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Research Article

Drinking water wastage through sanitary equipment

Desperdicio de agua a través del equipo sanitario

Alfonso Arellano*, Carlos Izurieta, Carlos Bravo, Alexis Merino, Danilo Yépez

Facultad de Ingeniería, Universidad Nacional de Chimborazo, Avda. Antonio José de Sucre, Km 1.5 Vía a Guano, Riobamba, Ecuador, 060108; cizurieta@unach.edu.ec; cbravo.fic@unach.edu.ec; amerino.fic@unach.edu.ec; dyepez@unach.edu.ec

* Correspondence: aarellano@unach.edu.ec

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Abstract: Considering the climatic changes, the overall urbanization problems, and the technological advances, drinking water demand should always be a matter to research yet. In developing countries, many people still do not get enough drinking water to satisfy their basic needs. There is insufficient technical information to apply in water management to optimize drinking water consumption (DWC) and distribute it better. This study identifies the correlation between DWC and sanitary devices (SD). It provides some models to calculate the DWC by knowing how many SD there are in a residential building. The primary data obtained from 11 Ecuadorean cities contains information about social, economic, climatic, demographic, anthropogenic characteristics, and DWC for six months. Some SD outliers are handled with a Box plot. We got some lineal models with a perfect or robust correlation (R>0.75; p-value< 0.05) in big cities. In medium cities, the Sanitary equipment (SE) is used to calculate the DWC by another lineal model (R=0.4315; p-value=0.0097). These mathematical models are essential tools to define DWC optimization policies. The DWC increases because of the number of SD increases in medium and big cities. Water wastage occurs through excessive SD in residential buildings.

Keywords: Consumption, drinking water, sanitary devices, wastage, water

Resumen: *Considerando los cambios climáticos, los problemas urbanísticos y los avances tecnológicos, la demanda de agua potable seguirá siendo un tema de investigación. En países en desarrollo mucha gente todavía no tiene suficiente agua potable para satisfacer sus necesidades básicas. No hay suficiente información técnica aplicada en la gestión del agua para optimizar los consumos de agua (DWC) y para mejorar su distribución. Este estudio identifica la correlación entre DWC y los aparatos sanitarios (SD). Provee modelos para calcular DWC a través del número de SD que hay en un edificio residencial. La información primaria obtenida en 11 ciudades ecuatorianas contiene las características sociales, económicas, climáticas, demográficas y antropogénicas y acerca de los consumos de agua potable durante seis meses. Algunos valores atípicos fueron procesados a través de los diagramas de cajas y bigotes. Utilizando análisis estadístico descriptivo se encontraron modelos lineales con una perfecta o muy fuerte correlación (R>0.75; p valor< 0.05) en las ciudades grandes. En las ciudades medianas, el equipo sanitario (SE) sirve para calcular el DWC a través de otro modelo lineal (R=0.4315; p-valor=0.0097). Estos modelos matemáticos son herramientas importantes para definir políticas para optimización del consumo de agua potable. En las ciudades grandes y medianas, el consumo de agua potable aumenta cuando el número de aparatos sanitarios (SD) aumenta. El desperdicio de agua potable ocurre a través de un excesivo número de aparatos sanitarios en los edificios residenciales.*

Palabras clave: *Agua, agua potable, consumo, desperdicio, dispositivos sanitarios.*

1 Introduction

There is still a considerable population globally that do not have drinking water while other people have it too much. The water distribution systems (WDS) do not have enough tools to balance the inequitable distribution. Some authors direct their research to the economic approach through tariff systems proposals (Sahin, Bertone & Beal, 2017; Santopietro *et al.*, 2018). Others Scientists are especially concerned about improving WDS (Tricarico, de Marinis, Gargano & Leopardi, 2007) because the freshwater availability (Rodell et al., 2018) is becoming scarce, and the urbanization increases together with the human comfort and the necessity to supply drinking water as well (UNESCO, 2009).

The climatic change also impacts freshwater availability (Rodell *et al.*, 2018) and consequently affects the drinking water consumption DWC. Since these events seem to be unavoidable, some authors have taken other directions to optimize the DWC. Some reports demonstrate that water consumption rises when the number of dishwashers and clothes washing machines increases at home (Morote Seguido, 2017).

