

1 **Impact of system factors on the water saving efficiency of household grey water recycling**

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30 **Abstract**

31 A general concern when considering the implementation of domestic grey water recycling is to
32 understand the impacts of system factors on water saving efficiency. Key factors include household
33 occupancy, storage volumes, treatment capacity and operating mode. Earlier investigations of the
34 impacts of these key factors were based on a one tank system only. This paper presents the results of an
35 investigation into the effect of these factors on the performance of a more realistic ‘two tank’ system
36 with treatment using an object based household water cycle model. A Monte-Carlo simulation
37 technique was adopted to generate domestic water appliance usage data which allows long term
38 prediction of the system’s performance to be made. Model results reveal the constraints of treatment
39 capacity, storage tank sizes and operating mode on percentage of potable water saved. A treatment
40 capacity threshold has been discovered at which water saving efficiency is maximised for a given pair
41 of grey and treated grey water tank. Results from the analysis suggest that the previous one tank model
42 significantly underestimates the tank volumes required for a given target water saving efficiency.

43

44 **Key words**

45 Grey water recycling, household water cycle, sustainability, water saving efficiency

46

47 **Introduction**

48 In a world of increasing population, urbanisation and consumption, prudent management of water
49 resources has never been more important. One element of a water conservation strategy is that of grey
50 water recycling, in which used water from the bathroom hand basin, shower and bath is recycled for
51 toilet flushing and/or gardening watering. Treated grey water represents water whose quality is
52 sub-drinking standard, but is suitable for uses such as garden watering or toilet flushing. Domestic grey
53 water recycling has found some applications in the drier parts of developed countries such as Australia
54 [1] and the USA [2] and more niche markets in Germany [3], Netherlands [4], Greece [5], Canada [6]
55 and Sweden [7]. In Australia, dual pipe system for potable water and treated grey water is commonly
56 installed in new development buildings in recent years [8]. In Tokyo, grey water recycling is
57 mandatory for buildings with a floor area over 30,000 m² or with the potential to reuse at least 100
58 m³/day [9] and there have been other ‘keynote’ applications at large scale elsewhere (e.g. the London
59 Millennium Dome, in which around 500 m³ of water per day was reclaimed to flush toilets and urinals

60 on the site [10]. In developing countries, in order to tackle water shortage problem, grey water reuse
61 has become a preferred choice [11-13].

62

63 An important reason for the lack of widespread adoption of household grey water recycling is the
64 financial viability of the system [14-15]. This is linked in part to the amount of water that can be saved
65 by such systems, which in turn is linked to their design. Critical factors must be the configuration and
66 volume of water storage tanks, and the throughput or capacity of any treatment used. Strangely, this has
67 received relatively little attention in the literature. For example, in Friedler and Hadari's example of
68 implementation of grey water reuse for multiple flats, two storage tanks of 1m^3 each were selected,
69 without specific reference to the building size [16]. Two storage tanks with size of 4.0 m^3 and 4.5 m^3
70 were employed in a grey water reuse system serving 81 rooms in a hotel [17]. Furthermore, Ghisi and
71 Mengotti de Oliveira determined the size of treated and grey water tank sizes simply according to the
72 daily toilet water demand and grey water production [18]. In Ghisi and Mengotti de Oliveira's example,
73 the authors argue that '*The daily production of grey water in houses A and B is 239.8 and 170.1 litres,*
74 *respectively. Therefore, a grey water tank of 250 litres would suffice. As for the daily grey water*
75 *demand for toilet flushing, it is 174.8 litres in house A and 62.2 litres in house B. Such a demand is*
76 *lower than the grey water production in both houses. Therefore, treated grey water tanks of 250 litres*
77 *were adopted in both houses.'* Therefore, a full understanding of the impacts of system factors on the
78 amount of water that can be saved and the determination of system configuration is desirable.

79

80 Probably the most comprehensive analysis of grey water system design and performance has been
81 undertaken by Butler and co-workers [19-20]. This has also formed the basis of UK advice on system
82 sizing [21]. In this work, a simple grey water recycling system configuration was analysed, consisting
83 of domestic appliances and a single grey water storage tank only. It was found that the percentage of
84 potable water (for toilet usage) displaced by non-potable water, for a given household size, was directly
85 (although non-linearly) related to grey water storage tank volume [19]. A system storing 100 to 200
86 litres was found to be optimal for a family of five persons, giving over 90% toilet flushing water
87 displacement. However, on further reflection it now seems these values may be optimistic, for the
88 following reasons:

89

- no treatment device was modelled. This effectively assumes an infinite treatment capacity.

90 • no non-potable water tank was modelled. This effectively assumes treated grey water is fed
91 into the toilet cistern directly.

92 Thus there is a need to represent the system more comprehensively and to re-evaluate potential water
93 savings in the light of this development. This paper introduces a new model developed to allow this
94 evaluation and systematically re-assesses the potential for water savings in such systems.

