Quantitative assessment of residential water end uses and greywater generation in the City of Al Ain
Rezaul K. Chowdhury, Walid El-Shorbagy, Mwafag Ghanma and Assem El-Ashkar

ABSTRACT

Diversification of water sources and water demand reduction are two vital tools in maintaining the security of urban water supplies in the United Arab Emirates (UAE). Reuse of greywater for non-potable end uses can be an effective alternative, but this resource has not yet received much attention in the UAE. Since the generation of greywater significantly differs from country to country – depending on age, gender, habits, lifestyle, living standards and the degree of water abundance – an attempt was made to estimate internal water consumption and greywater generation in the city of Al Ain, UAE. The frequency and water requirement for personal water uses (e.g. showers, ablutions, teeth brushing, hand washing, face washing and toilet flushing) and family water uses (e.g. laundry, dish washing and house cleaning) were estimated from about 100 villa-type detached homes randomly distributed across the city. A frequency analysis was carried out using normal, lognormal, gamma and logistic distribution. The estimated average generation rate of greywater was found to be 192 litres per capita per day, which is about 69% of the average internal water consumption. The generated greywater originates from showers (49%), ablutions (18%), laundry (10%) and washbasins (23%). Based on average quantities, it was shown that the generated greywater is sufficient to fulfil the non-potable water demand in houses, but further, more rigorous, investigation is required.

Key words | end use, frequency analysis, greywater, reuse, water saving

INTRODUCTION

Greywater is domestic wastewater, excluding that which originates from toilets (Jefferson et al. 1999; Eriksson et al. 2002) and sometimes kitchen water (Al-Jayyousi 2003; Li et al. 2008). Greywater generally constitutes about 50 to 80% of the total household wastewater (Eriksson et al. 2003). Generation of greywater differs from country to country, depending on age, gender, habits, lifestyle, living standards and the degree of water abundance (Mourad et al. 2011). The global average generation rate is about 90 to 120 litres per capita per day (lpcd) (Morel & Diener 2006; Li et al. 2009; Mourad et al. 2011), but in arid regions, the average rate is higher. For example, the greywater generation rate in Oman is about 151 lpcd, which is about 82% of its total potable water consumption (Jamrah et al. 2008). About 56% of generated greywater in Oman originates from showers, 28 to 33% from kitchens, 6 to 9% from laundries and 5 to 7% from sinks. In a typical urban area in Syria, the average greywater generation is about 46% of the total water consumption (Mourad et al. 2011). In low-income countries with water shortages and simple forms of water supply, greywater generation can be as low as 20 to 30 lpcd (Morel & Diener 2006).

Greywater generally contains less organic matter and nutrients as compared to other domestic wastewater; however, its characteristics are significantly variable because of differences in people’s habits, products used and the nature of installations (Eriksson et al. 2002). The variability of greywater quality has been described in Li et al.’s (2009) study, while several studies have investigated greywater treatment technologies (Birks et al. 2004; Friedler et al. 2005; Li et al. 2008). Because of low levels of pathogens and nutrients,
recycling and reuse of greywater is receiving significant attention, particularly in water-scarce countries (Li et al. 2009). Sheikh (1993) reported that 12 to 65% of potable water used annually could be saved by reusing greywater in irrigation in the city of Los Angeles, while according to Ghisi & Ferreira (2007), as much as 29 to 35% of potable water could be saved by reusing greywater for toilet flushing. Mourad et al. (2011) investigated the potential for saving water in the Syrian city of Sweida by reusing greywater. They showed that about 35% of mains water could be saved by reusing treated greywater in toilet flushing. Kotwicki & Al-Otaibi (2011) investigated the potential for saving drinking water through dual reticulation in Kuwait City. They found that, by reusing treated wastewater for toilet flushing and gardening, water demand can be stabilised over a 20-year period and about 25% of potable water can be saved in Kuwait City. In Australia, harvesting and reuse of alternative water resources (rainwater, stormwater and greywater) has proved to be an economically viable solution for water supply augmentation, capable of meeting targets for potable water savings (Chowdhury et al. 2011, 2012).

