Assessment of domestic consumption in intermittent water supply networks: case study of Puerto Ayora (Galápagos Islands)

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ABSTRACT

Intermittent water distribution systems are a stark reality in developing countries. Puerto Ayora, the centre of tourism of the Galápagos Archipelago, is not an exception, with its population and tourists suffering from scarce water resources. However, the extreme per capita consumptions, well above those in 24/7 supply situations in many other countries, contradict the (sense of) scarcity. In this study, 18 water meters were installed and a water-appliance diary was carried out in 15 randomly selected households in Puerto Ayora. The aim was to determine and analyse domestic water consumption, as well as the diurnal patterns, also by verifying per capita figures ranging from 40 to 380 litres per capita per day from a previous study. Also, the aim was to find a correlation between the consumption and schedules of distribution conducted by the municipality. The paper also elaborates on typical household appliances used, and gives an insight about a wide range of domestic demands in a predominantly water-scarce area. The conclusions indicate no influence of the specific intermittency patterns to the specific demand, but rather a wide range of different lifestyles, the possible presence of informal accommodations and excessive wastage.

Key words | domestic demand patterns, Galápagos, intermittent supply, specific water demand, water appliance

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INTRODUCTION

Limited water resources are considered one of the most sensitive issues in arid and semi-arid areas (Singh & Turkiya 2013). Urban settlements located in these areas experience water deficits, still showing no improvement after interventions have been made. Due to the population growth trends, as well as the specific water demands, the condition is expected to worsen. Therefore, rationing the distribution of water has been one of the most used strategies to reduce water demand. Until a few decades ago, water supply infrastructures were designed with the assumption of a continuous and unlimited supply, which nowadays hardly takes place, specifically in developing countries (Vairavamoorthy *et al.* 2008). That is mainly due to the fact that the intermittency is rarely foreseen by water utilities. The intermittent regime is therefore applied due to necessity, rather than being designed. According to Vairavamoorthy & Elango (2002), this intermittency often results in insufficient pressure in the network, increase in water contamination, as well as in inequity and limitation in the distribution of available water.

Due to the population growth trends, water demand has exceeded water supply capacity in many places around the world. Therefore, the water demand needs to be accurately assessed in order to ensure the resource for the coming

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years. This also includes the demand patterns and diurnal peak factors, which will provide useful inputs for the design of networks, reservoirs, and pumping stations (Trifunović 2008). In order to ensure a reliable infrastructure expansion strategy, reliable estimates of water consumption and use are required, especially while assessing peak demands (Bougadis *et al.* 2005).

Accurate demand quantification will also result in the calculation of the real range of consumption, making a basis for an optimal water tariff structure. According to Arbués *et al.* (2003), the price of water is the main tool that helps to control the demand. Moreover, Rogers *et al.* (2002) stated that low water prices cause consumers to forget important economic and environmental issues. In addition, according to OECD (2009), the lowering of water tariffs contributes to higher input volumes of water, its pollution, and discourages the efficient use of the resource. Therefore, an optimal water tariff is considered a step towards full-cost pricing of environmentally harmful activities and may lead to the development of policies which internalize social and environmental costs (Dinar 1998).

It is also imperative to understand the users' habits and behaviour within households regarding water consumption. This will help authorities to develop policies which address the preservation of the resource, as well as consumers' satisfaction (Fidar *et al.* 2010). For instance, water appliance analysis is a useful tool to understand which demand management measures are more suitable, such as installing water-saving devices.

CASE STUDY AREA DESCRIPTION

With more than 60% of the total population, Puerto Ayora is the main urban settlement and tourist centre of the Galápagos Archipelago, located on Santa Cruz Island. This settlement has been confronted by an exponential increase of local population and tourism over the last decades (INEC 2010), while the local authorities have not been able to cope with this growth; in turn, this has caused a significant impact on the water supply.