95

96 **Household water cycle model**

97 To carry out this assessment, a new model of the household water cycle has been developed using an
98 object-based approach. An object is a formal and simplified representation of a real world entity or
99 phenomenon, abstracted and viewed as a black box, that can receive external requests or stimulation
100 and perform corresponding responses by invoking its internal methods. An object is typically
101 composed of an interface, which facilitates the interaction with other objects, a method library, which
102 represents the functionality the object has, and a property table, which indicates the object's attributes.
103 The object's attributes and methods are neither visible from the outside of the object nor accessible by
104 other objects. They are encapsulated and private. Communication between objects is only facilitated
105 through their interfaces [22].

106

107 In the household water cycle context, the elements of the system, 'water source' (e.g. mains water
108 supplier, non-potable water), 'water use' (e.g. hand basin, toilet and shower), 'treatment unit' and
109 'sink' (e.g. downstream sewer) are all viewed as self-contained objects that encapsulate specific
110 attributes and behaviours and can interact with other objects by exchanging water quantity and quality
111 information. A storage tank, for example, is treated as a source object. The household water cycle is
112 then conceptualised as a combination of water source, water use, treatment and sink objects.
113 Construction of the object-based model consists of specifying and populating each object's interface,
114 method library and property table, and establishing the data communication between objects. In this
115 work, the household water cycle model was constructed on a MATLAB (Simulink) platform and the
116 property table is managed in Excel.

117

118 Two methods have been used to calculate the dynamics of water storage tanks: 'spill before yield' and
119 'spill after yield' [23]. 'Spill before yield' indicates that, in the modelling process, overflow takes place

120 *before* satisfying water demand in each time step. ‘Spill after yield’ assumes that overflow occurs *after*
 121 satisfying the demand. ‘Spill before yield’ generated more conservative estimates of system
 122 performance when compared to those predicted by the ‘spill after yield’ rule [24]. In the household
 123 water cycle model, the storage tanks aggregate the inputs and outputs in 10 minute time steps using the
 124 ‘spill after yield’ concept. If the tank volume is exceeded, then excess is discharged to waste (i.e. sink).
 125 If sufficient water is not available in the treated grey water tank to meet demand, mains potable (white)
 126 water supply makes up the difference.

127

128 The performance of the reuse system is evaluated in terms of water saving efficiency (*WSE*), defined as
 129 the percentage of white water saved by reusing grey water. The *WSE* reflects to what extent the toilet
 130 demand is satisfied by treated grey water.

$$131 \quad WSE = 100 * \frac{\sum_{t=1}^T W_t}{\sum_{t=1}^T D_t} \quad (1)$$

132 Where:

133 T = Run length

134 W_t = Amount of treated grey water used for toilet flushing

135 D_t = Toilet water demand

136

137 The benefit of such a modelling approach and this model in particular, is its transparency, flexibility,
 138 adaptability and speed/ease of coding. For example, the inclusion of a new appliance type can be
 139 achieved without revisiting the model code, making it straightforward to simulate the household water
 140 cycle with different system specifications and configurations.

141

142 **System configuration**

143 A domestic grey water reuse system is typically composed of a primary tank, which stores the grey
 144 water and provides inflow to the treatment unit; a treatment unit, which treats the grey water up to a
 145 certain quality to comply with relevant standards and a secondary tank, which stores and provides
 146 treated grey water to satisfy toilet water demand. A mains top up mechanism is typically included in
 147 the treated grey water tank to ensure continuity of supply at all times. A schematic illustration of such a

148 system is given in figure 1. In this work, use of grey water for garden watering is neglected and
149 attention focused on toilet flushing only. Two float switches are typically employed in the grey
150 recycling system to facilitate the top up of treated grey water and white water (see inset to Figure 1).
151 This mechanism is simulated in the household water cycle model, whereby white water top up, is only
152 triggered when enough water to supply toilet demand is not available.

153

154 (Figure 1 here)

155

156 The process efficiency of the treatment unit is not specifically represented in this work; rather it is
157 assumed that the reclaimed grey water produced is good enough for toilet flushing purposes. Also, it is
158 assumed that no water is lost during the treatment process. Thus, the treatment device is general and
159 not pointed to any specific technique although the capacity or throughput of the treatment unit is
160 specified.

161

162 **Data pretreatment**

163 In order to make useful observations for the performance of a water reuse system, it is necessary to
164 assess its behaviour over an extended period. Ideally, it should be evaluated over its expected lifetime.
165 Typical data requirements are frequency of use and volume per use for all relevant appliances,
166 throughout the day. However, it is hard to source this kind of water use profile data over a long period.
167 Therefore, in this project, the Monte-Carlo method was applied to generate the large data set required,
168 based on the data available. This method uses random numbers to index cumulative probability
169 distributions made up from the frequency and/or volume of water use by each appliance and generates
170 a time series of appliance events that have the same statistical properties as the parent data set. It is
171 assumed that each appliance water use event is statistically independent.