Several parameters affect household water consumption (e.g. type of toilet, household size and lot size). Therefore, residential water end uses and their conservation potential generally have to be calculated using empirically estimated parameters that affect water end uses and device turnover rates, as well as regression analyses of their historical trends. Along these lines, Cahill et al. (2013) calculated the probability distributions of these parameters. In some models, water end use data are used to estimate water conservation potential by assuming normal replacement rates of appliances – but with more efficient devices – and measuring the expected water savings (Blokker et al. 2010). Water end use data, along with survey responses and statistically significant parameters affecting end uses, were used in regression analyses to estimate water end uses in individual homes (DeOreo 2011; Cahill et al. 2013). Empirical equations have been generally developed as a function of these statistically significant parameters. In addition, Cahill et al. (2013) applied a Monte Carlo approach to estimate the distribution of residential water use and conservation potential, considering variables of household physical characteristics and behaviour. The authors used probability distributions of significant parameters instead of average numbers.

The United Arab Emirates (UAE) is one of the most water scarce countries, but its water consumption rate is significantly higher than average. In the Emirate of Abu Dhabi, water consumption in flats ranges between 170 and 200 lpcd and between 270 and 1,760 lpcd in villas (Environment Agency – Abu Dhabi 2009). Rapid population growth and the anticipated impact of climate change is worsening this water stress across the country (Chowdhury 2013). About two-thirds of Abu Dhabi’s water resources are used in agriculture and forestry and about three-quarters of the expensive desalinated water resources are used to irrigate parks, home gardens, private households and amenity plantations. Treated sewage effluent (TSE) in Abu Dhabi is used in roadside plantation irrigation systems but not for domestic non-potable purposes because of the high expense of dual reticulation systems. The Abu Dhabi Water Resources Master Plan (Environment Agency – Abu Dhabi 2009) emphasises water demand reduction and water supply augmentation to ensure the security of the city’s urban water supplies.

Greywater reuse has not yet received much attention in the UAE. While guidelines are available for TSE, specific guidelines for greywater reuse are not available or are inadequate, and the evaluation of greywater treatment technologies is almost non-existent in the UAE. Since greywater generation significantly differs from country to country – depending on age, gender, habits, lifestyle, living standards and the degree of water abundance – this study seeks to estimate greywater generation specifically in the city of Al Ain. This is the fastest changing city in the Arabian Peninsula, located at approximately 24°03’ N – 24°22’ N and 55°28’ E – 55°53’ E (Yagoub 2004). As described below, a stochastic method of calculating water consumption and greywater generation in Al Ain houses was used in this study.

**DATA AND METHODS**

A field survey using a questionnaire was conducted to investigate societal attitudes toward water consumption and reusing greywater in Al Ain and to discover some of the parameters affecting water end use through a survey and personal interviews. The survey was administered from February to June 2013. The number of interviewees was defined by using Equation (1), which estimates a population-based
the daily water consumption. Greywater generation (\(G_w\)) was estimated using Equation (6)

\[
G_w = F_s Q_s + F_{tb} Q_{tb} + F_{hw} Q_{hw} + F_{lw} Q_{lw} + F_s Q_a + F_{tv} Q_{tv}
\]

where \(W_d\) is daily water consumption in lpcd, \(W_p\) is personal water consumption (lpcd) and \(W_l\) is water consumption within the family (lpcd). In addition, \(F_s, F_{tb}, F_{hw}, F_{lw}, F_s, F_{tv}\) \(F_h, F_{dhw}, F_c, F_p, F_v\) and \(F_g\) are the daily frequency of using showers, teeth brushing, hand washing, face washing, ablutions, toilet flushing, laundry, dish washing, cleaning, pet water, vehicle cleaning and irrigation of gardens, respectively. Further, \(Q_s, Q_{tb}, Q_{hw}, Q_{lw}, Q_v, Q_{tv}, Q_h, Q_{dhw}, Q_c, Q_p, Q_v\) and \(Q_g\) are the water consumption, in litres, for each shower, teeth brushing, hand washing, face washing, ablation, toilet flushing, laundry, dish washing, house cleaning, pet water, vehicle cleaning and gardening, respectively. In turn, \(T\) indicates time requirements for water uses in minutes, and \(F_R\) indicates the flow rate in litre/minute. Finally, \(FM\) is the number of family members. Similar methodologies have been applied by Mourad et al. (2011) and Ghisi & Ferreira (2007).