The water in Puerto Ayora is supplied in an intermittent regime, with the aim to preserve scarce water resources. However, this intermittency is also caused by the lack of proper management, additionally obstructed by sensitive political issues (Reyes *et al.* 2015a). Due to this situation, the local population perceives the system as unreliable. The municipal water is supplied 3 hours per day on average, depending on the location of the neighbourhood. According to the municipality, the system was initially designed as a continuous supply. However, the lack of individual water meters and fixed tariff structure inflicted water wastages in households forcing the municipality to operate intermittently. In addition, the system has been expanded in an improvised way, adapting to the fast population increase. As a result, the municipality divided the town into five distribution zones with different schedules of supply. To mitigate the intermittency, the premises in Puerto Ayora have storage such as cisterns or elevated tanks. Due to the lack of monitoring/data and various forms of illegal extractions (Reyes *et al.* 2015a), the overall water demand in Puerto Ayora has been very difficult to estimate.

An additional problem to the reduced quantity is the poor water quality. The water supplied by the municipal system is brackish. During the operation of the system in the 2000s, the brackish water was treated with chlorine-gas to minimize the contamination of the source. However, this treatment was stopped, based on the recommendation of international technicians. In addition, there is evidence of contamination with *Escherichia coli* (Liu & d'Ozouville 2013), due to the proximity of septic tanks to the source and the filtration of untreated wastewater. The untreated brackish water from several sources is, therefore, considered unsuitable for human consumption (Liu 2011; Liu & d'Ozouville 2013). The only water considered safe for drinking is desalinated-bottled water sold by local vendors in different sized containers.

Reyes *et al.* (2015b) made an attempt to categorize and assess the water demand in Santa Cruz Island, which was derived from nearly 400 surveys carried out in domestic premises, hotels, laundries and restaurants. This study reported that average per capita water demand (from municipal supply only) ranged in Puerto Ayora from 40 litres per capita per day (lpcpd) to 380 lpcpd. In the same study, the total average domestic consumption was estimated at 163 lpcpd, considering only the municipal supply, adding up to a total average of 177 lpcpd (considering other sources such as bottled drinking water) with standard deviation of ±60 lpcpd. Another study, carried out by d'Ozouville (2009), estimated the specific demand to be as high as

1,500 lpcpd, suggesting informal/illegal accommodation. Also, the same study calculated specific demand based on the total supply records from the Municipality of Santa Cruz at approximately 500 lpcpd.

WMI, a non-governmental organization from Germany, installed approximately 300 water meters in the period 2013 to 2015, in three small and different pilot zones with the aim of monitoring water demand as well as making an attempt to quantify water losses. 115 water meters were installed in pilot zone 1 (PZ 1), located in the northern part of the town. This zone was chosen due to the prevalence of domestic premises. An additional 140 water meters were installed in pilot zone 2 (PZ 2), located in the south-western part of the town. Lastly, pilot zone 3 (PZ 3) was designed to cover the two main avenues of the town where most tourist facilities are located (Av. Baltra and Av. Charles Darwin). The readings in this zone were taken from 54 domestic water meters. All of these metering devices were placed in the distribution network before the individual storage facilities, accounting also for domestic spillage and wastage. The raw data obtained in all three zones were processed as a part of this research, and the results suggest a specific consumption ranging from 20 lpcpd to as high as 4,500 lpcpd. The latter figure is explained by Lupo (2015) as a likely result of illegal tourist accommodation. By all means, this extreme range questions the reason for intermittent supply in Puerto Ayora.

This study aimed to establish the range of domestic consumption in Puerto Ayora, by comparing it with the findings of the survey conducted on water demand by Reyes *et al.* (2015b), as well as to establish the domestic demand patterns using more accurate measurements. It further analyses the lack of equity by assessing the correlation between the schedules of intermittent distribution applied by the municipality and the water consumption in different zones, trying to find any influence of the network's pressure on the household consumption. For that purpose, an analysis of household water appliances was done with the aim of understanding the end uses of water in the domestic category.

METHODOLOGY

In order to verify the previously obtained and published data, fieldwork was carried out from June to August 2015. In collaboration with the municipality, 18 water meters (1/2″ Flodis-single jet turbine device) were installed in private premises based on the ease of accessibility (Figure 1). The meters were installed on the pipe after the individual storage, thus not accounting for spillage of tanks or cisterns. The meters were installed for 30 days and then dismantled. The hourly readings took place from 6:00 until 20:00 hours and then were completed on the following day at 6:00 hours, in order to register cumulative demand overnight. The readings were taken for each household during 2 working days and 1 weekend day (in the same week), to compare habits with respect to water use.

