

---

## USE OF GREYwater FOR FOOD PRODUCTION IN HOMESTEAD GARDENS OF SOUTH AFRICA

### UTILISATION D'EAU GRISE POUR LA PRODUCTION ALIMENTAIRE DANS LES JARDINS FAMILIAUX EN AFRIQUE DU SUD

N. Rodda, H.M. du Plessis and G. Backeberg

#### ABSTRACT

Indiscriminate greywater disposal can result in health risks and environmental degradation. This is more likely to occur in poor settlements which also experience food insecurity. Using greywater for small-scale irrigation of food crops is a possible means of addressing both problems. This paper describes the philosophy underlying the guidance developed for small-scale greywater irrigation in South Africa. A semi-quantitative risk-based approach was adopted. Three user groups and their associated exposures and risks were defined : human users and consumers (infectious diseases), crop plants (growth and yield), and irrigated soil (reduced ability to support plant growth). Limits on selected greywater constituents were defined, and greywater quality and/or exposure barriers were identified to allow risk and uncertainty to be balanced. In addition to quality, the importance of quantity of greywater applied was highlighted. Hurdles to the implementation of the guidance remain, and are listed. Despite these, carefully managed greywater use has the potential to address both water security and food security challenges in poor settlements in South Africa.

**Keywords:** Wastewater reuse; Greywater irrigation; Food security; Risk; Human health; Plant growth; Soil

#### 1. Introduction

South Africa is water-scarce, with approximately 65% of the country receiving an average annual rainfall of less than 500 mm, considered to be the minimum rainfall required for rain-fed cropping (Schulze, 1997). Climate change implies hotter and drier conditions with greater water stress in the future (Blignaut et al., 2009). As with most environmental and economic stressors, poor inhabitants of rural areas and of under-serviced informal settlements are affected the most. Food insecurity is closely linked to water stress. In 2009, South Africa had approximately 2.2 million food insecure households. Among the initiatives taken by the South African government to combat household food insecurity is a "one house, one food garden" policy (Morokolo, 2009). Despite this, household and small communal food gardens are not widely recognised as means of achieving household food security. There are many factors which contribute to this, but an important reason is that, for poor households, obtaining adequate quantities of reasonable quality water is arduous and possibly expensive.

#### 2. The role of greywater use in water security and food security

The same types of households that are affected by poor services and poor food security, often also lack infrastructure for greywater disposal. Greywater is untreated household wastewater from kitchens, bathing/showering and laundry. In the absence of sewers, greywater is commonly poured out on the ground outside the dwelling, contributing to adverse health effects and environmental degradation (Carden et al., 2007; Rodda et al., 2010). One way of addressing these interlinked problems is by reserving good quality water for household uses likely to be associated with ingestion (drinking, cooking, dishwashing, bathing) and using lower quality water for purposes involving lower risk of direct exposure. Greywater is one such example, providing an alternate water source for irrigation of food crops.

### 3. Greywater use in South Africa

The Water Research Commission, as the key funding body for water-related research in South Africa, has identified greywater as a potential alternate water resource for irrigation in small-scale agriculture and home gardens, particularly during periods of drought. It has supported projects on the fitness-for-use of greywater (Murphy, 2006), generation and quality of greywater in unsewered settlements (Carden et al, 2007), guidance for use of greywater in small-scale irrigation (Rodda et al., 2010) and management of greywater in unsewered settlements (Winter et al., 2011). This paper focuses specifically on the philosophy and structure of the 2010 Guidance Document (and supporting Technical Report) for small-scale irrigation use of greywater that is intended for use by local authorities and potential greywater users, and to support policy development at national scale.

### 4. Key concepts underlying guidance for greywater irrigation in South Africa

#### 4.1 Recognition of water users, exposures, hazards, risks and uncertainty

Water quality guidelines of any sort are intended to reduce the risks associated with a given water use. The concept of risk comprises two components, viz. the existence and extent of a hazard, and the extent of exposure of water users to that hazard (WHO, 2006). In the case of greywater use for small-scale irrigation, three classes of hazards were identified:

- (1) Possible adverse effects on human health
- (2) Possible adverse effects on plant growth and yield
- (3) Possible adverse effects on the environment, specifically on the long term ability of irrigated soil to support plant growth.

