Journal of
Water, Sanitation & Hygiene for Development

PUBLISHING

 Journal of Water, Sanitation and Hygiene for Development Vol 12 No 2, 200 doi: 10.2166/washdev.2021.175

Research Paper

Determinants of household water demand: a cross-sectional study in South West Nigeria

A. O. Oyerinde * and H. E. Jacobs

Department of Civil Engineering, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa
*Corresponding author. E-mail: oyerinde.abiola@mapoly.edu.ng

AOO, 0000-0001-7486-7596; HEJ, 0000-0002-7360-6375

ABSTRACT

Estimating residential water demand in developing countries is complicated by the unique nature of water supply, characterised by unequal access and multiple water sources. Using cross-sectional data obtained from a survey of 1,300 households, the determinants of residential water demand were predicted using a multiple linear regression model. The determinants include access to water, household size, trip number, monthly income, payment for water, educational qualification, trip time and house type. The determinants predicted daily water consumption with an $F(9,\ 1{,}014) = 81.063$, $P < 0.05$, $R^2 = 0.450$. Daily water consumption was found to be 2.8 times more per household and 4.4 times more *per capita* for those with on-site access, compared to those with off-site access. Moreover, consumption was influenced by the various water source categories.

Key words: access, demand, household, sources, urban

HIGHLIGHTS

- The study addresses developing countries, especially sub-Saharan Africa.
- It focused on South West Nigeria.
- It addresses heterogeneous suburbs where households have access to multiple sources of water.
- It is the first known study addressing the subject of determinants of water.
- It supported the concept of multiple water variable determinants.

INTRODUCTION

A proper understanding of urban water demand and its determinants is a prerequisite to planning new water projects, while solving the future water demand challenges requires an understanding of the current water use. The nature and characteristics of water demand and supply in sub-Saharan countries are heterogeneous and complex this is further complicated by multiple water supply scenarios, multiple demand variables, varying degree of access to multiple water sources, lack of continuous and comprehensive data, lack of metering, poor water pipe network coverage and aging infrastructure.

Estimating residential water demand has been daunting and the statistical analysis involved in the use of multiple system equations is challenging (Coulibaly *et al.* 2014). Past studies are limited in outlook and focused on individual supplementary sources (Nel *et al.* 2017), where all *r* non-piped sources are classified as additional sources (Nauges & Whittington 2009). Unreliable supply has forced many households to depend on multiple sources of water (often privately owned on-site sources), which makes it difficult to identify the significant variables influencing demand (Klassert *et al.* 2015). Van Koppen *et al.* (2020) addressed the multiple water sources in the rural areas of South Africa, but a knowledge gap remains with regard to urban consumers.

Several socio-economic, demographic and climatic factors influence the demand for residential and municipal water. Bradley (2004) suggests that a mix of socio-economic variables of the target population should be considered as determinants, as the traditional method of using *per capita* demand resulted in over-estimation (Donkor *et al.* 2014). In the developed world, water price, income and income elasticity are prevalent variables (Schleich & Hillenbrand 2008). In the developing world, the determinants of water demand are numerous and include household income (wealth index), income elasticity, household size, plot size, population, water cost, asset score, distance to the water source, trip time and waiting time, quality and reliability of source, pressure of water, daily water demand, water leakage and losses, source of water (level of access) and seasonality (Bradley 2004; Jansen & Schulz 2006; Nauges & van den Berg 2006; Arouna & Dabbert 2009; Nauges & Whittington 2009; Choudhary *et al.* 2012; Poustie & Deletic 2014; Hussein *et al.* 2016; Makwiza & Jacobs 2016; Ahmad *et al.* 2017; Marinez-Santos 2017; Purshouse *et al.* 2017; Meyer *et al.* 2018).

