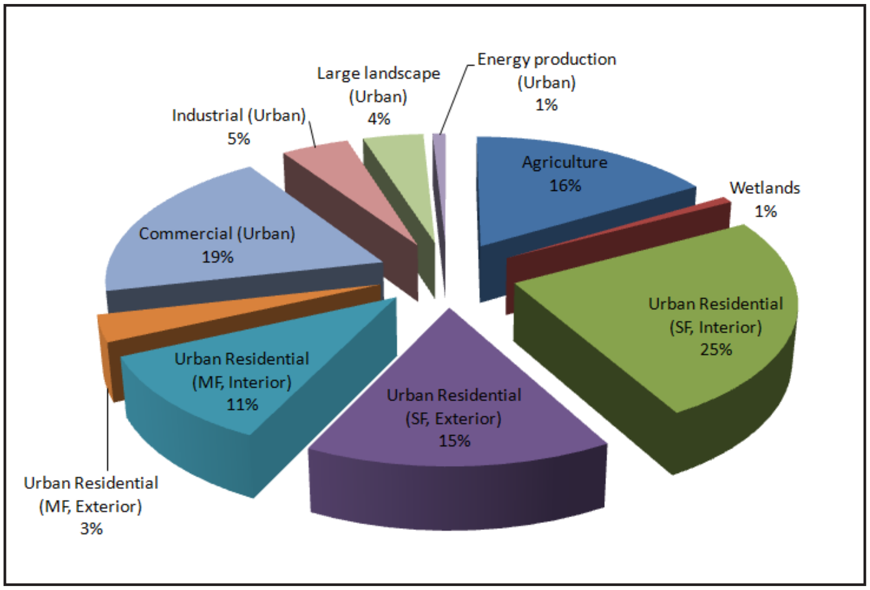

Figure 2. Water use distribution in California's South Coast Hydrologic Region (Source: [3]).

In order to meet California's future water supply needs, it is clear water conservation must be implemented as a component of the State's overall water plan. Domestic measures of water conservation, which are of great importance to the M&I sector, include expanding the use of ultra low-flow toilets and low-flow shower heads, as well as efficient washers for laundry and the kitchen. In addition, water recycling, particularly of graywater, which has been gaining popularity in various countries, is now being advanced as a potential water source that could alleviate some of the water shortage pressure in Southern California.

GRAYWATER: LIGHT AND HEAVY

Graywater, as defined in Chapter 16A Part I of the 2007 California Plumbing Code [4], is untreated wastewater that has not been contaminated by any toilet discharge, has not been affected by unhealthy bodily wastes, and does not present a threat from contamination by unhealthful processing, manufacturing, or operating wastes. Under this definition, toilet wastewater (also known as blackwater) is not considered graywater and would require significant treatment in centralized wastewater plants. The importance of graywater recycling and reuse has been recognized recently by California's Department of Housing and Community Development which proposed the adoption of emergency graywater regulations into the 2007 California Plumbing Code. Approved by the California Building Standards Commission in August 2009, the revised plumbing code now presents clearer and less restrictive regulations for graywater reuse.

Graywater is typically wastewater low in turbidity, clear in color, and found from the drainage of bathtubs, showers, bathroom washbasins, clothes washing machines, and laundry tubs. Graywater quality is highly variable because it is source dependent given the variability in household water use. For example, water from clothes washers is high in phosphate content, whereas water from the shower has high turbidity and suspended solids. Residential graywater can be categorized as light graywater or heavy graywater.

Light graywater is wastewater from the shower, bath, bathroom washbasin, and clothes washing machine. Heavy graywater is wastewater from the kitchen sink and dishwasher. According to the revised 2007 California Plumbing Code, heavy graywater is not considered graywater in California. Commercial technologies already exist for processing both light and heavy graywater on-site for non-potable usage. However, the recycling and reuse of graywater requires careful considerations of potential health and environmental risks that can arise due to improper use.

Health risk concerns include potential exposure to pathogenic bacteria and viruses, which may occur through direct contact with graywater as well as through exposure to graywater contaminated irrigated areas, crops, or groundwater. For this reason, it is important that human contact with untreated graywater or its areas of exposure are minimized. Under the revised 2007 California Plumbing Code, for example, protective regulations limit direct reuse of untreated graywater to landscape irrigation. Furthermore, the revised Code specifies untreated graywater cannot be used for spray irrigation, but must only be conveyed and distributed underground (e.g., drip irrigation) or below at least two inches deep of mulch, rock, soil, or under a solid shield.