Table 1 shows the records of 18 water meters over a period of one month. The average specific demand refers to the weighted average of the readings corresponding to the 3 days (Equation (1)), and the monthly specific demand refers to the per capita average from the 30 days

Figure 1 | Installation of water meters.

Table 1 | Consumption registered in 18 installed water meters

Water meter	Consumption working day 1 (lpcpd)	Consumption working day 2 (lpcpd)	Consumption weekend (lpcpd)	Weekly specific demand[a] (lpcpd)	Monthly specific demand[b] (lpcpd)
M1	151	117	208	153	158
M2	101	82	94	91	150
M3	132	78	143	115	140
M4	48	187	216	144	172
M5	257	169	90	176	172
M6	176	114	74	124	288
M7	62	25	76	52	52
M8	247	117	116	162	223
M9	238	238	269	244	275
M10	370	215	97	235	410
M11	140	175	241	179	250
M12	105	71	129	99	86
M13	56	90	80	74	96
M14	80	151	116	114	126
M15	90	54	80	73	71
M16	79	147	51	94	127
M17	78	46	90	69	80
M18	113	50	52	72	75
Average	140	118	123	126	164
Standard deviation	±87	±62	±66	±56	±94

[a]This value refers to the weighted average of specific demand of the 3 days of measurement.
[b]Refers to the average specific demand based on the monthly measurement taken when the water meters were uninstalled after 30 days and considering the number of inhabitants.

the meter was installed.

$$\textit{Weekly specific demand} = \left(\frac{C_{w1} + C_{w2}}{2}\right) * 0.714 + \left(C_{wk}{}^{*} 0.286\right) \quad (1)$$

where C_{w1} refers to consumption on the working day 1; C_{w2} refers to consumption on the working day 2; and C_{wk} refers to the consumption on the selected day of the weekend.

In addition, a diary of domestic water appliance analysis was made for 15 premises, one per neighbourhood. The tenants were asked to register the frequency of use of each appliance (toilet, bathroom basin, kitchen basin and shower) during 7 days. Also, hand counters were installed in toilets to register every flushing. The consumption was then calculated based on the time registered and the flow of each appliance, which was previously measured. For the toilets, the size of the flush cisterns was previously annotated.

Finally, the information from the water cadastres belonging to the pilot zones was thoroughly assessed for each zone. The results were analysed in order to find some relation between the schedules of distribution and the wide ranges of consumption.

RESULTS AND DISCUSSION

Results based on installed water meters

Water consumption

The average specific demands for the measured week (weekly average specific demand) and the entire month (monthly specific demand) vary significantly. Moreover, most of the average monthly demands are higher than the average weekly demands, suggesting different daily routines of the users. Furthermore, the results show surprisingly high (up to 410 lpcpd), as well as low demands (46 lpcpd). The measurements were further assessed from the perspective of the water meter location in a particular distribution zone and its specific schedule of supply, as well as by anticipating the standard of living in the metered premises.

The comparisons could not give any correlations between the demands and specific zones, i.e., the schedule of intermittency. At first, it was hypothesized that the households located the furthest from the sources of supply could experience lower network pressures and, consequently, the lower consumptions. However, this hypothesis could not been proven. In contrast, the meter with the highest specific demand is located in the distribution zone with supply of only 2 hours per day. Hence, these figures may possibly be explained by significant differences in lifestyles and/or volume of individual storage, as well as more negligence in some households than in the others, and/or an indication of some sort of informal/illegal tourist business, as the literature suggests. Furthermore, the inspection of water appliances in some houses, such as in toilets, revealed additional water losses.

Consumption classification

Using the average specific demands, the consumption classification was made as in Table 2.

Table 2 shows that the majority of the observed population consumes above 100 lpcpd, suggesting reasonable access to water measured by Ecuadorian and international standards. Moreover, the measurements showed that around 50% of the metered households consume more than 150 lpcpd, which contradicts widespread perception on the island that the water availability is restricted.

Water demand patterns

For practical reasons, the daily demand patterns were composed from the hourly measurements during daytime only. According to the schedule of intermittency, there is no supply between 18:00 hours and 6:00 hours; hence, the water in this period is consumed exclusively from the individual storage volume.