The time requirements (\(T\)) for one instance of the different personal and family water end uses were estimated based on a group of twelve volunteers: seven males and five females, of different age and marital status. The participants performed different water end uses and their time requirements were recorded. All participants completed each type of end use five or six times. This method was previously used by Mourad et al. (2011) with 10 volunteer participants. The 12 volunteer participants in this study were selected based on their willingness to participate in the experiments and were part of the randomly selected participants in the survey. The quantity for each toilet flush was estimated from the volume of each toilet tank. The estimated time for activities other than toilet flushing was multiplied by the flow rates (\(F_R\)). Average \(F_R\) were measured using a known volume (350 ml) of a measuring cylinder/container and a stopwatch. The measuring container was filled with running tap water and the time required to fill 350 ml was recorded. Seven or eight volunteers (out of the selected twelve volunteers) performed the experiment for each type of end use, and the average flow rate was estimated. The experiments were conducted during the water use activities of volunteers. Variation in faucet types was not considered in this study because only the flow rate is required in Equation (5). This method of estimating water \(F_R\) was previously used in the above mentioned study by Mourad et al. (2011).

Probability distributions of the frequency of different water end uses and their time requirements were performed.
using four distributions (normal, lognormal, gamma and logistic distributions). Outliers of the data were identified and removed from the analysis. Using the best-fitted probability distributions at a 95% significance level, daily indoor water consumption and greywater generation in residential premises were calculated. A description of selected probability distributions (probability density function and parameters) can be found in Chowdhury & Beecham (2013).

RESULTS AND DISCUSSION

Frequency analysis of water end uses

Statistical characteristics of different water end uses per person (or per house) per day (or per week) are shown in Table 1. Best-fitted probability distributions at a 95% significance level of water end use frequency are shown in Figure 1. The number of bedrooms per house is best fitted by the lognormal distribution, whereas the number of people and vehicles is best fitted by the gamma distribution. The number of toilet flushes, hand washings, face washings, laundry (per week), dish washings and car washings (per week) is best fitted by the normal, logistic, gamma, normal, gamma and logistic distributions, respectively, at a 95% significance level. All of the houses surveyed were villa-type detached houses and generally included provision for amenity plantation. However, the area of gardens in houses was not estimated. The average family members of around 12 people per house and the high variance (21.35) are a representation of the cultural practice of joint families (brothers and their families live in the same house, along with their parents and grandparents) in the region. The five ablutions each day is a religious practice, and an average ablution frequency of 4.42 per person per day indicates that some people perform ablutions outside (possibly at mosques) or they manage to perform more than one prayer with the same ablution. Previously, Mourad et al. (2011) estimated the per capita frequency of water uses in Syria. Their estimated frequencies (per day) were face washing 4, hand washing 8.6, teeth brushing 1.7, showering 0.6 and toilet flushing 4.1. Their hand washing frequency of 8.6 is significantly higher than our finding of 4.71, most probably because ablution water use is separated in our study. Other differences in water use frequency between the two studies are due to different climates, geographical settings, life styles and relatively higher levels of water availability.

Table 1 | Statistical characteristics of the frequency of water end uses on residential premises in Al Ain