The publication of the 2006 *Guidelines for Reuse of Wastewater, Excreta and Greywater* by the World Health Organisation firmly established the principles of risk identification, risk assessment, and risk management as the underlying processes in guideline development. Because of the wide range of potential users of greywater (humans, plants, soil) and of classes of outcomes associated with exposure of users (human health impacts, reduction of plant growth and yield, reduction in the capacity of irrigated soil to support plant growth), it was not possible to use quantitative risk assessment as described in WHO (2006) and other sources. Instead, an extensive survey of the peer-reviewed literature and the increasing 'grey literature' on greywater was conducted to establish the quantitative limits on water quality commonly associated with the three different classes of greywater users and potential adverse outcomes.

In order for risks to be managed, some data, preferably quantitative, are required regarding the exposure of water users to identified hazards. Because the population groups most likely to show interest in greywater irrigation initially are individuals, small collectives of individuals or NGOs, it is likely that many would be unable (and possibly unwilling) to carry the cost of greywater analysis. As local authorities or larger concerns become involved, capacity and willingness to undertake characterisation of greywater quality before planning reuse can be expected to increase. These considerations gave rise to the definition of three exposure scenarios for management of risks associated with greywater irrigation:

Category 1: Users who are unable or unwilling to undertake any greywater analysis.

Category 2: Users who are willing and able to undertake some analysis of greywater. A 'minimum analysis' of pH, electrical conductivity (EC), sodium adsorption ratio (SAR) and faecal/thermotolerant coliforms or *E. coli* was defined. Limits are specified for these, and implicit for Category 2 use is that compliance with these limits can be achieved.

Category 3: Users who are willing and able to undertake a more comprehensive analysis of greywater. A 'full analysis' was defined, comprising the same constituents as for minimum analysis, plus boron, chemical oxygen demand (COD), oil and grease, suspended solids, total inorganic nitrogen and total phosphorus. Limits are specified for these additional constituents and, as for Category 2, it is implicit that compliance with these limits can be achieved.

Categories 1-3 represent a balance of managing risk and managing uncertainty. Uncertainty arises from the degree to which the quality of greywater, or the improvement in quality as a result of some form of intervention, is known. If there is adequate knowledge of the quality of the greywater, as represented incrementally by Categories 2 and 3, then uncertainty is relatively lower and fewer exposure barriers are needed. Where there is little or no knowledge of the quality of greywater, as for Category 1, then uncertainty is relatively larger and risk needs to be managed primarily by instituting exposure barriers to reduce potential risk. User categories 1 to 3 are each linked to tables of exposure which allow for a balance between risk and uncertainty. Examples of exposure barriers include not using kitchen greywater without a minimum level of treatment, specified as a mulch tower (reducing COD, oil and grease, suspended solids, and health-related bacteria); application of greywater in a manner that avoids contact with leaves and crop (mitigating health effects and leaf burn effects of pH and EC); washing, peeling or cooking crops before consumption (reducing health effects); applying excess greywater (leaching of salts from soil) or adding gypsum to soil (mitigating SAR).

While the identified ranges of users and hazards are too varied to allow for a consistent quantitative risk assessment methodology across all risk types, a semi-quantitative categorisation of risk associated with each greywater constituent was made, similar to the approach adopted in the *South African Water Quality Guidelines for Irrigation* (DWAf, 1996). Risk-based concentration ranges of greywater constituents were defined, in order of increasing risk, as follows : a target

range; a maximum range for longer term use; a range which allows for site-specific use for limited periods only ; and concentrations which make greywater unsuitable for irrigation use unless the greywater is treated first.