In eastern Nairobi, where there is restricted access to taps, consumption varies from 27.8 to 69.0 litres *per capita* per day (L/c/d), compared to Lagos where 96% of households used non-tap sources, daily consumption varies from 2,150, 1,250, 534, 380 and 200 L/c/d for boreholes, wells, tankers, pushcarts and water retailers, respectively (Sample *et al.* 2013). In Nauges & Whittington (2009) household consumption varies from 72–135, 110 and 25 L/c/d for those with piped connections, private wells and standpipes, respectively; while daily household water consumption varies between 70.44 and 82.04 litres per household per day (L/hh/d) and 145.46–169.76 L/d in the dry- and rainy season, respectively (Arouna & Dabbert 2009).

In developing countries like Nigeria and other cities in sub-Saharan Africa, how effective is the impact of price, income and other socio-economic variables in determining water demand? This research investigates the impact of several socio-economic and household characteristics on residential water demand in developing countries. The emphasis of this study is on water quantity, while the influence of water quality, seasonality, elasticities of price and income were not examined because of a lack of data. Households in the study area used different water sources for different purposes. Drinking water is typically reserved exclusively for water sources with higher quality, that are relatively more expensive (e.g., sachet water, bottled water and processed water bought from vendors). This study gives insight into the determinants of water demands among households that have unequal access to multiple water sources and adds to the existing body of literature on studies in developing countries. The results are expected to improve the future estimation of residential water demand and assist with informed decisions about domestic water issues.

METHODS

Study area

This case study in the South West region of Nigeria used data obtained from a household survey carried out between May and July 2019. The study area falls within the tropical zone that includes the mangrove swamps in Lagos, the thick rain forest in the hinterland and the savanna in the northern part of the region. The population of the region is estimated at 55 million. The towns included in the study are Ibadan (Oyo State), Abeokuta, Mowe, Ibafo, Arepo, Ijebu ode, Sagamu, Ifo, Sango Ota, Agbado (Ogun State), Isolo, Oshodi and Ajegunle (Lagos State). The average annual rainfall is about 1,800 mm, reducing towards the hinterland. Rain falls from March to November in most of the region. Piped water in the region, supplied via potable water distribution systems, is restricted to limited consumers. Most households have personal on-site water sources. Housing patterns varied between the planned (estate) and the unplanned (old cities and urban outskirts).

Field survey (selection of households and data collection)

An application for field work was submitted to the Stellenbosch University Research and Ethics Committee and ultimately approved, paving the way for the field work phase. A total of 1,300 survey responses were obtained and used in the analysis. A breakdown of responses shows 920 households with water on the premises including piped connections (67), private wells (439) and private boreholes (414). The remaining 380 households obtained water from various off-site sources. The study sample was limited to single-family households including single-family detached houses and single-family apartments. This selection was necessary in order to simplify the estimation of water consumption. Attempts at installing water meters at each home during this study failed because of the financial cost involved, ethical considerations, issues with regard to vandalism and theft of meters and the fact that several households used multiple sources and/or did not have access to a water distribution system. Water consumption was estimated for households with off-site access per day using the number of trips to the water point and the size of the container for water collection; size and capacity of tanker that supplied the household; the number of containers purchased from the water truck; and, for households with water access within their premises, the size of the storage tank and the number of tank refilling per week was determined based on the response from house owners. Data collection was conducted between May and August 2019; this period is within the rainy season when groundwater is more available and accessible. The situation would be more dire in the dry season. However, this study did not consider the impact of seasonality caused by a lack of data covering the dry season period.

Data analysis

The determinants of water demand were analysed using various statistical methods. Data entry was originally done in Microsoft Excel (MS Office 365), while IBM SPSS 27.0 was used for the analysis. Simple descriptive measures, analysis of variance, multiple linear regression (STEPWISE) and correlation analysis were performed. Prior to analysis, the data set was assessed for linearity, outliers and multicollinearity.

Multiple linear regression analysis

Multiple linear regression (stepwise) was used to predict the value of a dependent variable (daily household water consumption) and a host of independent (explanatory) variables, which are the determinants of water demand. The correlation and strength of the relationship of cause and effect were investigated. Linear regression was used for the analysis. Daily water use and weekly water consumption were the dependent variables, while all other socio-economic and household characteristics were employed as co-variates and the source of water was the fixed factor.