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>St dev</th>
<th>Variance</th>
<th>CV</th>
<th>Min</th>
<th>Q1</th>
<th>Median</th>
<th>Q3</th>
<th>Max</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedroom/house</td>
<td>6.76</td>
<td>2.18</td>
<td>4.75</td>
<td>32.22</td>
<td>2.00</td>
<td>5.00</td>
<td>6.00</td>
<td>8.00</td>
<td>12.00</td>
<td>0.61</td>
<td>0.22</td>
</tr>
<tr>
<td>Car/house</td>
<td>4.41</td>
<td>1.81</td>
<td>3.27</td>
<td>40.96</td>
<td>2.00</td>
<td>3.00</td>
<td>4.00</td>
<td>6.00</td>
<td>9.00</td>
<td>0.81</td>
<td>– 0.01</td>
</tr>
<tr>
<td>People/house</td>
<td>11.60</td>
<td>4.62</td>
<td>21.35</td>
<td>39.82</td>
<td>4.00</td>
<td>8.00</td>
<td>11.00</td>
<td>15.00</td>
<td>24.00</td>
<td>0.41</td>
<td>– 0.31</td>
</tr>
<tr>
<td>Shower/p/d</td>
<td>1.68</td>
<td>0.73</td>
<td>0.53</td>
<td>43.04</td>
<td>1.00</td>
<td>1.00</td>
<td>2.00</td>
<td>2.00</td>
<td>4.00</td>
<td>0.74</td>
<td>– 0.08</td>
</tr>
<tr>
<td>Toilet flushing/p/d</td>
<td>4.29</td>
<td>1.04</td>
<td>1.09</td>
<td>24.30</td>
<td>2.00</td>
<td>3.25</td>
<td>4.00</td>
<td>5.00</td>
<td>6.00</td>
<td>– 0.14</td>
<td>– 0.72</td>
</tr>
<tr>
<td>Teeth brushing/p/d</td>
<td>2.15</td>
<td>0.65</td>
<td>0.42</td>
<td>29.97</td>
<td>1.00</td>
<td>2.00</td>
<td>2.00</td>
<td>3.00</td>
<td>4.00</td>
<td>0.10</td>
<td>– 0.04</td>
</tr>
<tr>
<td>Hand washing/p/d</td>
<td>4.71</td>
<td>1.52</td>
<td>2.32</td>
<td>32.37</td>
<td>1.00</td>
<td>4.00</td>
<td>5.00</td>
<td>5.00</td>
<td>9.00</td>
<td>0.47</td>
<td>1.19</td>
</tr>
<tr>
<td>Face washing/p/d</td>
<td>3.52</td>
<td>1.34</td>
<td>1.79</td>
<td>38.00</td>
<td>1.00</td>
<td>2.00</td>
<td>3.00</td>
<td>5.00</td>
<td>7.00</td>
<td>0.21</td>
<td>– 1.02</td>
</tr>
<tr>
<td>Ablution/p/d</td>
<td>4.42</td>
<td>0.98</td>
<td>0.96</td>
<td>22.21</td>
<td>1.00</td>
<td>4.00</td>
<td>5.00</td>
<td>5.00</td>
<td>6.00</td>
<td>– 1.50</td>
<td>1.48</td>
</tr>
<tr>
<td>Laundry/w</td>
<td>6.44</td>
<td>2.91</td>
<td>8.49</td>
<td>45.26</td>
<td>1.00</td>
<td>4.00</td>
<td>7.00</td>
<td>7.00</td>
<td>14.00</td>
<td>0.35</td>
<td>– 0.10</td>
</tr>
<tr>
<td>Dish washing/d</td>
<td>4.03</td>
<td>1.29</td>
<td>1.65</td>
<td>31.85</td>
<td>2.00</td>
<td>3.00</td>
<td>4.00</td>
<td>5.00</td>
<td>8.00</td>
<td>0.85</td>
<td>0.84</td>
</tr>
<tr>
<td>House cleaning/d</td>
<td>1.24</td>
<td>0.65</td>
<td>0.43</td>
<td>52.76</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>2.00</td>
<td>3.00</td>
<td>1.00</td>
<td>1.08</td>
</tr>
<tr>
<td>Gardening/d</td>
<td>1.56</td>
<td>0.64</td>
<td>0.41</td>
<td>41.14</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>2.00</td>
<td>4.00</td>
<td>1.03</td>
<td>1.48</td>
</tr>
<tr>
<td>Carwash/w</td>
<td>2.03</td>
<td>1.09</td>
<td>1.19</td>
<td>53.75</td>
<td>1.00</td>
<td>1.00</td>
<td>2.00</td>
<td>3.00</td>
<td>5.00</td>
<td>1.01</td>
<td>0.64</td>
</tr>
<tr>
<td>Pet water/d</td>
<td>0.62</td>
<td>1.20</td>
<td>1.43</td>
<td>191.94</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>5.00</td>
<td>2.05</td>
<td>3.64</td>
</tr>
</tbody>
</table>