#### 4.2 Mitigating risks associated with greywater quality

There are two complementary ways of mitigating risks associated with greywater irrigation, reflecting the flexibility introduced by adopting a risk-based approach. Risks associated with physico-chemical constituents (e.g. boron, EC, pH, SAR) are best mitigated by integrative agricultural practices such as choice of greywater application method; soil amelioration by addition of mulch or gypsum; leaching of soil by application of excess greywater or alternating greywater irrigation with fresh water irrigation; planting tolerant crops; or accepting a reduced crop yield. Risks associated with organic and biological constituents (e.g. COD, oil and grease, suspended solids, health-related bacteria) are best mitigated by treatment, usually some form of biological treatment.

#### 4.3 The role of volume of greywater and recognition of plant-, season- and site-specific factors

Greywater irrigation requires consideration of both the quality and the quantity of greywater applied. The latter aspect is especially important for maximising plant growth and yield, and for prevention of soil degradation. Quantitative estimates for maximum volumes of greywater (EWU) which can be applied were derived from evapotranspiration rate ( $E_0$ ), a crop factor (CF) indicating plant-water use, and area to be irrigated (HA), as shown in Equation 1 (based on Green, 1985).

$$EWU = E_0 \times CF \times HA \quad (\text{Equation 1})$$

where  $EWU$  = maximum estimated water use (measured in  $\ell \cdot d^{-1}$ );  $E_0$  = reference evapotranspiration rate (location-specific and season-specific; a meteorologically-derived measure, measured in  $mm \cdot d^{-1}$ );  $CF$  = crop factor, a measure of plant-specific water use (a unit-less ratio) ; and  $HA$  = area to be irrigated (measured in  $m^2$ )

EWU represents the amount of water required by a plant in light of climatic conditions only. It does not include other factors which could modify plant-water use and so represents the maximum amount of water which can be applied. To facilitate use by even unsophisticated irrigation water users, EWU values were calculated for a number of combinations of  $E_0$  (from Green, 1985) representing a number of climatic zones (selected according to Blignaut et al., 2009) in both winter and summer. Representative crop factors (0.8 for high water-use plants; 0.5 for moderate water-use; 0.3 for low-water use), and representative irrigated areas (5, 10, 20  $m^2$ ) were used to construct look-up tables of EWU. These allow users to select combinations of  $E_0$ , CF and HA closest to their application and obtain a simple estimate of the maximum amount of greywater which should be applied. The look-up tables intentionally avoid the most recent irrigation science since this would require considerably greater data availability and technical expertise than may be expected in small-scale irrigation applications. Additional qualitative guidance is provided to support users in making judgements in relation to site-specific factors such as frequency and means of greywater application, and adjustment of greywater volumes for recent rainfall.

### 5. Challenges facing greywater use for small-scale irrigation in South Africa

The guidance developed in this study makes significant strides towards bringing greywater use for irrigation into the mainstream of options available for water resource protection. A number of pressing factors stand in the way of wider implementation.

- (1) At the level of national government, and hence at all lower levels too, greywater is not explicitly recognised as a waste stream which can be separated at source and used beneficially.
- (2) Workshops held with local authorities (municipalities) showed clearly that, except for the major metropolitan municipalities, almost none had a policy for greywater collection, treatment or use.
- (3) Interviews with greywater generators in poor unsewered settlements and in lower to middle income sewerred settlements also had little concept of greywater as a separate wastewater stream which could be captured and reused. Many indicated distaste or fear about using "dirty water" to grow plants that produce edible crops.
- (4) Informal settlements present a particular problem. Carden et al. (2007) and Winter et al. (2011) highlight that these settlements lack a sense of community which would motivate inhabitants to handle waste streams in and around their individual living spaces in such a way as to serve the greater good. In addition, on the scale of daily problems to be faced by inhabitants, greywater is not seen as a priority pollutant. Greywater projects planned in such settlements would require a great deal of community liaison work by local authorities to prepare the way for successful greywater irrigation initiatives.
- (5) Robust on-site treatment systems are needed that can improve the organic and biological quality of greywater at household and community level, and that can be operated and maintained with minimum technical and financial capacity.