The revised 2007 California Plumbing Code has now eased previous permit requirements for certain untreated graywater delivery and distribution systems. Permit requirements are now based on daily discharge volume, number of household sources, and number of graywater system fixtures. According to the Draft 2010 California Plumbing Code proposed by the California Department of Water Resources [5], expanded indoor and outdoor uses of graywater (e.g., toilet flushing, spray irrigation, etc.) are also possible if the source graywater is treated to meet the California Department of Public Heath statewide uniform criteria for disinfected tertiary recycled water. This implies that, for expanded use graywater (i.e., besides in underground irrigation systems), water quality of treated graywater from small-scale, on-site residential treatment systems would be held to the same regulatory standards as large-scale, centralized municipal water treatment plants.

TREATMENT AND REUSE

The recycling and reuse of graywater requires careful considerations of potential health and environmental risks that can arise due to improper use.

At present, given the revised 2007 California Plumbing Code definition of graywater, both heavy graywater and blackwater must be conveyed to and treated by centralized wastewater treatment plants. Only light graywater can be treated on-site for non-potable usage. Clearly, in order to evaluate the potential significance of graywater to the water portfolio in Southern California, it is instructive to first assess the volume of domestically produced graywater that can be treated and reused relative to the volume of municipal and industrial water usage by California's 37 million residents. California's municipal and industrial water use currently is about 7,600 million gallons of water per day (MGD) of which the South Coast Hydrologic Region uses about 3,650 MGD (nearly 50%). The LADWP service area (~3.8 million people) and the Metropolitan Water District of Southern California service area (~16.8 million people) use about 600 MGD and 3,200 MGD which represent about 8% and 42%, respectively, of California's total M&I water use. It is interesting to note the combined municipal and industrial per capita water consumption in Southern California is nearly twice that of Sydney, Australia – an urban region of similar climate and severe water shortage. The lower residential water consumption in Sydney is due to a multi-faceted approach to water conservation, and a positive change in public attitude.

Single-family and multi-family homes use about 50% (or about 1,800 MGD) and 17% (600 MGD), respectively, of the M&I water used in the South Coast Hydrologic Region, with commercial, industrial and large landscape comprising the bulk of the remaining M&I water use in that region (Figure 3). Water usage in a typical home includes water used for showering, clothes washing, toilet, dishwashing, sinks, and irrigation (Figure 4). In the LADWP service area, the 2010 projection is that indoor water use in single-family homes will be about 127 MGD with outdoor use being about 85 MGD, resulting in an average annual water bill of about $900 for a single-family home. It is interesting to note single-family residents use a greater percentage of water outdoors (62%) relative to multifamily residents (20%) who have limited access to private landscapes (Figure 5).

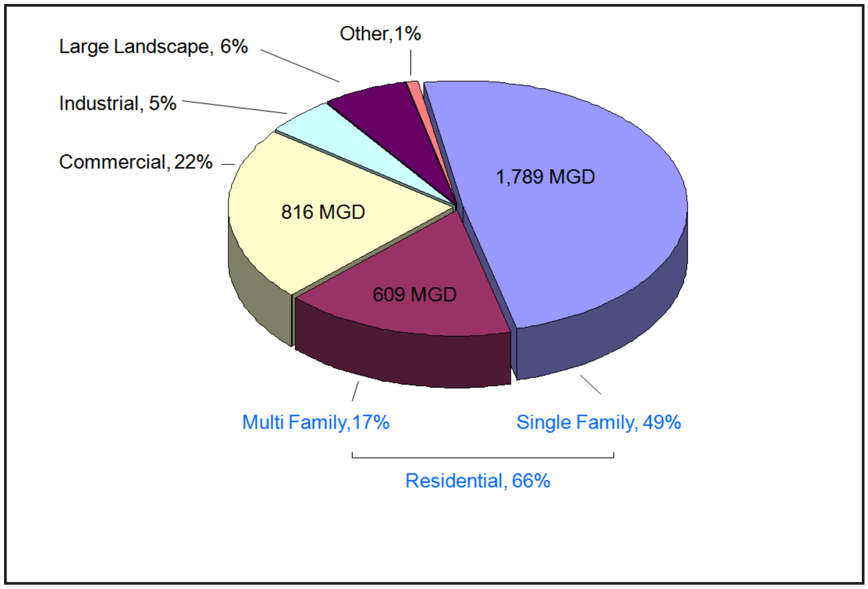

Figure 3. Municipal and industrial water use in the California's South Coast Hydrologic Region (Source: [3]).