172

173 The data used in this study was obtained from a large-scale survey conducted by WRc to investigate
174 water consumption trends in different parts of the UK. The data collection procedure involved
175 installation of a consumption monitoring system outside each participating household. The system
176 consisted of a flow meter and data logger capable of recording every 10ml of water used at 1 second
177 intervals for periods up to 2 week. The logged consumption data was processed using the Identiflow

178 software [25]. This identifies flow characteristics and classifies water-use events, as one of: toilets,
179 showers, baths, internal and external taps, washing machines and dishwashers. A sub sample of this
180 data set was assembled consisting of water usage data over 7 consecutive days from 16 households in
181 England [26]. The data was regrouped into 10 minute time steps and classified according to occupancy
182 ranging from 1 to 5 people. For each occupancy, a cumulative probability distribution of frequency of
183 water used by each appliance was assembled for each ten minute interval. Distributions of water use
184 events in terms of time and household were examined. Spatial and temporal differences of water use
185 event were found. Taking toilet flushing as an example, Figure 2 shows the cumulative number of toilet
186 use event in every 10 minutes interval during a day (144 intervals) for the 100 households. Except for
187 the morning and evening peak uses, toilet flushing is featured as a randomized event. Figure 3 displays
188 the distribution of number of toilet use event and household numbers, which reveals that most
189 households (79 households) use 10-14 times of toilet per day. It is also noticed from Figure 3 that 8
190 households use less than 7 times of toilet per day, which might be because of less people living in. In
191 generating water use profile time series data using Monte-Carlo method, spatial and temporal
192 differences were taken into account to represent the differences of water use event in term of time and
193 household.

194 (Figures 2,3 here)

195

196 **Model simulation runs**

197 A 10-year dataset was derived as input into the household water cycle model. Given the flexibility of
198 the model and the interest in re-evaluating water saving efficiency for more realistic configurations, a
199 scenario-based approach was used (five in all) based on varying the key factors of storage tank number
200 and volume, treatment capacity, treatment operating mode and dwelling occupancy.

201

202 Scenario 1 is designed to investigate the water cycle for a single (grey water) tank system. Scenarios 2,
203 3, 4 and 5 are designed to analyse the water dynamics in two tank (grey and treated grey) systems. In
204 each scenario, the values of one or two factors were changed while the others kept as default values.
205 Unless stated otherwise, default values are: grey water tank volume = 50 litres; treated grey water tank
206 volume = 100 litres; treatment operating mode = continuous; household occupancy = 3 people. The
207 configuration of factors in each scenario is summarized in Table 1.

208

209 (Table 1 here)

210

211 Two types of treatment operating mode were considered: continuous and intermittent. The former
212 reflects the treatment device operating at a constant production rate over 24 hours. In the latter situation,
213 the device operates part-time designed to be consistent with the peak uses of toilet in the morning and
214 evening periods.

215

216 **Results and discussion**

217 *Scenario 1: Single tank system --- without treatment device constraint.* Scenario 1 is designed to
218 investigate the relationship between water saving efficiency and grey water tank volume without
219 treatment capacity constraint for a ‘one tank’ system. The treatment device is assumed to have an
220 unlimited capacity and perform in a continuous mode. With this assumption, it is deemed that grey
221 water can be treated and utilised immediately when a toilet water demand occurs. Therefore, no treated
222 grey water tank is required. This actually represents an extreme system situation and is the same as the
223 one investigated in [19]. In the model simulation, the grey water tank size was allowed to vary from
224 zero to 100 litres. The average water saving efficiency (over the 10 year period) for different grey water
225 tank sizes is shown in figure 4. As expected, efficiency increases with volume, but at a declining rate.
226 Thus, the percentage of potable water saved is more sensitive to grey water tank volume when it is
227 relatively small, i.e. in the range of 0 to 50 litres. For the three-person household under discussion (with
228 a daily toilet demand of 94 litres), a 20 litre grey water tank saved 67% of toilet water demand, 40 litres
229 87% and 60 litres 92% respectively. These findings are consistent with results reported in [19] in which
230 a similar relationship between water saving efficiency and grey water tank volume was obtained.

231

232 (Figure 4 here)

233

234 *Scenario 2: Two tank system --- treated grey water tank volume.* The relationship between water saving
235 efficiency and treated grey water tank size in a ‘two tank’ system was investigated in scenario 2. A
236 default value of 50 litres was adopted for the grey water tank volume. Results are presented in figure 5.
237 It was found that the impact of treated grey water tank volume is similar to the findings for the grey

238 water tank in scenario 1. This is reflected in three aspects. First, for a given treatment capacity, water
239 saving efficiency increases with increasing volume of treated grey water tank, but the rate of increase
240 weakens with increasing volume of tank up to an asymptote. Second, the water saving asymptote value
241 is directly related to the treatment capacity. Third, given appropriate treatment capacity, grey and
242 treated grey water tank volumes, it is possible that 100% of toilet water demand can be satisfied by
243 treated grey water.

244 (Figure 5 here)

245

246 *Scenario 3: Two tank system --- treatment capacity.* As previously suggested, treatment capacity can
247 have a significant impact on grey water reuse system performance. When the treatment capacity is low
248 (for example, 20 litres per day, shown in figure 5), a maximum water saving efficiency of just 20% can
249 be reached regardless how big the treated grey water tank is. Within a certain range (up to 140 litres per
250 day, see figure 5), the maximum water saving efficiency increases with increasing treatment capacity.
251 However, beyond 140 litres per day (figure 5), performance is hardly affected, particularly at higher
252 treated grey water tank volumes.