Figure 2 shows the diurnal patterns based on the registrations of the 18 water meters done every hour, representing total demand variation of all meters for every day the readings were carried out. The highest peak is observed at the weekend (Saturday), due to the fact that cleaning, laundry and gardening are usually performed then. Also, the lowest peak is observed at the weekend, portraying the habits of spending some time outside home during the weekend. Furthermore, the three peaks (morning, midday and night) are more evident during the working days. These peaks occur in the morning between 6:00 and 7:00 hours, at midday, and in the evening between 17:00 and 20:00 hours. This is explained by the common practice of the local population to have a lunch break at home, due to the short distances in the small town.

Water appliances household analysis

This analysis yielded the results of 15 households who kept diaries on their own water use over a week. This was distributed between the toilet, bathroom basin, kitchen basin and shower. Not surprisingly, the toilets and showers are the appliances that discharge the most of the domestic water, as stated by EPA (2014). Other water appliances were not included since the selected premises did not have gardens or any outdoor water activity. Table 3 shows the average quantities, considering the number of inhabitants per household.

Table 2 | Consumption classification of metered households

Description (lpcpd)	Consumption classification[a]	No. of households	Percentage (%)	Average consumption (lpcpd)
<100	Low	6	33	76
100–180	Medium	7	39	149
>180	High	5	28	289

[a]Classification is based on Ecuadorian standards where average per capita supply should be 150 lpcpd.

Figure 2 | Diurnal patterns in Puerto Ayora registered from 18 installed water meters.

Table 3 | Water use of household appliances per person

Water appliance	Average demand (l/person/day)	Standard deviation (l/person/day)
Toilet	28	13
Toilet sink	7	6
Shower	30	13
Kitchen sink	25	29
Total	**90**	**11**

Comparison of the demand from water meters and water appliance analysis

In the next stage, the consumptions observed from 18 water meters were compared with the quantities registered in 15 water diaries. This relation was drawn based on relative proximity of the households. Yet, the correlation (R^2) found between the specific demand and the location was extremely low (0.06). Figure 3 shows a map with the average specific demand from water meters and from the water appliance analysis.

This reconfirms the conclusion that the zone of distribution, as well as the schedules, do not influence the specific domestic demand. This may suggest either different lifestyles and/or likely presence of informal (possibly also illegal) tourist businesses, resulting in unreasonably high specific demands calculated by neglecting a 'hidden' tourist population.

Analysis of water demand in pilot zones

The information from the water cadastres of the municipality were thoroughly organized and analysed. Table 4 summarizes the water consumption of the three pilot zones.

Table 4 shows a comparable situation in PZ 1 and PZ 2 that have similar averages of specific demand and standard deviations, showing a wide range of consumption for different households. However, the range of consumption is wider when compared to the results obtained from the surveys done by Reyes *et al.* (2015a). The highest average values of specific demand are shown in PZ 3. Most of the tourist facilities are also located in this zone, meaning the accumulation of different consumption categories.

The measurements done in PZ 1 and PZ 2 showed the specific demands as high as 1,600 lpcpd and as low as 50 lpcpd. No other assumption could have been made, other than that the highest values indicate excessive wastage in the form of spillage from elevated tanks or cisterns and/or informal tourist businesses. According to a survey done by WMI-GIZ (2013), some of the metered premises were confirmed to be informal tourist accommodation. Moreover, in PZ 3, there were premises observed consuming as high as 4,500 lpcpd, leading to a conclusion that these households are actually tourist facilities. Furthermore, most of the peaks observed were in the months of March, April and May, corresponding to the warmest months of the year. Also, the lowest consumptions are observed in