RESULTS AND DISCUSSION

Socio-economic and household characteristics

The analysis of socio-economic characteristics of 1,300 residential units consisted of 63% standalone houses and 37% apartments. The average household size was found to be 5.09, equivalent to a standard family size of 5 persons and the number of children was 3. Over 90% of the household heads were educated beyond the primary level, portraying a high level of literacy. Many of them are in paid employment as only 8% claimed not to be properly employed, implying economically viable households. There is significant variation in household income that ranges from 50,000 Nigerian Naira ($100)[1] to 500,000 ($1,000) per month. A wide variation in the level of access to a portable water supply was noted, as only 5% had access to private in-house connections. About 66% had a private well or borehole within their premises while about 29% used various off-site sources. The results show that 64% of the respondents lived in personal residences (owned) and 95% claimed to use additional water sources for drinking.

Daily domestic water consumption

The water consumption of households with on-site sources and those with off-site access varied notably. The lowest recorded household water use was ~50 L/hh/d, while about 11 households in the sample consumed above 3,000 L/hh/day. The first 25% or quartile households with access to water within their premises used less than 200 L/hh/d. The largest cluster of households (middle 50%) used between 200 and 600 L/hh/d, while the last quartile used between 600 and 3,000 L/hh/d. The average daily *per capita* water use varied between 140 and 397 L/c/d. More than half (55%) of households without access to water within their premises used less than 200 L/hh/d. The largest cluster (12–90%) used between 100 and 400 L/hh/d, and the daily average *per capita* water use ranged from 36 to 100 L/c/d for households in this category (see Figure 1). Many households used sachet water, bottles or refill packs as an additional source for drinking purposes. This source is the most expensive per unit volume of water.

Determinants of household domestic water consumption

Multiple linear regression analysis was used to identify the determinants of daily water consumption (dependent variable). Only nine variables explained daily household water consumption significantly. The determinants predicted daily water consumption with an $F(9, 1{,}014) = 81.063$, $P < 0.05$, $R^2 = 0.450$. The significance was determined using ANOVA. The complex nature of the water supply system within the study area makes it difficult to assess the determinant, as such the regression model could only explain 45% of variables influencing water consumption. There are other variables that influenced water consumption but are not significant based on available data. Moreover, the R^2 value for cross-sectional data is usually lower than for time-series data (unavailable for this study). Heteroscedasticity is checked using a robust standard error, as the standard error must remain around 1. Multicollinearity was checked using variation inflation factor (VIF) and tolerance value (Basu *et al.* 2017). VIF ranges between 1.008 and 2.482, while a value greater than 5 represents the critical level of collinearity. The tolerance value for the model is 0.403–0.992, while a value of 0.20 is recommended as the minimum value. The model efficiently predicted water consumption and details for each determinant are described in Table 1.

[1] As at May 2021, USD $1 exchanged for 500.