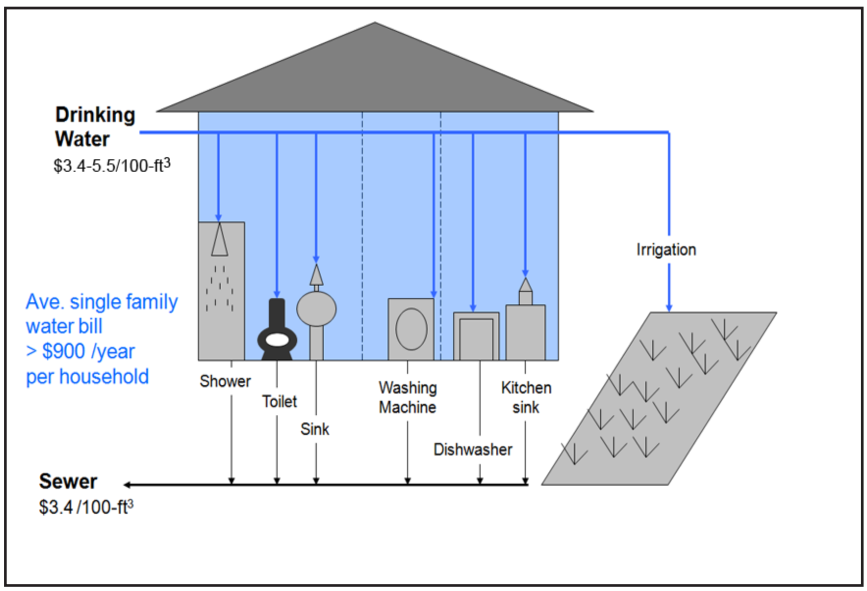

Figure 4. Water use in a single-family home (drinking water and sewer charges are for LADWP rates).

With only 10% of Southern California homes participating, the volume of water saved would be equivalent to the capacity of a modern, large seawater desalination plant such as those proposed for California.

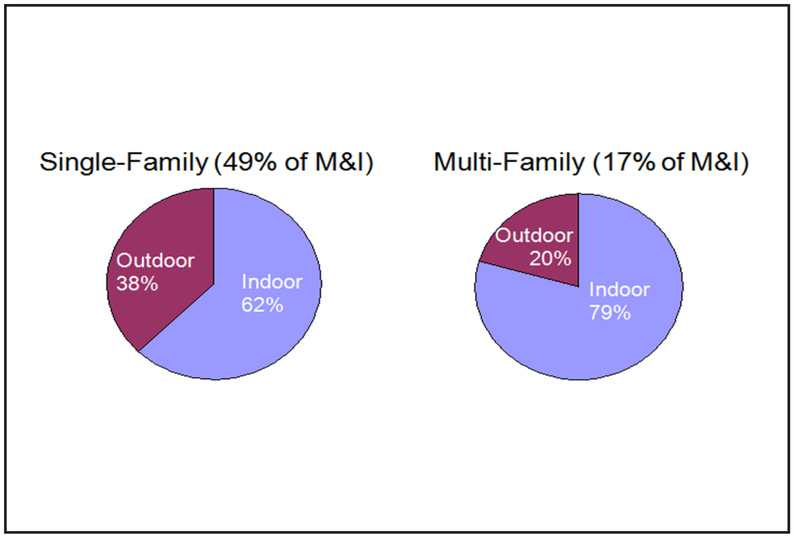

Figure 5. Indoor and outdoor water use in single- and multi-family homes in California's South Coast Hydrologic Region. Source: [3].