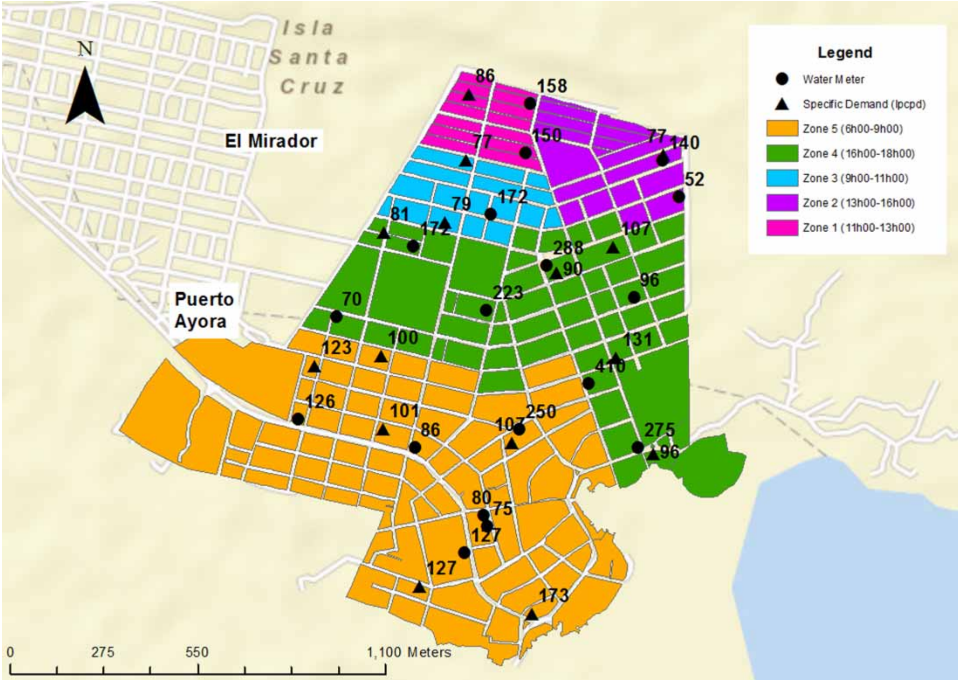

Figure 3 | Map with average specific demand from installed water meters and water appliance analysis (lpcpd).

Table 4 | Summary of water demand for three metered pilot zones in Puerto Ayora for 2013, 2014 and 2015

Pilot zone	Year	Total average consumption per month (m^3)	Average consumption per premise (m^3)	Specific demand (lpcpd)	Standard deviation (lpcpd)
PZ 1	2013	2,689	23	156	±19
	2014	1,039	29	191	±39
	2015	3,449	30	200	±36
	Average	2,393	27	182	±31
PZ 2	2013	–	–	–	–
	2014	2,175	24	158	±37
	2015	4,877	35	232	±93
	Average	3,526	26	195	±80
PZ 3	2013	2,197	33	217	±32
	2014	4,041	75	499	±88
	2015	4,599	85	568	±92
	Average	3,612	64	428	±70

Source: Water cadastres from the Municipality of Santa Cruz.

August, September and October, the coldest months of the year, suggesting some influence regarding the season.

Consumption classification in the pilot zones

With the information obtained from the water cadastres, it was possible to classify the consumers into low, moderate and high, depending on their average specific demand for the entire period each pilot zone was metered.

As observed in Table 5, water demand in some households is very high, especially for a place where water resources have been considered to be scarce and the inhabitants' perception is that there is a lack of water. The results suggest that there might be a lack of equity in the

Table 5 | Consumption classification for three pilot zones

Description (lpcpd)	Consumption classification	No. of households	Percentage (%)	Average consumption (lpcpd)
Pilot zone 1				
<100	Low	18	17%	77
100–180	Medium	29	27%	144
>180	High	62	57%	262
Pilot zone 2				
<100	Low	18	13%	78
100–180	Medium	47	34%	148
>180	High	72	53%	293
Pilot zone 3				
<100	Low	18	53%	75
100–180	Medium	8	24%	164
>180	High	8	24%	637

distribution of water, since houses that consume higher quantities leave less amount of water for the rest of the households in the same distribution zone.

Analysis of water scarcity in Puerto Ayora

Table 6 shows the comparison of the average supply per day obtained from the municipal records, against the estimated average water demand from the three metered pilot zones and the 18 installed water meters (referred to as scenarios). The total water demand is based on the average specific demand and the local population per year (INEC 2010). The leakage was taken as a half of the non-revenue water estimated at ±35% by Reyes *et al.* (2015a). The remaining water calculated (m^3/day) refers to the difference between supply and demand, suggesting that for most scenarios there is enough water to supply average per capita consumption.

The comparisons show that there is mostly enough water to satisfy the average specific demand. Only for the pilot zone 3 scenario (2014 and 2015), the average amount of supplied water would not suffice. This also indicates that the perception of 'scarce' water is not accurate. Yet, potentially high numbers of unreported tourists lower the extreme values of specific demand significantly. Furthermore, an interesting observation is that over the period 2014–2016, the amount of water extracted increased by 50%, while the schedule of intermittency did not change.