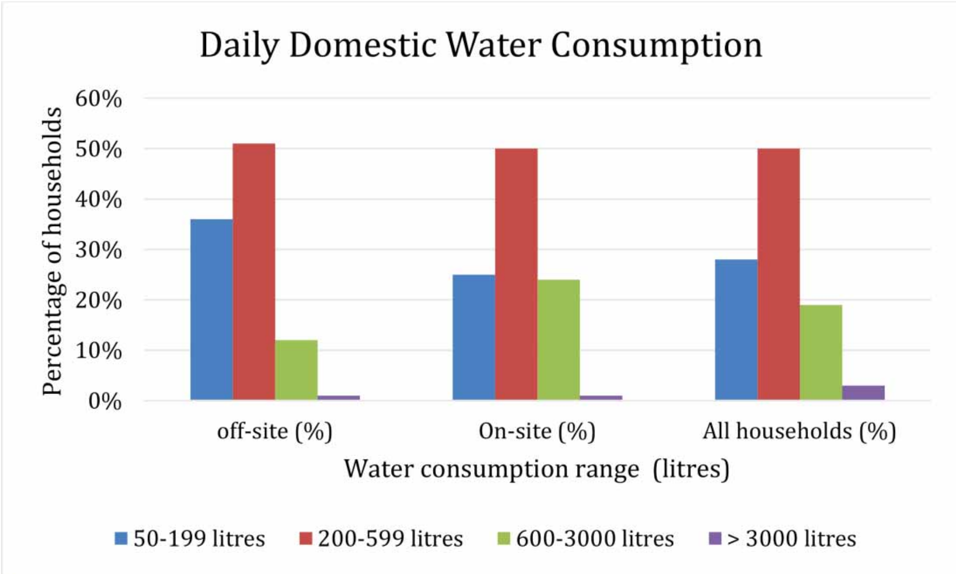

Figure 1 | Daily water consumption for households with on-site and off-site access.

Access to water within the premises (A_w)

Access to water within the premise (private connections, wells and boreholes) is the most significant determinant of water consumption. About 71% of the households surveyed have water within their premises with $r = 0.402$, $P < 0.05$. Consumption ranged from 178 to 384 L/c/d for consumers with access to 36–100 L/c/d for those without access. A large percentage of the population acquire access to water sources through wells and boreholes that are constructed by house owners.

Household size (H_s)

Household size is a significant determinant of household water consumption. An increase in household size caused a similar increase in domestic water consumption, while *per capita* water demand decreases with an increase in household size (Crouch *et al.* 2021). A decrease in *per capita* use as occupancy increased was reported in Bradley (2004) and Basu *et al.* (2017), while Hussein *et al.* (2016) observed that water use is more efficient on a per person basis for higher occupancy (Table 2).

Table 1 | Multiple linear regression estimating the determinants of household water consumption

Variables	Coefficients	Std. error	Significance
Access to water within the premises (A_w)	0.402	0.095	0.000
Household size (H_s)	0.167	0.041	0.000
Trip number (T_n)	0.253	0.060	0.000
Presence of storage (P_s)	0.156	0.091	0.000
Household monthly income (M_i)	0.093	0.026	0.000
Payment for water (P_w)	−0.086	0.031	0.005
Educational qualification (E_q)	−0.061	0.034	0.021
Building/house type (H_t)	0.052	0.021	0.036
Trip time (T_t)	−0.061	0.030	0.000
F(9, 1,039)	86.164		
R^2	0.450		
N	1,330		

Dependent variable: daily water consumption in L/c/d.

Table 2 | Variation of the household size with daily and *per capita* water consumption

	Off-site water source		On-site water source	
Household size	**Household (L/hh/d)**	***Per capita* (L/c/d)**	**Household (L/hh/d)**	***Per capita* (L/c/d)**
1 – 3	301	100	1,153	384
4–5	322	64	1,192	283
6–7	342	48	1,402	200
>7	361	36	1,421	178

Presence of in-house storage facilities (P_s)

Studies in developing countries (Bradley 2004; Cheesman *et al.* 2008; Klassert *et al.* 2015) refer to the impact of on-site storage, especially during the supply interruption as it enhances continuous supply. On-site storage enhances continuous supply. Nauges & van den Berg (2006) discovered a 13% increase *per capita* in piped water consumption for households with storage tanks in South West Sri Lanka, while 90% of respondents in the present study reported on-site storage. On-site storage is significant and positively correlated with water consumption, $r = 0.056$, $P < 0.05$.

Household monthly income (M_i)

Average household water consumption increases with the household income. Household income is positively correlated with water consumption, $r = 0.093$, $P < 0.05$. Most studies agree that an increase in household income is usually accompanied by an increase in water consumption (Husselmann & Van Zyl 2005; Hussein *et al.* 2016; Basu *et al.* 2017). This could be attributed to private ownership of water source, improved lifestyle, water use appliances, garden and swimming pool. Rizaiza (1991) noted that in Saudi Arabia, residential water use varies with income and water price, while the amount of water used for outdoor purposes is directly related to lifestyle and available income (Bradley 2004).

Payment for water (P_w)

Payment for water in developing countries is rather cumbersome, though most households have access to free water sources. Households that use water from similar sources pay the same amount per unit of water. Piped water is the cheapest though highly inaccessible. Tanker water is more expensive and is readily available. Payment for water was significant and negatively correlated with water consumption, $r = -0.086$, $P < 0.05$. In addition, households that pay for water were found to consume less (329–677 L/hh/dd) compared to those with in-house access or free water (1,073–1,321 L/hh/d).