253

254 Figure 6 shows water efficiency versus treatment capacity for a range of grey and treated grey water
255 tank volumes. It clearly indicates that water saving efficiency is maximised at a threshold treatment
256 capacity of 200 - 350 litres per day for these configurations in scenario 3. Beyond this point, efficiency
257 slowly declines or keeps static regardless the increasing of treatment capacity. This effect is produced
258 by the complex interaction between water supply and demand in relation to the filling of the two tanks,
259 remembering that the treated grey water tank has the potential for mains top up if it cannot supply the
260 requested demand. Whether the water saving efficiency keeps constant or declines beyond the
261 threshold point is dependent on the interactions between grey and treated grey water tank volumes,
262 treatment capacity, grey water production and toilet water demand. For given volumes of grey and
263 treated grey water tank volumes, a bigger treatment capacity means more grey water could be treated
264 into treated grey water. However, it might also result in less grey water to be actually reused for toilet
265 flushing because a bigger treatment capacity can encourage overflow from the treated grey water tank
266 and deficit of grey water. Other pairs (grey and treated grey) of storage tank volumes in the range of 0
267 to 200 litres have also been analysed and it was found that a threshold point exists for each pair.

268

269 Apart from the existence of a treatment threshold, it is also observed that the increasing trend is greater
270 than the decreasing trend on each side of the threshold point. This explains why the water saving
271 efficiency curves corresponding to a treatment capacity from 160 litres per day to 280 litres per day are
272 closely overlain in figure 5, while curves for treatment capacity below 80 litres per day are well spaced.

273

274 From Figures 5 and 6, it is clear that the relationships of water saving efficiency with grey and treated
275 grey water tank sizes and treatment capacity is quite complicated. No simple equations are available to
276 express their relationships. Based on the findings from Figure 5 and Figure 6, the pair of grey and
277 treated grey water tanks sizes corresponding to the treatment capacity at the threshold are
278 recommended in system design to achieve a maximum system saving efficiency. Meanwhile, the
279 family plots in Figure 6 can be utilised for system design. When a targeted water saving efficiency is
280 specified, the treatment capacity and tank sizes can be determined according to Figure 6.

281

282 (Figure 6 here)

283

284 *Scenario 4: Two tank system --- treatment operating mode.* In scenarios 2 and 3, the treatment device is
285 assumed to operate at a constant production rate. This is not, of course, consistent with the pattern of
286 toilet water demand. In scenario 4, the treatment device is set to operate intermittently to mimic the
287 morning and evening peak uses of the toilet noted in previous studies [27]. For comparison purposes,
288 two intermittent modes were considered: intermittent and continuous modes. In the intermittent mode,
289 the treatment device is set to operate at two intervals: from 6:00 to 9:00 and from 18:00 to 21:00. For
290 each mode, a constant production rate is adopted during operating time periods. To facilitate easy
291 comparison, the same treatment capacity, 94 litres per day, which is determined by the actual toilet
292 water demand per day (three person household), was applied to all operating modes. Results from the
293 model simulation are displayed in figure 7, in which it is shown that the water saving efficiency
294 corresponding to the intermittent operating mode is about 4% higher than for continuous mode. It
295 indicates that the better the treatment operating schedule fits with the actual demand, the greater the
296 water saving efficiency. In practice, for some treatment techniques, the intermittent mode is difficult or
297 impossible to implement. However, this comparison indicates that the operating mode of the treatment

298 device does or could play a role in the performance of grey water reuse system in principle, and the
299 more flexible the treatment operating mode is, the smaller storage tank volumes are required to achieve
300 a certain water saving efficiency.

301 (Figure 7 here)

302

303 *Scenario 5: Household occupancy.* It has been previously reported [28] that increasing occupancy is
304 linked with decreasing per capita water consumption. This result is broadly confirmed by the data
305 adopted in this project (Table 2). Similar patterns were observed in the variation of water saving
306 efficiency with occupancy and storage volumes. In addition, results indicate that volume of total
307 storage tank required increase with increasing occupancy. Total storage tank required per capita shows
308 an opposite trend with increasing occupancy. This finding applies to all household occupancies except
309 for three person household (Table 2). The tank volumes required for a target *WSE* is dependent on the
310 total amount of toilet demand, the water consumption water profile, and the pattern of water
311 consumption for each appliance in a household. All these factors vary spatially and temporally. For
312 example, the percentages of water consumption for toilet flushing (*P_{wc}*) for different household
313 occupancies are shown in Table 2, which shows a variance from 18% to 41% for different household
314 occupancies. For three person households, the averaged toilet demand contributes to 22% of household
315 water consumption, while 33% for two person households, although the total household water demand
316 for three person household is higher than the one for two person households. In terms of replacing toilet
317 water demand with treated grey water, a bigger *P_{wc}* indicates that more water will be required for toilet
318 flushing; therefore, a bigger total tank volume will be required to cope with this demand. This explains
319 why the grey and treated grey water tanks required for the same target *WSE* for three person
320 households is smaller than the one for two person households.

321

322

323 (Table 2 here)

324

325 Previous study suggested that a system storing 100 litres can achieve over 90% of potable water saved
326 for a household with less than 5 people according to the analysis for a one tank based model with
327 unlimited treatment capacity [19]. This work, however, better represents a real system with a second

328 treated grey water tank and limited treatment capacity included. For a target water saving efficiency of
329 replacing 80% of toilet water demand with treated grey water, the required water tank volume(s) from
330 both models are presented in table 3, from which it is clear that Dixon et al.'s model underestimates the
331 required tank volume significantly, justifying this reanalysis work.