St dev = standard deviation, CV = coefficient of variation, Q1 = 25th percentile, Q3 = 75th percentile, per person per day = /p/d, per week = /w.
Figure 1 | Best-fitted probability distributions of water use frequency at a 95% significance level. (continued)
Frequency analysis of time requirement for water end uses

The time requirements for different water end uses were estimated, with their statistical characteristics shown in Table 2 and their frequency distributions in Figure 2. The time requirements for teeth brushing and car washing are best fitted by the logistic distribution, whereas the time requirements for hand washing, face washing, showers, ablations and dish washing are best fitted by the gamma distribution. The time requirements for different personal water uses (e.g. showers, hand washing and ablations) generally depend on cultural practices, degree of water abundance and water tariff structure. It can be seen from Table 2 that showers and dishwashing times are highly variable, with an average duration of 9.71 and 31.67 minutes and a standard deviation of 4.4 and...
4.2 minutes, respectively. This is likely due to variations in people’s shower water use practices and variations in dishwashing techniques. In most homes surveyed, the family has a hosepipe connected to the garage, used to wash vehicles and water gardens. The car washing time shown in Table 2 represents the hosepipe running time only.

Water end use and greywater generation

The estimated average water consumptions for different water end uses (except irrigation of gardens) are shown in Table 3. Using Equation (6), an average greywater generation rate of 192 lpcd was calculated, also shown in Table 3. This was done using the average time requirement of individual end uses and the frequency of end uses. For personal water end uses, it is clear that the highest consumptive uses include showers, toilet flushing and ablutions. The shower consumption (94 lpcd) is much higher, probably because of higher temperatures in the region. The average ablution water consumption is almost equal to the toilet flushing consumption. From a different perspective, it can be concluded that the reuse of ablution water can meet the quantitative requirements for toilet flushing consumption. For family water end uses, dishwashing consumption (44 lpcd) is more than double that of laundry water consumption (20 lpcd). External water consumption (gardening) was not estimated in this study; however, it was observed that two types of gardening practices appear in Al Ain: piped surface irrigation systems and hosepipe connections used for car washing purposes. Table 3 shows that greywater generation averages about 69% of the indoor water consumption. The estimated average greywater generation of 192 lpcd is the sum of showers (49%), ablutions (18%), laundry (10%), hand washing (10%), teeth brushing (7%) and face washing (6%). Although average water consumption and greywater generation rates are shown in Table 3, it is possible to estimate variations in water consumption by considering the probability distribution of their frequency and time requirements.

In the questionnaire answers and staff interviews, about 70% of respondents showed an interest in reusing greywater for gardening in Al Ain. This result is quite similar to the results in Muscat (Oman), where approximately 76% of respondents accepted the reuse of greywater for gardening, 53% for car washing and 66% for toilet flushing (Jamrah et al. 2008). Greywater production in Muscat ranges between 80 to 83% of the total internal domestic water consumption, while this study found only about 69% of internal residential water is greywater, which is still within the internationally reported average of 50 to 80%.

The fitted probability distribution of water use frequencies and their time requirements can generate synthetic data for water consumption. This could help explain the variability of water consumption and greywater generation rates in villa-type houses in Al Ain. In addition, generated synthetic data can be used to investigate the potential for saving water through greywater reuse schemes.

CONCLUSION

There is a growing interest in the reuse of greywater. One driving force is water shortages caused by low amounts of rainfall in combination with high evaporation and large

Table 2 | Statistical characteristics of time requirements for different water uses