Graywater that can be used directly or with a reasonable level of local treatment (i.e., at the point of use) includes clothes washer, shower/bath and faucet (non-kitchen) water constituting about 60% of the total indoor water use in single-family homes (Figure 6). Only 1.3% of the total indoor water in a single-family home is used for washing dishes. This relatively small wastewater stream, from dishwashing or the kitchen sink, is typically not included as graywater because it has a high level of suspended solids and also a high organic content, thus requiring a significant level of treatment to allow even non-potable reuse. Given the above, it is estimated the capacity for graywater recycling and reuse for single- and multi-family homes in the South Coast Hydrologic Region is about 650 MGD and 285 MGD, respectively, or about 25% of the total M&I water used in that region. It is estimated that the residential graywater reuse capacity in the LADWP service area could range from a low of 50 MGD to a high of 165 MGD (or about 8-27% of the total M&I for LADWP service area).

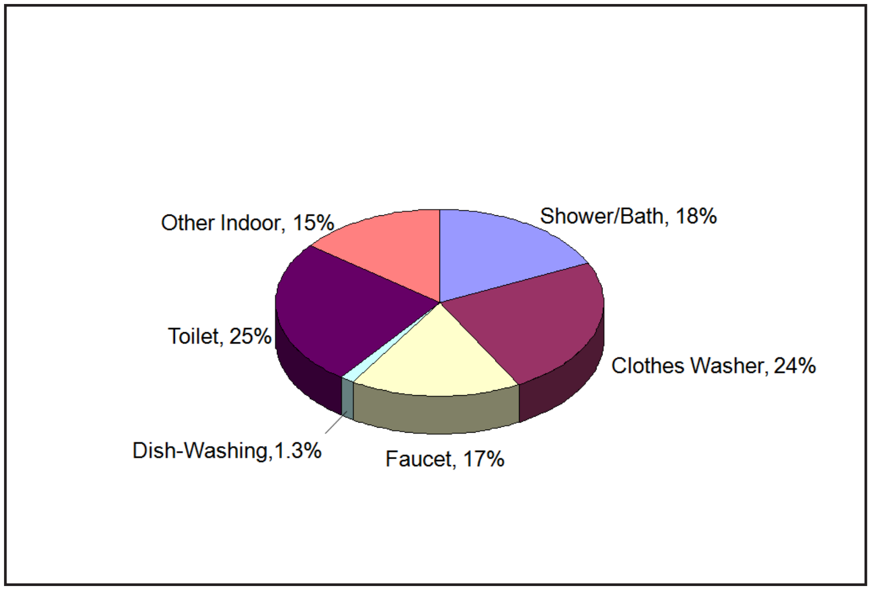

Figure 6. Indoor distribution of water use in a single-family home, based on average per capita indoor consumption data for four cities in Southern California (Source: [6]).

POTENTIAL WATER SAVINGS

In order to assess the potential for potable water savings in the residential sector, it is useful to consider three tiers of graywater reuse and how these can be matched with water demand (Figure 7). Tier 1 includes laundry water, Tier 2 adds shower water, and Tier 3 adds dishwasher and faucets water (including kitchen). As noted earlier, Tiers 1 and 2 are considered light graywater while Tier 3 is considered heavy graywater. It is clear that recycling all of Tier 1 and Tier 2 graywater would be sufficient to meet outdoor water use in Southern California. Adding heavy graywater would meet up to 41% of toilet water use provided this heavy graywater undergoes treatment before use. The estimated residential per capita potable water savings range from 16% - 40% for Tiers 1-3 (Table 1).

Total savings for the 2,400 MGD of residential water use in the South Coast Hydrologic Region would depend on the level of public participation in adopting graywater recycling and reuse practices at the single-residential and community-levels. For example, for a participation of only 10% for Tiers 1-3, the potable water savings for the South Coast Hydrologic Region would range from about 40 to 100 MGD (1.6% - 4%). Although the percent saving may seem small, it is worth noting the volume of water saved is equivalent to, or larger than, the capacity of a modern, large seawater desalination plant such as those proposed for California. Also, the reuse of graywater at the point-of-use has the potential advantage of a lower cost than would be expected for centralized graywater treatment and distribution systems.

Coordinated government assistance for the selection, installation and deployment of distributed graywater systems is needed to accelerate the development of graywater recycling, and to alleviate the pressure on already dwindling potable water resources.