Educational qualification (E_q)

Educational qualification is associated with the choice of water source, housing type especially modern apartment and lifestyle. In this study, education qualification is significant and negatively correlated, $r = -0.061$, $P < 0.05$.

Building/house type (H_t)

The type of building determines the size, built-up area and available household facilities. A house uses more water compared to an apartment at $r = 0.052$, $P < 0.05$. Future development could consider more apartments than standalone buildings, since this could help lead to reduced consumption, although water use per unit land area has been found to remain relatively constant, irrespective of dwelling type (Jacobs *et al.* 2013).

Trip numbers (T_n)

The number of round trips to collect water from a remote source is a significant determinant of residential water consumption among households with off-site water sources. The number of trips is directly correlated to the volume of water collected, purchased or used by households. The result obtained shows $R = 0.253$, significance at 0.000, with an average number of trips at 4.3 trips per day maximum daily number of trips of 10. The method of conveying water includes hauling, carrying and transporting by bicycle and wheelbarrow. The method of conveying was regressed against water consumption, but was found to be insignificant, and as such it was omitted. The frequency of trips is correlated with household water demand, distance to the water source and available labour. The result is similar to Basu *et al.* (2017) where the number of trips per household per day ranged between 4 and 8.

Table 3 | Variation of daily water consumption with household income

Group	Household monthly income range ([a] N,000)	Off-site water source (L/hh/d)	On-site water source (L/hh/d)
1	<50	300	1,183
2	50–100	309	1,198
3	100–200	320	1,324
4	200–500	335	1,336
5	>500	350	1,466

[a]As of July 2021, USD $1 exchanged for 500.

Trip time (T_t)

Trip time or time spent on water collection is negatively correlated with household water consumption. The longer it takes to complete a trip, the fewer the number of trips made per day per household. This is further influenced by water pressure, travel distance and number of water points. Howard & Bartram (2003) concluded that as the time taken to water source increased, the volume of water reduced proportionally, this situation is reportedly aggravated in the dry season as water sources dried up and households had to travel farther to collect water (Arouna & Dabbert 2009).

Socio-economic influence on household water consumption

The influence of income on household water consumption for on-site and off-site water access is reported in Table 3. Consumption varies linearly with income. High-income households consumed more water, and low-income households consumed less. Access to water sources is the most significant variable in this study – high-income households have better accessibility to water sources, and consequently, consumed more water than other income groups.

Source categories and variation of household water consumption

Heterogeneous suburbs are characterised by uneven access to multiple sources of water. The results of the study with regard to water access are presented in Table 4. The highest access was found to be groundwater use from private wells and boreholes at 34 and 32%, respectively (accounting for 66% of users). Delivered water and piped connection represented 5% of the respondents in each case. Conveyed water, defined as all water carried, hauled or transported without a vehicle or pipe, represented -24% of the sample. Access to piped water connection is the lowest, but piped water corresponds to the highest consumption because of the low price of piped water. The access to piped connection was reported in Sample *et al.* (2013) as 4% for Lagos, Nigeria.

CONCLUSION

The present study evaluated the determinants of residential water consumption in heterogeneous suburbs of South West Nigeria using a multiple linear regression model. The determinants include access to water within the premises, household size, presence of storage, monthly income, payment for water, educational qualification, house type, the trip number and trip time.

Table 4 | Variation of daily consumption with water source categories

Source categories	Percentage of access (%)	Average daily consumption (L/hh/d)
Piped	5	1,496
Borehole	32	1,321
Well	34	1,078
Delivered	5	664
Conveyed	24	329

Access to water is a problem faced by many developing countries. Governments, international donors and private organisations have invested notably in domestic water supply, yet water supply coverage and access remain relatively poor. This problem could be addressed by bringing water sources closer to the people. A large variation in water consumption was noted between households that have access to water within their premises and those without access. Decentralised water supply is integral to developing regions, especially for emerging towns and suburbs in the urban fringes. Community-based water projects could reduce the travel distance and trip time – thus reducing water stress. This will in turn increase the level of access, thereby increasing household consumption. On the other hand, the management and control of water quality would become more complex if sources were to be decentralised and could lead to increased community health problems.