Other Authors go further and quantify water use per person in residential buildings (Matos, Teixeira, Duarte & Bentes, 2013). Morote Seguido (2017) did a comprehensive bibliographic review about DWC. He identified the following factors: social, demographic, economic, management, psychological, urban, and climatological factors, which affect the DWC. The demographical and climatological incidence was recently quantified by Arellano, Bayas, Meneses & Castillo (2018)

From the demographic approach, the DWC shows different patterns in small, medium, and big cities (Arellano *et al.*, 2018). This report keeps the same range of city sizes and quantifies the DWC per capita upon the number of sanitary devices at home. It aims to provide some linear models to quantify the DWC by knowing how many sanitary devices there are in a residential house. The SD is easy to identify when designs and building construction need authorization by WDS managers. The models allow managers to set up tariffs or bonds to the users to change the water consumption habits. This article contributes to water conservation as well as water management literature.

2 Methodology

2.1 Cities characteristics

The cities are located in three geographical regions in Ecuador, with different socio-economical and climatic characteristics. Arellano *et al.* (2018) reported three groups of cities (small, medium, and big) with DWC similarities. This paper analyzes the variables in each group of cities. Cities' population were withdrawn from national census reports carried out in 2010 (Table 1).

2.2 Samples

Every month the researchers wrote down the water consumption data from residential buildings micrometers. The data had registered m^3 consumption with a decimal fraction and converted to liters per month. The fields' work in 11 cities started in 2013 and finished in 2015 (Carrillo & Quintero, 2013; Montenegro & Tapia, 2014; Morillo & Luna, 2013; Barreno, 2015; Cáceres & Rubio, 2015; Noriega, 2015; Patiño & Pino, 2014; Sagñay & Carguachi, 2015; Samaniego & Muela, 2015).

The field's work on each city took six months. The whole field information contained mainly: how many people live in a residential building, how many and which sanitary devices they have. Therefore, we could know how much drinking water per person is consumed and how many sanitary devices per person.

Table 1: Cities, population, size, and samples.

Population range	Size	City	Population inhabitants 2010	Sample records
500 – 8000	Small	Columbe	526	258
		Cubijíes	588	264
		Guamote	2648	294
		Chambo	4459	330
		Quimiag	5257	270
		Guano	7758	354
8000 – 30000	medium	Joya Sachas	11480	312
		Macas	18984	406
		Guaranda	23874	678
30000 – 150000	Big	Ventanas	38168	588
		Riobamba	146324	1296

2.3 Variables

The DWC is expressed as per capita consumption (PCC) (l/person-day). The primary information shows sanitary, social, and economic characteristics from each house sampled. The sanitary devices (SD) are the toilet, washbasin, shower, kitchen sink, and clothes washing machine (CWM). We call sanitary equipment (SE) to all devices together. The SD and SE area expressed in units per person. Since people's habits are somewhat different, this study includes SD more often used in South American countries. Therefore, the bath, as well as dishwasher machines, were not.

2.4 Data process

The Statistical software R was applied to make a descriptive statistical assessment due to a small amount of data.

We applied the simple lineal regression technique to infer data from others. We calculated the Pearson correlation coefficient R to determine a parameter variation related to another parameter (SD related CPC or SE related CPC). We also calculated the Spearman determination coefficient R^2. The R^2 values are between 0 and 1. The closer to 1, the better the model is. When R^2 values are higher than 0.6, the relation is significant. When R is between 0.50 and 0.75, the correlation is considerable. When R is between 0.75 and 0.90, the correlation is very strong. When the R is between 0.90 and 1.00, the correlation is perfect (Hernández, Fernández & Baptista, 2006).

A correlation will be statistically significant when $p < 0.05$. It will be statistically significant when $p < 0.001$ (less than one in a thousand chance of being wrong). When the pattern showed a lineal tendency, the model is:

$$y = mx + b + \varepsilon$$

where the constants m and b are determined by the least square method.

3 Results and Discussion

3.1 Big cities (*30000-150000* inhabitants)

When the analysis is done individually, between each sanitary device and the DWC, there is a perfect correlation between the toilet, washbasin, shower, and CWM, respectively, with PCC values ($R^2 > 0.8$; $p<0.05$). There is a strong correlation between the kitchen sink and PCC ($R^2 > 0.60$; $p<0.05$). The p-value so low means it is significant from a statistical point of view.

The equations state:

y= monthly average drinking water per capita consumption (l/ person-day).

x= number of each sanitary device individually (toilet, washbasin, shower, kitchen sink, and clothes washing machines) per person (units/person).

These equations could be used to predict the DWC from a residential building by counting the number of sanitary devices.

When we consider SD as a set, we call it sanitary equipment (SE). Figure 3 plots SE against drinking water per capita consumption. The lineal model obtained is considerable and highly significant statistically (Pearson R = 0.6146 y p-valor = 0.001, table 2). The DWC increases when SD and SE increase. It seems that water consumption increases because there is more sanitary device rather than water necessities. Will water demand dropdown if people would not have many SD at home? It confirms that water consumption increases and that sanitary water users increase at home (Morote Seguido, 2017).