<table>
<thead>
<tr>
<th>Variable (minute)</th>
<th>Mean</th>
<th>St dev</th>
<th>Variance</th>
<th>CV</th>
<th>Min</th>
<th>Median</th>
<th>Q3</th>
<th>Max</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teeth brushing</td>
<td>1.55</td>
<td>0.82</td>
<td>0.67</td>
<td>52.77</td>
<td>0.39</td>
<td>1.08</td>
<td>1.44</td>
<td>2.00</td>
<td>0.74</td>
<td>0.96</td>
</tr>
<tr>
<td>Hand washing</td>
<td>1.09</td>
<td>0.86</td>
<td>0.73</td>
<td>78.81</td>
<td>0.12</td>
<td>0.29</td>
<td>1.02</td>
<td>2.00</td>
<td>0.68</td>
<td>−0.60</td>
</tr>
<tr>
<td>Face washing</td>
<td>0.87</td>
<td>0.69</td>
<td>0.47</td>
<td>79.03</td>
<td>0.13</td>
<td>0.21</td>
<td>1.02</td>
<td>1.08</td>
<td>0.57</td>
<td>−0.89</td>
</tr>
<tr>
<td>Shower</td>
<td>9.71</td>
<td>4.40</td>
<td>19.38</td>
<td>45.33</td>
<td>5.01</td>
<td>6.32</td>
<td>7.73</td>
<td>12.72</td>
<td>19.22</td>
<td>−0.44</td>
</tr>
<tr>
<td>Ablution</td>
<td>2.06</td>
<td>0.89</td>
<td>0.79</td>
<td>42.97</td>
<td>0.57</td>
<td>1.34</td>
<td>2.00</td>
<td>3.00</td>
<td>0.67</td>
<td>−0.34</td>
</tr>
<tr>
<td>Dish washing</td>
<td>31.67</td>
<td>4.20</td>
<td>17.65</td>
<td>13.27</td>
<td>25.00</td>
<td>30.0</td>
<td>30.0</td>
<td>35.0</td>
<td>40.00</td>
<td>0.60</td>
</tr>
<tr>
<td>Car washing</td>
<td>6.76</td>
<td>1.56</td>
<td>2.45</td>
<td>23.15</td>
<td>5.00</td>
<td>5.00</td>
<td>7.00</td>
<td>8.00</td>
<td>10.00</td>
<td>0.67</td>
</tr>
</tbody>
</table>

St dev = standard deviation, CV = coefficient of variation, Q1 = 25th percentile, Q3 = 75th percentile.
demands for freshwater from population centres. Another driving force is the need to lower the cost of wastewater treatment plants (Eriksson et al. 2002). Internal water consumption in Al Ain was found to be extremely high because of cultural practices, high temperatures in the region and a subsidised water tariff structure for consumers. In addition, the ablution water consumption is almost equal to toilet flushing water requirements. A reuse of shower and laundry greywater is also possible for non-potable water end uses. In the survey, about 70% of the respondents agreed that
greywater can be reused for gardening purposes and about 18% agreed to reuse greywater for toilet flushing purposes. Because of the high variability of different water uses – by frequency and number of uses – a model including the probability distributions of different variables in Equations (2) to (6) is recommended over considering only average generation rates. Sensitivity analysis and comparison with an averaging method is also important, and a stochastic method can be used to estimate potable water savings from greywater reuse. Other than the quantities of greywater examined in this paper, other criteria need to be considered when selecting a greywater reuse scheme. These criteria include societal acceptance, greywater quality, treatment technologies and requirements for irrigation water quality. The problems associated with greywater reuse involve the risk of spreading diseases through exposure to microorganisms and soil pollution and receiving waters due to different pollutants in greywater.

This study specifically explored the quantitative aspects of greywater reuse potential in villa-type houses in the city of Al Ain. The water consumption data reported in this paper were estimated based on self-reported estimates of frequency and duration, so the results could best be used in combination with pilot studies measuring end uses. Unfortunately, this kind of study has not been realised yet; therefore, an attempt was made to compare the results with other published studies, particularly in arid regions. As a continuation of this research project, flow-measuring devices have already been installed on residential water end use pipes, and monthly residential water consumption data are being collected from these water meter readings. After this successful installation of flow meters and the collection of water consumption records, more reliable water consumption and greywater generation rates will be possible. Fitted probability distributions can be used to generate synthetic water consumption rates that could help understand variations in water consumption and greywater generation and could be used in simulations of water savings from greywater substitutions. Research on greywater quality and appropriate treatment technologies is being examined and will be included in subsequent publications.

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‘Al Ain’. Some parts of this article were published in the proceedings of the 20th International Congress on Modelling and Simulation (MODSIM 2013) (Chowdhury 2013).

REFERENCES


Morel, A. & Diener, S. 2006 Greywater Management in Low and Middle-Income Countries. Water and Sanitation in Developing Countries (Sandec), EAWAG: Swiss Federal Institute of Aquatic Science and Technology, Switzerland.

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