The discussion of the results therefore points to an evident lack of management regarding the water distribution system. According to the results, the quantity of water does not seem to be the key issue; it is more the quality. As observed from specific demand figures, some premises registered as domestic, seem to be offering services to tourists, especially in PZ 3. This refers also to the lack of cross-checking of information among institutions. Even though there are only around 40 premises registered as hotels in the water cadastre of the Municipality of Santa Cruz, the Ministry of Tourism affirms there are around 150 tourist accommodations.

Extremely high specific consumption in some households suggests that there is enough brackish water, for at least more hours than currently supplied. Due to the negligence allowing the overflow of individual tanks, this form of storage may not be aiding the intermittency, as originally considered, but actually amplifying it, as well as causing the inequity in consumption; the bigger the storage facilities, the less the availability of water for the rest of the consumers in each zone of distribution. For this reason, the installation of individual water metering is imperative in order to monitor more accurately the domestic consumption. Also, the tariff structures should be changed to a volumetric system.

Finally, monitoring and registering of tank overflows and the development of policies involving penalties should be put into place, with the objective of creating awareness within the population of the excessive wastage of water.

Table 6 | Estimation of water remaining based on different scenarios of consumption

	2013					2014					2015				
Source of info	**Average specific demand 2013 (lpcpd)**	**Total demand 2013 (m^3/day)**	**Total average supply 2013 (m^3/day)**	**Leakage[a] (m^3/day)**	**Remaining (m^3/day)**	**Average specific demand 2014 (lpcpd)**	**Total demand 2014 (m^3/day)**	**Total average supply 2014 (m^3/day)**	**Leakage[a] (m^3/day)**	**Remaining (m^3/day)**	**Average specific demand 2015 (lpcpd)**	**Total demand 2015 (m^3/day)**	**Total average supply 2015 (m^3/day)**	**Leakage[a] (m^3/day)**	**Remaining (m^3/day)**
Pilot zone 1	156	2,026	3,224	564	634	191	2,480	4,305	753	1,071	200	2,598	4,303	753	952
Pilot zone 2	–	–	–	–	–	158	2,051	4,305	753	1,500	232	3,020	4,303	753	530
Pilot zone 3	217	2,819	3,224	564	159	499	6,483	4,305	753	−2,932	568	7,378	4,303	753	−3,828
Water meters	–	–	–	–	–	–	–	–	–	–	164	2,130[b]	4,303	753	1,420

[a]Leakage was assumed to be 50% of previously calculated NRW (35%) by Reyes *et al.* (2015a) since there is no other estimation of leakage in the literature and it represents an average leakage figure. It assumes only leakage along the distribution system.

[b]Calculated based on the projection of population for 2015 (INEC 2010).

CONCLUSIONS

The results of the measurements in this study indicate that the extreme range of specific consumptions can be most likely attributed to three different factors: (1) diverse domestic habits within the local population; (2) lack of awareness and consequent wastage of water within premises, which could also be a direct consequence of fixed tariff structure; and (3) inequity in the distribution. The spillage from elevated tanks and other storage facilities has been identified previously as a major problem, which can be further supported by the figures in this research. Furthermore, the high specific demands create the suspicion of informal accommodations/any other type of tourist business, which may be drastically inflating the specific consumption figures. For these reasons, the municipality needs to develop strict monitoring programmes, as well as specific policies that will incentivize the population to reduce water demand and reduce wastage in households. When it is known that every single visitor needs permission to enter the island and is registered upon arrival and departure, pinpointing illegal tourist facilities should not be too difficult; the results in this research could actually serve as complementary information to that survey.

Furthermore, the wide range of consumptions are surprising for an island where water resources are perceived as scarce. This study suggests that the average per capita demand is even higher than the study made previously by Reyes *et al.* (2017). The obtained figures suggest that there is enough water available, leading to a reduction of intermittency. Unfortunately, no correlation could be found between zone of distribution of supply and measured consumptions. On the other hand, based on the water appliance diary, if toilets were to be replaced by more efficient ones (current ones have tanks of approximately 12 litres), it is believed that the domestic demand could be reduced by approximately 25%. This would also contribute to the improvement of the supply system, allowing more hours of service as well.