Another problem faced in the developing world is the rapid urbanisation without commensurate infrastructure and services, leading to a wider supply–demand gap. This problem could possibly be solved by increasing private participation in the water service provision. Increased poverty and limited household income have hampered the capacity of households to develop private water sources and storage facilities, both of which have been used as coping mechanisms to bridge supply issues in many parts of the developing world. Water sources that are easily accessible to the people are often the most expensive per unit of water. Improved provision of standalone public taps and subsidised tanker waters could improve this imbalance.

The present study also encouraged developmental policies geared at the building of apartments rather than standalone houses – since it is techno-economically feasible to extend water facilities to apartments than standalone houses. Governments could sustain an increased investment in building, equipping and funding water facilities in order to reduce the supply–demand gap and improve water service delivery.

The data used in this study were collected over 3 months, which is one of the limitations of the study. Future research could set out to collect data over a relatively longer period of time and/or other regions to expand on this work. The subsequent time-series data would improve the understanding of household water consumption and policy. Lack of access to pipe connections is another limiting factor to comprehensive water demand analysis. Many households use private water sources (wells and boreholes), but do not have data on their consumption that could be used for analysis. Until such a time when there is universal access, an analysis will be limited in scope. Nonetheless, the study has helped to identify the key drivers of water use and unveil the dynamism of water use in heterogeneous suburbs of the developing world.

ACKNOWLEDGEMENTS

The authors are grateful to the Tertiary Education Fund (TETFUND), Nigeria for partially funding the PhD of the main author and for Moshood Abiola Polytechnic, Abeokuta for supporting this study.

CONFLICT OF INTEREST

There is no known conflict of interest.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

REFERENCES

Ahmad, S., Ali, S. H., Mirza, U. M. & Lotia, H. 2017 The limits of water pricing in a developing country metropolis: empirical lessons from an industrial city of Pakistan. *Water* **2017** (9), 533. doi:10.3390/w9070533.

Arouna, A. & Dabbert, S. 2009 Determinants of domestic water use by rural households without access to private improved water sources in Benin: a seemingly unrelated Tobit approach. *Water Resources Management*. doi:10.1007/s11269-009-9504-4.

Basu, M., Hoshinoa, S., Hashimotob, S. & DasGuptab, R. 2017 Determinants of water consumption: a cross-sectional household study in drought-prone rural India. *International Journal of Disaster Risk Reduction* **24** (2017), 373–382.

Bradley, R. M. 2004 Forecasting domestic water use in rapidly urbanizing areas in Asia. *Journal of Environmental Engineering* **130** (4), 456–471.

Cheesman, J., Bennett, J. & Son, T. V. H. 2008 Estimating household water demand using revealed and contingent behaviours: evidence from Vietnam. *Water Resources Research* **44**, W11428. doi:10.1029/2007WR006265.

Choudhary, M., Sharma, R. & Sudhir, K. 2012 Development of residential water demand model for a densely populated area of Jaipur city, India. *Journal of Water Sanitation, and Hygiene for Development* **2** (1), 10–19. doi:10.2166/washdev.2012.029.

Coulibaly, L., Jakus, P. M. & Keith, J. E. 2014 Modelling water demand when households have multiple sources of water. *Water Resources Research* **50**. doi:10.1002/2013WR015090.

Crouch, M. L., Jacobs, H. E. & Speight, V. 2021 Defining domestic water consumption based on personal water use activities. *Journal of Water Supply: Research and Technology – AQUA* **70** (7), 1002–1011. https://doi.org/10.2166/aqua.2021.056.

Donkor, E. A., Thomas, A. M., Soyer, R. & Roberson, J. A. 2014 Urban water demand forecasting: a review of methods and models. *Journal of Water Resources Planning and Management* **140** (2), 146–159.