332 (Table 3 here)

333

334 In general, grey water can be reused for toilet flushing, garden watering and even for cloth washing
335 after suitable treatment. From the aspect of household water cycle modelling, the main differences
336 between these water uses are demand patterns. The frequencies and amounts of water required during a
337 single use event are different. For the purpose of simplification, only toilet flushing is considered in the
338 modelling process in this paper. However, this simplification does not reduce the model's capability. In
339 a situation where garden watering and cloth washing are main usage of reclaimed water, the household
340 water cycle model can be easily modified to cope with. Meanwhile, the nature of the toilet flushing
341 facilities is overlooked in the model and generalised as a single flush with 9 liters water. In practice,
342 dual flush toilets, low flush toilets and toilets fitted with a recycled hand washing basin have been
343 installed in some areas. For the first two types of toilets, the model can be applied without modification.
344 However, the third type of toilet is not suitable for the model because no treatment is required for this
345 kind of toilet.

346

347 This paper mainly focuses on the physical aspect of grey water reuse systems and its impact on the
348 potential for water saving. Based on this, tank size and treatment capability design rules are presented
349 for the sake of achieving the greatest water saving efficiency. However, the actual amount of water
350 saving might also depend on social and economic factors since they impose significant influence on the
351 willingness to embrace grey water reuse. The perception of grey water reuse may vary from region to
352 region and culture to culture. In some areas, people might think it is unacceptable to reuse grey water
353 from their neighbour's household although treatment and disinfection have been applied. Meanwhile,
354 drinking water price is also a key factor. In some areas, household customers do not have a water meter
355 installed and water price is low compared with other living costs. There is no financial incentive for
356 these occupants to consider saving water. The installation and running costs are also important factors.
357 Therefore, to promote implementation of grey water reuse, further investigation should be undertaken

358 in the fields of drinking water pricing strategy, perception of reclaimed water and cost-effective
359 technology development.

360

361 **Conclusions**

362 The impact of key factors on the performance of a water reuse system were investigated by simulating
363 the water cycle process in a household using an object-based modelling method. The water dynamics
364 within the household over 10 years based on a time step of 10 minutes was simulated using
365 Monte-Carlo simulation- derived data. Results show that the water saving efficiency of a grey water
366 recycling system is linked to dwelling occupancy, storage tank volume and treatment capacity and
367 operating mode. The performance of ‘one tank’ and ‘two tank’ systems was also compared. It can be
368 concluded that:

- 369 • The object-based household water cycle model works well in practice. Model simulations for
370 one and two tank systems suggest that it is more flexible and extendable compared with earlier
371 models. Model simulation results for the ‘one tank’ system are consistent with the findings in
372 previous studies.
- 373 • Treatment capacity and storage tank volumes both impose impacts on water saving efficiency
374 for a ‘two tank’ system. Generally, the bigger the storage tank, the more potable water can be
375 saved. The rate of increase is greatest at lower volumes and beyond this range the gains reduce.
376 Water saving efficiency is sensitive to low treatment capacity. When the treatment capacity is
377 greater than a specific threshold, efficiency slowly declines with increasing of tank volume.
378 The value of this threshold has been found to be a function of the volume of the storage tanks
379 used, the treatment operating mode and treatment capacity.
- 380 • It was observed that the nearer the operating mode approaches the actual toilet water demand
381 pattern, the higher water saving efficiency can be achieved.
- 382 • Houses with higher occupancy levels require larger storage tanks and treatment capacity than
383 lower occupancies for the same water saving efficiency. However, volumes of storage tanks
384 required per capita decrease with increasing occupancy.
- 385 • Dixon et al.’s one tank model significantly underestimates the tank volume required for a
386 given water saving efficiency compared to the results from the model in this work.
- 387 • In addition to a system’s physical properties, social and economic factors also impose

388 significant impact on the amount of water to be saved. Further investigation should be
389 undertaken in these fields.

390

391 **Acknowledgement**

392

393 This work is jointly support by the ‘Water Cycle Management for New Developments’ (WaND)
394 project [www.wand.uk.net] and the Program of Research on Key Technology of Environmental
395 Pollution Control and Quality Improvement (2007DFC90170).