In both cases, either with sanitary devices individually or as equipment, the models could predict the DWC in big cities.

3.2. Medium cities (*8000-30000* inhabitants)

In the medium-sized cities (Guaranda's data was removed), the relations between al SD and PCC are considerable (R > 0.5), but they do not have statistical significance because their p-values are much higher than 5% (Table 3). Therefore we did not calculate linear equations.

3.3 Small cities (*8000-30000* inhabitants)

In the cities' smaller than 8000 people, the results are much different from the previous ones. There is no statistical significance between sanitary devices and PCC (p-value is much higher than 5%, table 4), and there is no acceptable correlation (R values are too low). The DWC in small cities does not depend on the number of sanitary devices at all. The correlation between DWC and SE in small cities is harmful and is not valid from a statistical point of view (Pearson R =-0.2166, table 4) although it is highly significant (p-value of 0.0568, figure 5). Perhaps other factors affect the DWC in small cities because the graphic trends are different from big and medium cities.

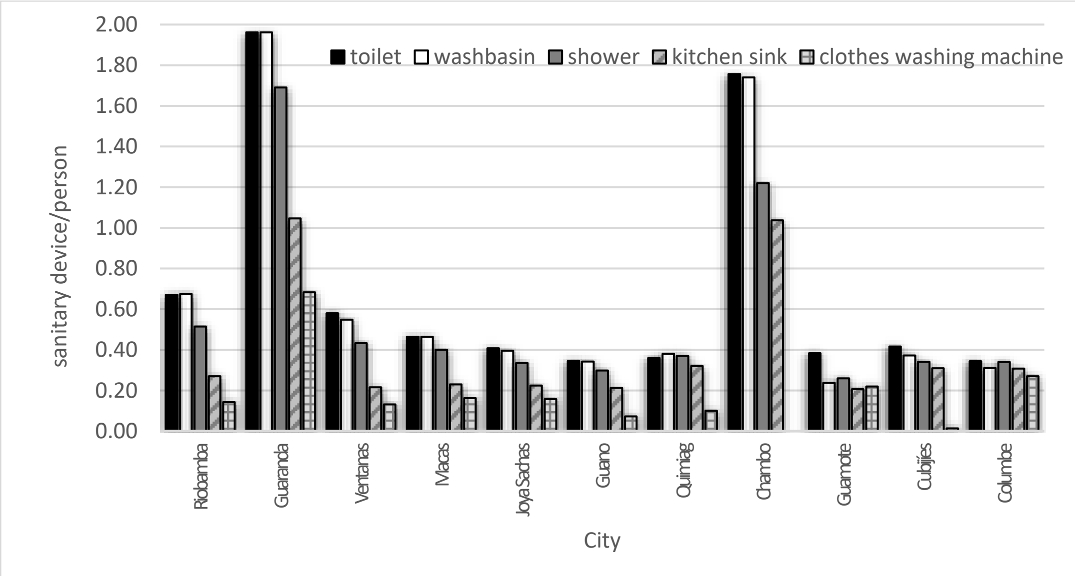

Figure 1: Sanitary devices per capita from 11 cities.