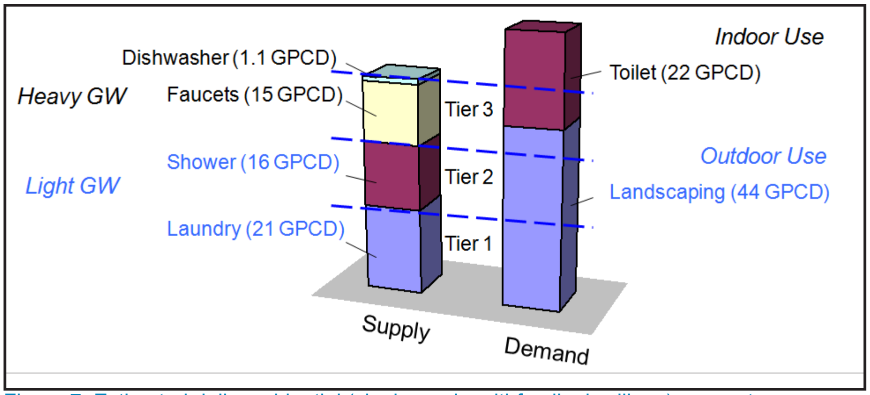

Figure 7. Estimated daily residential (single- and multi-family dwellings) graywater generation (supply) and demand per capita (GPCD = Gallons per capita per day) in Southern California (based on data from Figs. 3, 5, and 6).

Table 1. Estimated potable water savings for residential homes in Southern California

	Daily Potable Water Savings per Capita (gallons)	Daily South Coast Hydrologic Region Total Savings (million gallons) Participation Level		
		100%	10%	1%
Tier 1	21 (16% savings)	383	38	4
Tier 2	37 (28% savings)	672	67	7
Tier 3	53 (40% savings)	964	96	10

Note: Tiers 1-3 are defined consistent with Fig. 7.

TREATMENT LEVEL

Under the revised 2007 California Plumbing Code, Tiers 1 and 2 untreated graywater recycling can be used for subsurface or covered irrigation provided it is not for root crops or food crops with edible parts that contact the soil. According to the Draft 2010 California Plumbing Code, indoor use of Tiers 1-3 for toilet flushing would require water treatment to meet disinfected tertiary recycled water criteria as regulated by the California Department of Public Health. This proposed code implies treated graywater (from small and large volume generators) could be used for unrestricted non-potable use (outdoor and indoor) with the requirement of online water quality monitoring and regulatory oversight that seems to be approaching the level of large-scale centralized water treatment plants.

Three levels of graywater treatment steps are required in order to meet the level of recycled graywater quality for the above stated unrestricted non-potable use: a primary treatment for removal of suspended matter (e.g., sedimentation or filtration), a secondary step for stabilizing organic matter (e.g., biological treatment), and a third step that includes finishing filtration (using membranes or media filters) and disinfection (e.g., UV irradiation). Upgrading the quality of graywater to unrestricted non-potable use may require a significant investment and technical know-how to ensure an effective treatment that will provide adequate public health protection. Therefore, it could be argued the level of sophistication and expense of treating graywater may not be justified, relative to the demand (Figure 7), given that all light graywater (Tiers 1 and 2) can be used to meet about 84% of outdoor residential water use without the need for treatment under current California regulations.

It is undeniable that graywater treatment would provide a protective measure that could garner greater public and regulatory support for the acceptability of graywater as an indispensible part of California's water portfolio. At the same time, the significant added expense and the high level of treatment and monitoring required for upgrading graywater quality to a level allowed for unrestricted non-potable reuse may be an impediment for the deployment of distributed small-scale residential systems for graywater recycling and reuse.

GOVERNMENT INCENTIVES AND PUBLIC INVOLVEMENT

The state of California's recognition of the potential benefit of graywater recycling and its importance in the State's overall water plan is a key step forward. In implementing this approach, California could benefit from the experience other countries have had with graywater recycling. In Australia, for example, government-provided information and certification regarding commercial graywater systems is clear and posted on government web sites. In addition, detailed information is provided to the public sector on available and acceptable graywater recycling technologies and approaches. Moreover, the Australian government has established a National Rainwater and Greywater Initiative with funding and rebates to promote efficient and safe graywater recycling and rainwater storage. Like Australia, Southern California can develop a more sustainable water program by increasing graywater recycling to a level at which it becomes a measurable part of the State's water portfolio. However, an effective graywater recycling program will have to include broad public education and participation, certified and properly managed distributed graywater recycling systems, centralized recycling plants where applicable, and incentives for graywater recycling programs.