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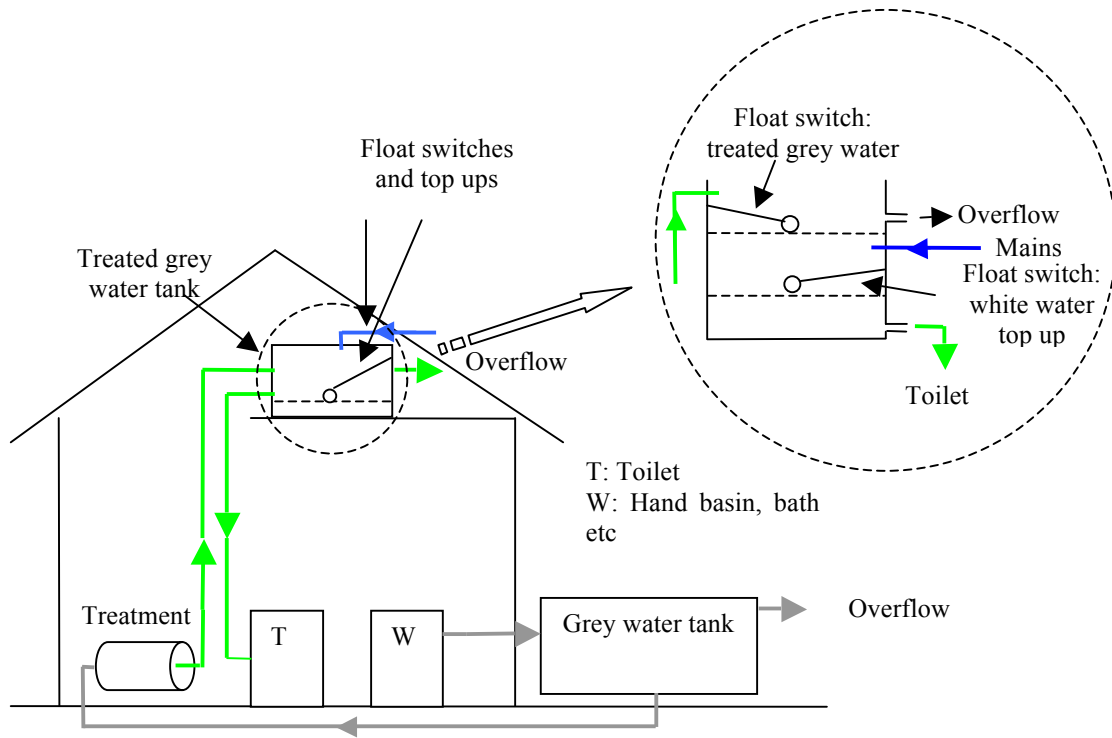
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Figure 1

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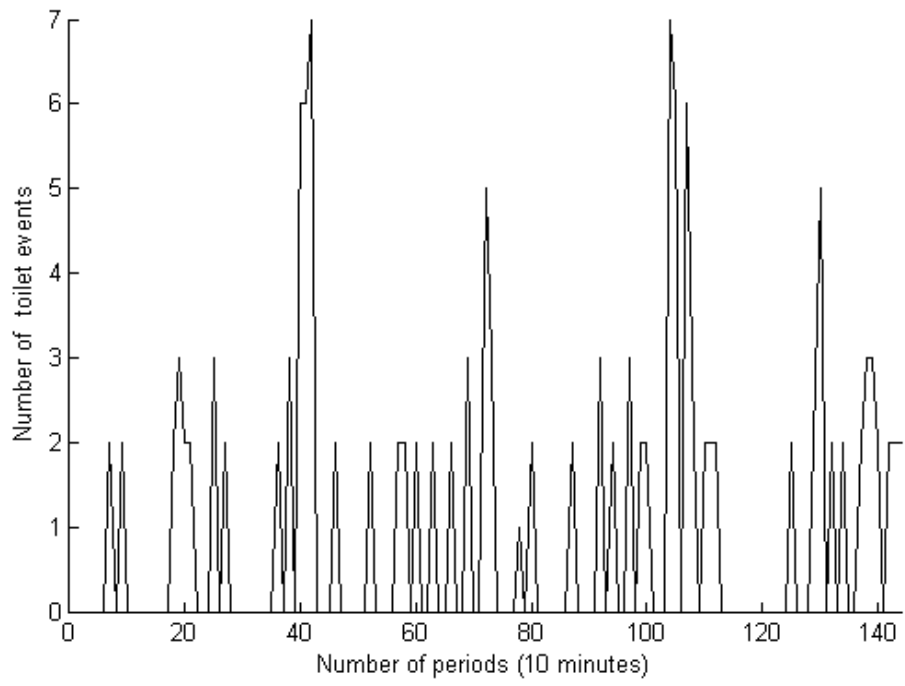


Figure 2

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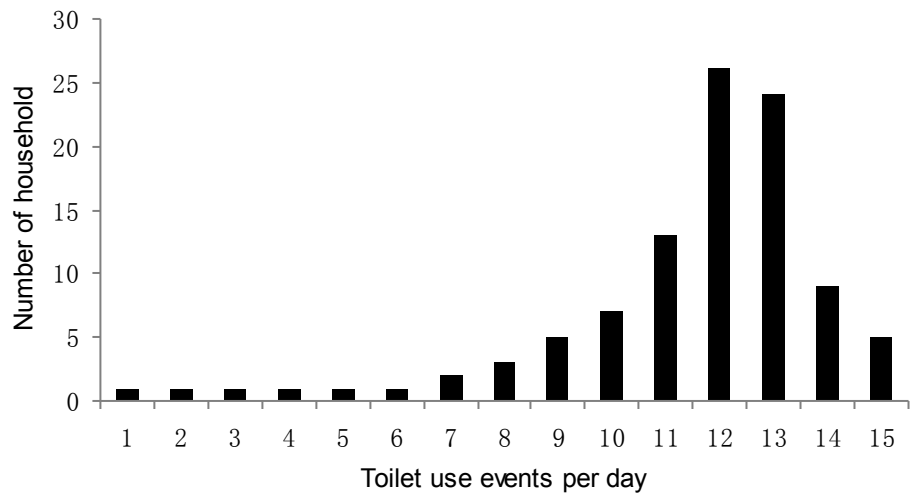