Finally, this study has shown that the need for storage facilities should also be reassessed. These facilities do not seem to be helping the local population as has been thought over the last two decades, but may be limiting the performance of the supply system. Finally, the leakage levels need to be further investigated, since this is an important figure when calculating the amount of total actual supply to consumers.

REFERENCES

Arbués, F., Garcıa-Valiñas, M. & Martınez-Espiñeira, R. 2003 Estimation of residential water demand: a state-of-the-art review. *The Journal of Socio-Economics* **32** (1), 81–102.

Bougadis, J., Adamowski, K. & Diduch, R. 2005 Short-term municipal water demand forecasting. *Hydrological Processes* **19** (1), 137–148.

Dinar, A. 1998 Water policy reforms: information needs and implementation obstacles. *Water Policy* **1** (4), 367–382.

d'Ozouville, N. 2009 *Water Resources Management: The Pelican Bay Watershed*. *Galapagos Report 2007–2008*, pp. 146–151.

EPA (Environmental Protection Agency) 2014 Green Building. Available from http://www.epa.gov/greenhomes/bathroom.htm.

Fidar, A., Memon, F. & Butler, D. 2010 Environmental implications of water efficient microcomponents in residential buildings. *Science of the Total Environment* **408** (23), 5828–5835.

INEC 2010 *Censo de Población y vivienda del Ecuador 2010 (Population and living census of Ecuador 2010)*. National Institute of Statistics and Census, Ecuador.

Liu, J. 2011 *Investigación de la Calidad Bacteriológica del Agua y de las Enfermedades Relacionadas al Agua en la Isla Santa Cruz – Galápagos (Research of the bateriological quality of water and sicknesses related to water in Santa Cruz)*. Report from Fundación Charles Darwin – Comisión Fullbright.

Liu, J. & d'Ozouville, N. 2013 *Water Contamination in Puerto Ayora: Applied Interdisciplinary Research Using Escherichia coli as an Indicator Bacteria*. *Galápagos Report 2011–2012*, 76.

Lupo, F. 2015 *Informe Ejecutivo del Mejoramiento del Sistema Municipal de Distribución de Agua y Reducción de las Pérdidas*. Galapagos-Ecuador, Proyecto WMI-GIZ-Gobierno Municipal de Santa Cruz.

OECD 2009 *Managing Water for all: an OECD Perspective on Pricing and Financing*. Report for the Organisation for Economic Co-operation and Development.

Reyes, M., Trifunović, N., Sharma, S. & Kennedy, M. 2015a Data assessment for water demand and supply balance in the Island of Santa Cruz (Galápagos Island). *Desalination and Water Treatment Journal* 1–15. DOI: 10.1080/19443994.2015.1119756.

Reyes, M., Trifunović, N., Sharma, S. & Kennedy, M. 2015b Water supply and demand in Santa Cruz Island-Galápagos Archipelago. *International Water Technology Journal* **6** (3), 212–221.

Reyes, M., Trifunović, N., D'Ozouville, N., Sharma, S. & Kennedy, M. 2017 Quantification of urban water demand in the Island of Santa Cruz (Galápagos Archipelago). *Desalination and Water Treatment*. **64**, 1–11.

Rogers, P., De Silva, R. & Bhatia, R. 2002 Water is an economic good: how to use prices to promote equity, efficiency, and sustainability. *Water Policy* **4** (1), 1–17.

Singh, O. & Turkiya, S. 2013 A survey of household domestic water consumption patterns in rural semi-arid village, India. *GeoJournal* **78** (5), 777–790.

Trifunović, N. 2006 *Introduction to Urban Water Distribution*. Unesco-IHE Lecture Note Series. CRC Press, Boca Raton, FL, USA.

Vairavamoorthy, K. & Elango, K. 2002 Guidelines for the design and control of intermittent water distribution systems. *Waterlines* **21** (1), 19–21.

Vairavamoorthy, K., Gorantiwar, S. & Pathirana, A. 2008 Managing urban water supplies in developing countries – Climate change and water scarcity scenarios. *Physics and Chemistry of the Earth, Parts A/B/C* **33** (5), 330–339.

WMI-GIZ, P. 2013 Mejoramiento del sistema municipal de distribución de agua y reducción de las pérdidas informe ejecutivo – misión operativa No. 4. Water Management International, Gobierno Autonomo Descentralizado Municipal de Santa Cruz, Santa Cruz-Galápagos.

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