Howard, G. & Bartram, J. 2003 *Domestic Water Quantity, Service Level and Health*. World Health Organization, Geneva, Switzerland.

Hussein, W. A., Memon, F. A. & Savic, D. A. 2016 Assessing and modelling the influence of household characteristics on per capita water consumption. *Water Resources Management* **30** (2016), 2931–2955. doi:10.1007/s 11269-016-1314-x.

Husselmann, M. L. & van Zyl, J. E. 2005 Effect of stand size and income on residential water demand. *Journal of the South African Institution of Civil Engineering* **48** (3), 12–16.

Jacobs, H. E., Scheepers, H. M. & Sinske, S. A. 2013 Effect of land area on average annual suburban water demand. *Water SA* **39** (5), 687–694. http://dx.doi.org/10.4314/wsa.v39i5.13.

Jansen, A. & Schulz, C. 2006 Water demand and the urban poor: a study of the factors influencing water consumption among households in Cape Town, South Africa. *South African Journal of Economics* **74**, 3.

Klassert, C., Sigel, K., Gawel, E. & Klauer, B. 2015 Modelling residential water consumption in Amman: The role of intermittency, storage and pricing for piped and tanker water. *Water 2015* **7**, 3643–3670. doi:10.3390/w7073643.

Makwiza, C. & Jacobs, H. E. 2016 Assessing the impact of property size on the residential water use for selected neighbourhoods in Lilongwe, Malawi. *Journal Water Sanitation and Hygiene for Development* **06** (2), 242–251. doi:10.2166/washdev.2016.014.

Marinez-Santos, P. 2017 Determinants for water consumption from improved sources in rural villages of southern Mali. *Applied Geography* **85**, 113–125.

Meyer, N., Jacobs, H. E., Westman, T. & McKenzie, R. 2018 The effect of controlled pressure adjustment in an urban water distribution system on household demand. *Journal of Water Supply: Research and Technology – AQUA* **67** (3), 218–226. doi:10.2166/aqua.2018.139.

Nauges, C. & van den Berg, C. 2006 *Perception of Health Risk and Averting Behaviour: An Analysis of Household Water Consumption in Southwest Sri Lanka*. Working Paper 08.09.253. LERNA, Toulouse, France.

Nauges, C. & Whittington, D. 2009 Estimation of water demand in developing countries: an overview. *The World Bank Research Observer*. doi:10.1093/wbro/lkp016.

Nel, N., Jacobs, H. E., Loubser, C. & Du Plessis, J. A. 2017 Supplementary household water sources to augment potable municipal supply. *Water SA* **43** (4), 553–562.

Poustie, M. S. & Deletic, A. 2014 Modelling integrated urban water systems in developing countries: case study of Port Vila, Vanuatu. *Ambio*. doi:10.1007/s13280-014-0538-3.

Purshouse, H., Roxburgh, N., Javorszky, M., Sleigh, A., Kimani, D. & Evans, B. 2017 Effects of water source accessibility and reliability improvements on water consumption in eastern Nairobi. *Waterlines* **36** (3), 204–215.

Rizaiza, O. 1991 Residential water usage: a case study of the major cities of the western region of Saudi Arabia. *Water Resources Management* **27** (5), 667–671.

Sample, E. D., Awopetu, M. S. & Harou, J. 2013 Modelling urban water use in developing countries: A preliminary application to Lagos metropolitan area of Nigeria. *International Journal of Engineering Research & Technology* **02** (11), 1388–1400.

Schleich, J. & Hillenbrand, T. 2008 Determinants of residential water demand in Germany. *Ecological Economics*. doi:10.1016/j.ecolecon.2008.11.012.

Van Koppen, B., Hofstetter, M., Nesamvuni, A. E. & Chiluwe, Q. 2020 Integrated management of multiple water sources for multiple uses: rural communities in Limpopo Province, South Africa. *Water SA* **46** (1), 1–11. https://doi.org/10.17159/wsa/2020.v46.i1.7870.

First received 16 August 2021; accepted in revised form 23 November 2021. Available online 9 December 2021