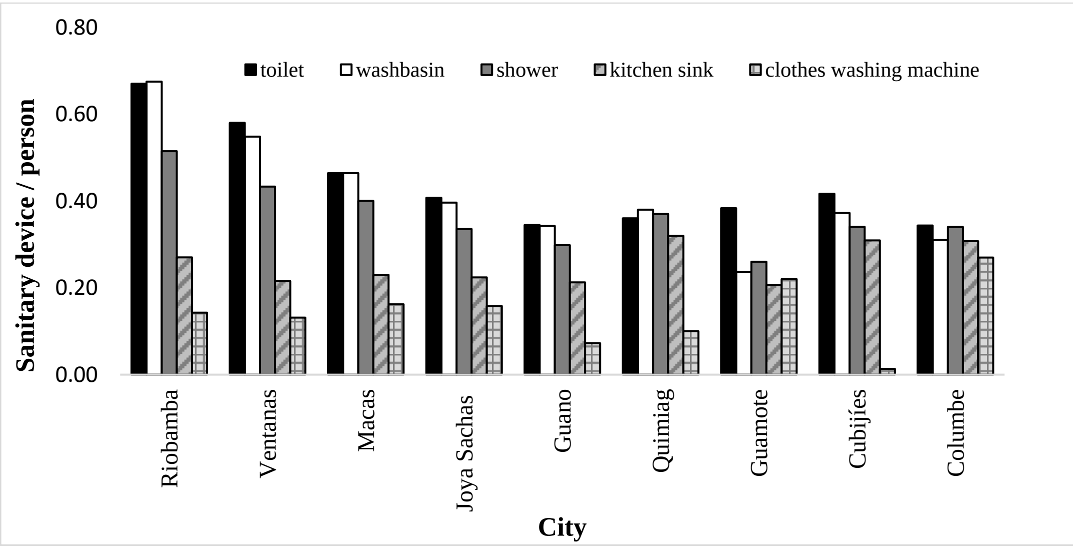

Figure 2: Sanitary devices per capita from 9 cities.

Table 2: Sanitary devices and equipment, versus drinking water per capita consumption in big cities (30000-150000 inhabitants).

Sanitary device	R^2	R	p-value	Equation
Toilet	0.908	0.9529	0.0003	y = 165.86x + 101.2
Wash basin	0.8902	0.9435	0.0004	y = 160.23x + 107.65
Shower	0.8954	0.9463	0.0004	y = 221.69x + 100.59
Kitchen sink	0.6046	0.7776	0.0231	y = 621.7x + 53.306
Clothes Washing Machine (CWM)	0.9573	0.9784	0.0001	y = 434.48x + 145.79
Sanitary equipment	0.3777	0.6146	0.001	y = 103.5x + 163.94

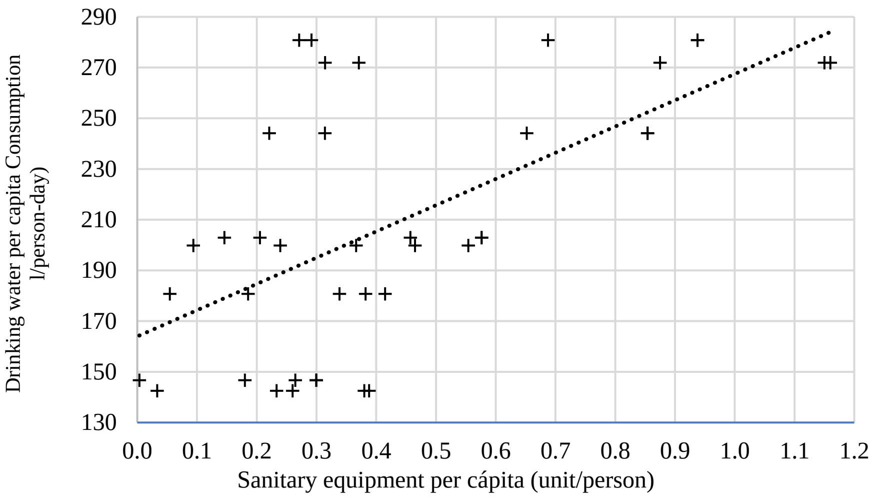

Figure 3: Drinking water consumption and sanitary equipment in big cities (30000-150000 inhabitants).

Table 3: Sanitary devices and equipment, versus drinking water per capita consumption in medium cities (8000-30000 inhabitants).

Sanitary devices	R^2	R	p-value	Equation
Toilet	0.3023	0.5498	0.2010	-
Washbasin	0.3093	0.5561	0.1948	-
Shower	0.3285	0.5731	0.1786	-
Kitchen sink	0.3457	0.5880	0.1650	-
Clothes Washing Machine	0.5439	0.7375	0.0585	-
Sanitary equipment	0.1862	0.4315	0.0097	y = 190.54x + 180.82

The research about water quality, water cost, total inflation, and leaking will provide more information. Figure 1 shows high peaks in two cities (Guaranda and Chambo).

Applying the box plots to identify the outliers and remove the data from those cities, we obtain figure 2, which diminishes the data. However, when the sanitary equipment SE is drawn against the drinking water per capita consumption (Figure 4), it yields a medium correlation (R=0.4315; R^2= 0.1862) with statistically highly significance (p-value=0.0097).

The DWC could be predicted by counting all sanitary devices and applying the following lineal model. It is valid for residential buildings.

The R-value is relatively low, perhaps due to a lack of data.

Where y is the label for monthly average drinking water consumption (l/person-day); and X represents the number of toilets, washbasins, showers, kitchen sinks, and clothes washing machines together (units/person).

Table 4: Sanitary devices and equipment, versus drinking water per capita consumption in small cities (less than 8000 inhabitants).