### 6. Conclusions

Uncontrolled discharge of greywater poses a threat to human health and the environment, especially in poor and informal settlements where greywater mingles with other waste streams. If greywater can instead be used for irrigation of home or food gardens, indiscriminate greywater disposal to the ground around dwellings can be reduced. Greywater holds the

potential to provide a reliable water source for irrigation and can contribute to improving food security of poor households. However, certain constituents of greywater may be hazardous to users and consumers, to plants and to irrigated soil. The Water Research Commission has funded a series of studies on greywater, culminating in the formulation of guidance for greywater irrigation in South Africa. The underpinning principles of the Guidance Report comprise risk identification, risk assessment and risk management, with recognition of the importance both of managing the quality of greywater and of implementing exposure barriers. Guidance is also provided on the volume of greywater which can be applied and the manner in which this can be achieved, with some flexibility in terms of site-specific factors.

The greatest priorities moving forward include resolving ambiguity surrounding the legal status of greywater use in South Africa; education about greywater use, particularly of local authorities and of inhabitants of poor settlements experiencing food insecurity; development of robust simple household-based treatment systems; and addressing the greater socio-economic and service delivery problems of informal settlements which mean that greywater is perceived as low priority in terms of its management and its potential as an alternate water resource.

## **7. Acknowledgement**

This paper is based largely on information emanating from a project entitled “Sustainable Use of Greywater in Small-scale Agriculture and Gardens in South Africa” (WRC Project No. K5/1639), which was funded by the South African Water Research Commission.

## **REFERENCES**

- Blignaut, J., Ueckermann, L., Aronson, J. 2009. Agriculture production's sensitivity to changes in climate in South Africa, *South African Journal of Science* 105, 61-68 and online supplementary material.
- Carden, K., Armitage, N., Sichone, O., Winter, K., 2007. The Use and Disposal of Greywater in the Non-Sewered Areas of South Africa. WRC Report No. 1524/1/07, Water Research Commission, Pretoria, South Africa.
- DWAF, 1996. South African Water Quality Guidelines (SAWQG), 2<sup>nd</sup> edition, Volume 4: Agricultural Water Use: Irrigation. Department of Water Affairs and Forestry (now Department of Water and Sanitation), Pretoria, South Africa.
- Green, G.G., (editor), 1985. Estimated Irrigation Requirements of Crops in South Africa, Parts 1 and 2. *Memoirs on the Agricultural Natural Resources of South Africa*, No. 2. Soil and Irrigation Research Institute, Department of Agriculture and Water Supply, Pretoria, South Africa.
- Morokolo, B., 2009. Short-term policy response to higher and volatile food prices. Presentation to the Global Forum on Agriculture, 29-30 June, France <http://www.oecd.org/dataoecd/2/50/43039179.pdf> (accessed February 2012).
- Murphy, K., 2006. *A Scoping Study to Evaluate the Fitness-For-Use of Greywater in Urban and Peri-Urban Agriculture*. WRC Report No. 1479/1/06, Water Research Commission, Pretoria, South Africa.
- Rodda N., Carden K. and Armitage N., 2010. Sustainable Use of Greywater in Small-scale Agriculture and Gardens in South Africa, Guidance Report. (WRC Report No. TT469/10) and Technical Report (WRC Report No. 1639/1/11), Water Research Commission, Pretoria, South Africa.
- Schulze RE, 1997 *South African Atlas of Agrohydrology and Climatology*. WRC Report No. TT 82/96. Water Research Commission, Pretoria, South Africa.
- WHO, 2006. WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater, Vol IV: Excreta and Greywater Use in Agriculture. World Health Organisation, Geneva, Switzerland.
- Winter K; Spiegel A; Armitage N; Carden K, 2011. Sustainable Options for Community-level Management of Greywater in Settlements Without On-site Waterborne Sanitation. WRC Report No. 1654/1/11, Water Research Commission, Pretoria, South Africa.