Figure 3

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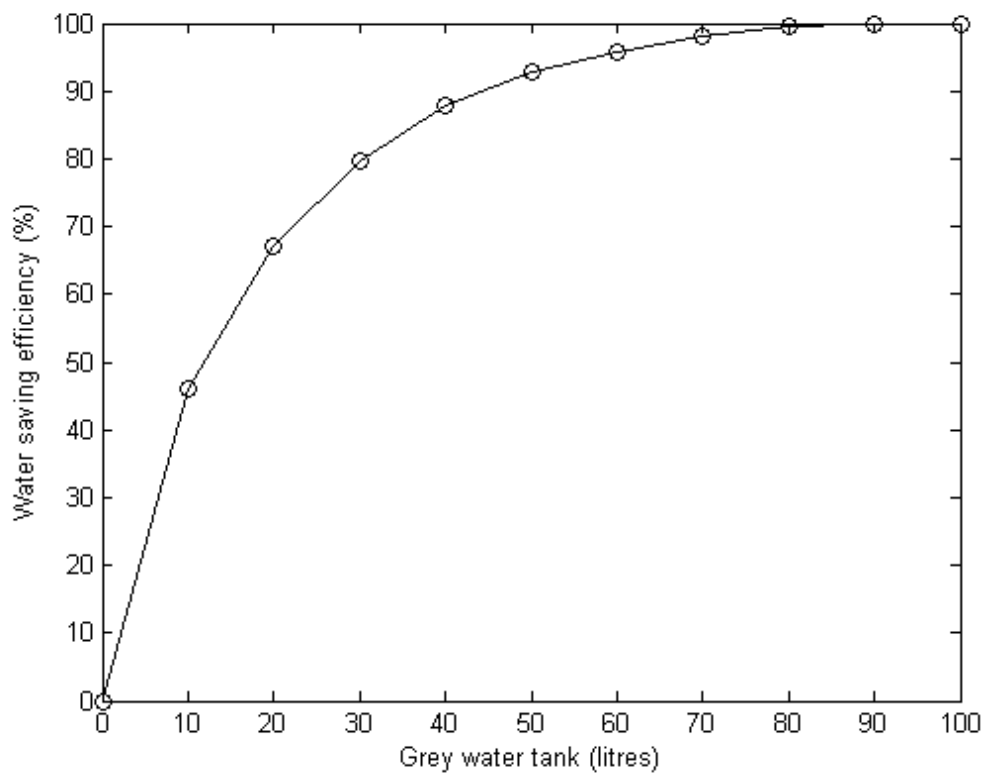


Figure 4

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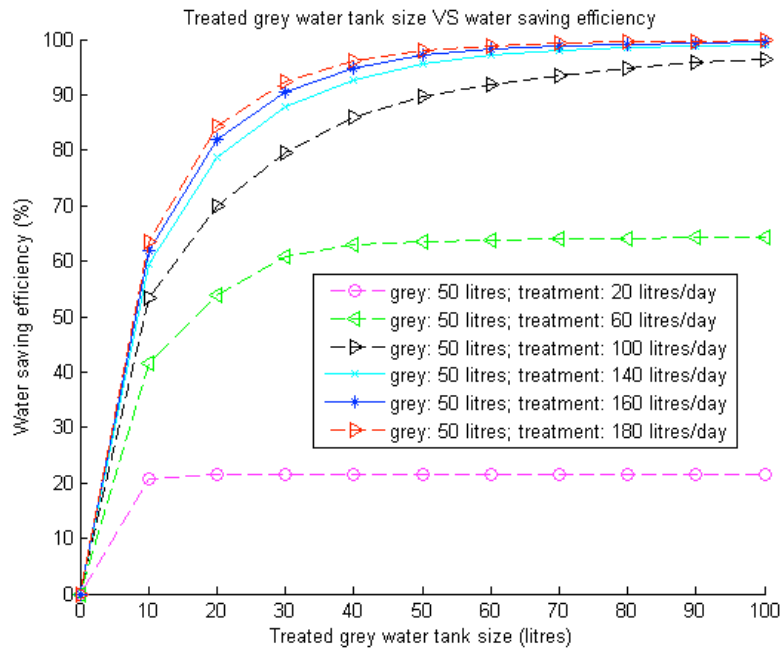