Sanitary devices	R^2	R	p-value
Toilet	0.0138	-0.1175	0.6768
Wash basin	0.0043	-0.0656	0.8171
Shower	0.0439	-0.2095	0.4536
Kitchen sink	0.2130	-0.4615	0.0833
Clothes Washing Machine	0.1866	-0.4320	0.0735
Sanitary equipment	0.0469	-0.2166	0.0568

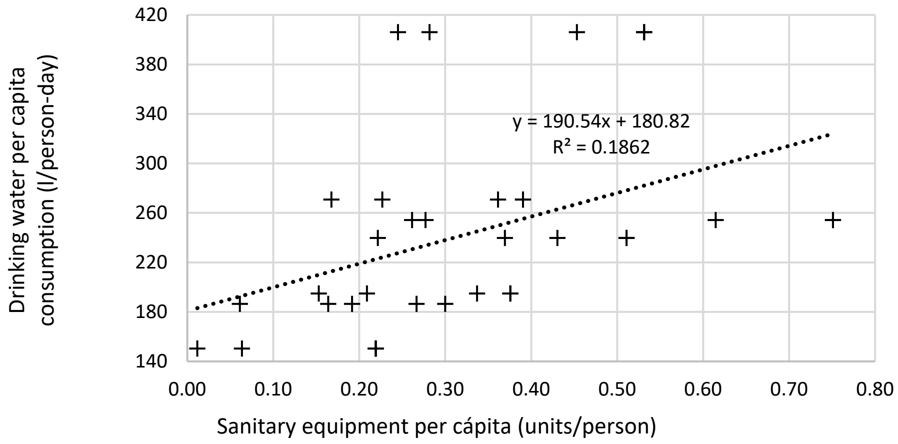

Figure 4: Drinking water consumption and sanitary equipment in medium cities (8000 a 30000 inhabitants).

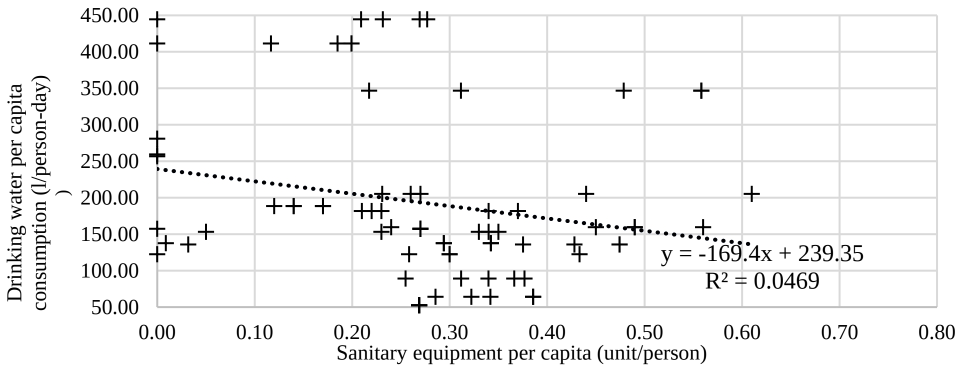

Figure 5: Sanitary equipment and drinking water consumption per capita (less than 8000 inhabitants).

4 Conclusion

The drinking water consumption (DWC) in medium and big cities depends directly on the number of sanitary devices (SD). The clothes washing machines (CWM) lineal models seem to give better results than the other devices' equations. In big cities, the CWM and DWC got a perfect correlation, with high statistical significance. In medium cities, the same device and DWC model got a considerable correlation with statistical significance. In big cities, the sanitary equipment and DWC model also got a considerable correlation with high statistical significance. In medium cities, an unacceptable correlation was got. We can not calculate the DWC in small cities because it does not correlate with SD.

It seems people misuse water when they have too many sanitary devices in medium and big cities. The DWC rises when SD rises, too (Morote Seguido, 2017). If we see the other way around, the DWC will diminish if the number of SD diminish. This correlation gives a significant contribution to defining awareness' strategies to optimize DWC in Ecuador.

The equations yield useful values to fix the water tariff in the SD number function in a residential building (Santopietro *et al.*, 2018). The more SD, the higher the water tariff. Santopietro *et al.* mention the economic value of water recognized by the International Conference on Water and Sustainable Development (ICWE). If it is so, these mathematical models help calculate the water distribution cost based on the SD number. Santopietro *et al.* calculated the WDS rehabilitation cost, but he does not mention the consumption cost. The WDS managers could apply these models to set up differentiated rates for water consumption. The more sanitary devices at home, the higher the tariff to pay.

Conflict of Interest

The authors declare there is not conflict of interest at all.

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