CONCLUSION

The volume of residential graywater in Southern California appears sufficient to meet a significant portion of outdoor residential water demand. Coordinated government assistance for the selection, installation and deployment of distributed graywater systems is needed to accelerate the development of graywater recycling, and to alleviate the pressure on already dwindling potable water resources.

GRADE

The State of California earns an overall **Grade B+**. First, for moving forward to address the need to increase California's water portfolio and for recognizing the potential of graywater recycling and reuse; and second, for easing graywater permitting requirements, allowing the use of a variety of technologies. But the State receives a **Grade B-** for providing insufficient public information and guidance regarding graywater recycling technologies and regulations.

ACKNOWLEDGEMENTS

Dr. Anditya Rahardianto and Rose Eng contributed importantly to the development of quantitative data and other information in the preparation of this article. Their efforts are greatly appreciated.

SOURCES

1. California Department of Water Resources California Drought Condition. http://www.water.ca.gov/drought

2. Association of California Water Agencies; California Department of Water Resources California Ends Third Dry Year - Public Called On to Continue Conserving Water. http://www.saveourh2o.org (September 30, 2009).

3. California Department of Water Resources California Water Plan Update 2005, December 2005. http://www.waterplan.water.ca.gov

4. California Building Standards Commission Recently Approved Changes in Code Standards. http://www.bsc.ca.gov/apprvd_chngs/default.htm (August 4, 2009).

5. California Department of Water Resources Draft 2010 California Plumbing Code: Chapter 16 – Part II, Recycled Water Systems.

6. Mayer, P.W., W.B. DeOreo, E. Opitz, J. Kiefer, B. Dziegielewski, W. Davis, J.O. Nelson, American Water Works Association (AWWA), Residential End Uses of Water Study (REUWS), Denver, CO, 1999.

Yoram Cohen, Ph.D.

AUTHOR BIO

Dr. Yoram Cohen received his B.A.Sc., M.A.Sc., in 1975 and 1977, respectively, both in Chemical Engineering, from the University of Toronto, and his Ph.D. from the University of Delaware in 1981. He has been on the Faculty of Chemical and Biomolecular Engineering at the University of California, Los Angeles (UCLA) since 1981. He is the founder and Director of the Water Technology Research Center and the Center for Environmental Risk Reduction, and a member of the UCLA/National Science Foundation Center for the Environmental Implications of Nanotechnology. Dr. Cohen is an Adjunct Professor at Ben-Gurion University and a member of the International Advisory Committee to the Stephen and Nancy Grand Water Research Institute at the Technion.

Dr. Cohen is a UCLA Luskin Scholar and a recipient of the 2008 Ann C. Rosenfield Community Partnership Prize in recognition of his environmental research. He received the 2003 Lawrence K. Cecil award in Environmental Chemical Engineering from the American Institute of Chemical Engineers (AIChE), as well as the AIChE Separations Division Outstanding Paper Award (1997). In 2008 he received a County of Los Angeles Commendation, a State of California Senate Certificate of Recognition, and a Certificate of Special Congressional Recognition (U.S.) for contributing to legislation to protect public health and dedicated service to the Los Angeles community. Dr. Cohen has published over one hundred and fifty research papers and book chapters in water technology, separations processes, transport phenomena, polymer science, surface nano-structuring and environmental engineering. Dr. Cohen developed patented technologies in membrane synthesis, reverse osmosis desalination, surface nanostructuring and chemical sensors.

Credits

Editor: Arthur M. Winer, Ph.D.
Managing Editor: J. Cully Nordby, Ph.D.
Design: Vita Associates
Website and Print Production: Scott Gruber
Title Photo: Ivan Mikhaylov

UCLA Chancellor: Gene D. Block, Ph.D.
IoE Acting Director: Glen M. MacDonald, Ph.D.

UCLA Institute of the Environment
La Kretz Hall, Suite 300
Box 951496
Los Angeles, CA 90095-1496
Tel: (310) 825-5008
Fax: (310) 825-9663
www.ioe.ucla.edu