Figure 5

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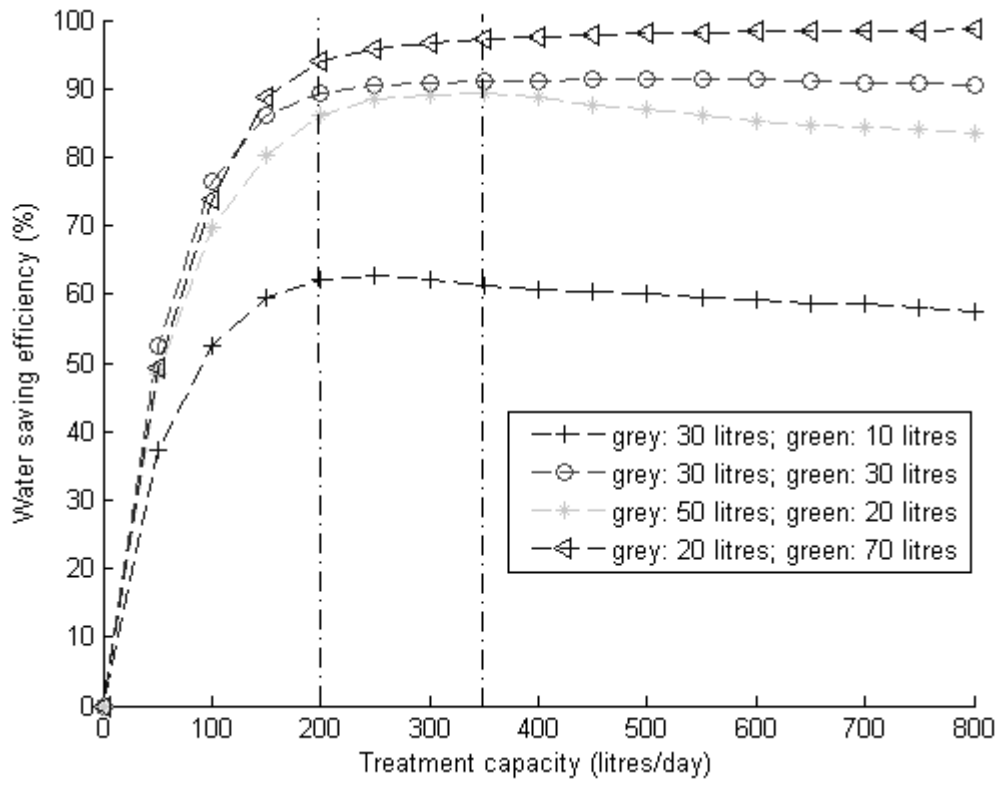


Figure 6

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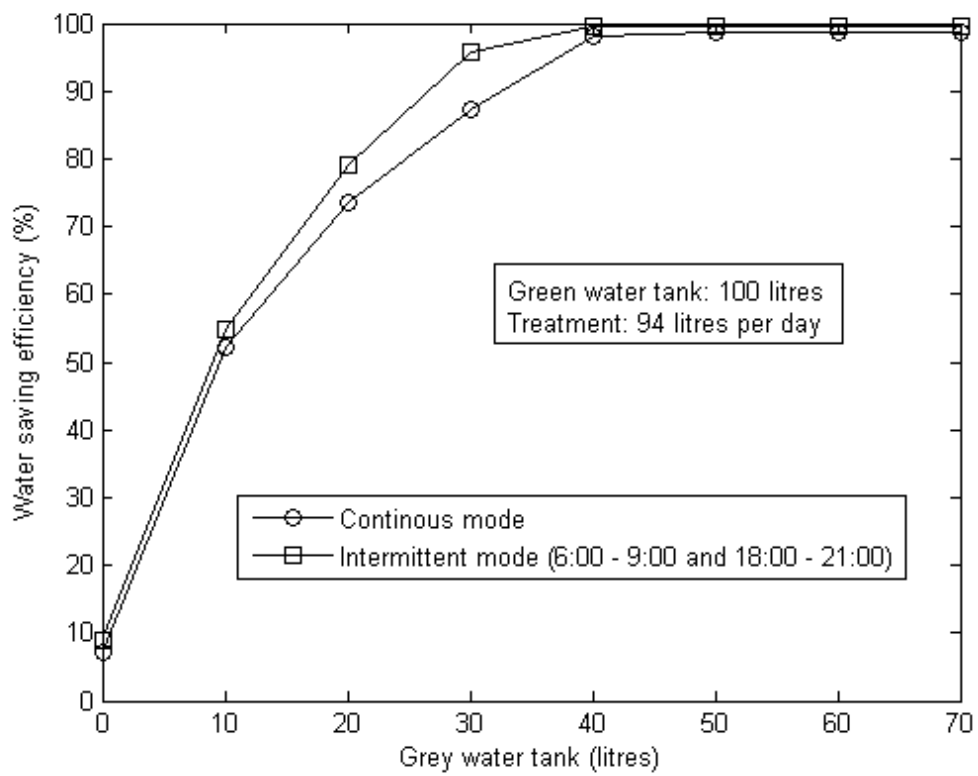


Figure 7

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	Grey water tank volume	Treated grey water volume	Treatment capacity	Treatment operating mode	Household occupancy
Scenario 1 One tank system: without treatment device constraint	Change	N/A	Infinite	continuous	3 people
Scenario 2 Two tank system: treated grey water tank	50 liters	Change	Change	continuous	3 people
Scenario 3 Two tank system: treatment capacity	50 liters	100 liters	Change	continuous	3 people
Scenario 4 Two tank system: treatment operating mode	50 liters	100 liters	94 liters	Change	3 people
Scenario 5 Two tank system: household occupancy	Change	Change	Change	continuous	Change

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Table 1