

Preliminary assessment of the drinking water consumption at the residential level in the province of Panamá and Panamá Oeste

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Abstract– Panama is one of the most water-rich countries. Considering the available water resource, it would be expected that access to potable water would not be a problem in terms of quantity. However, many regions nationwide do not have a continuous drinking water supply. The accelerated population growth, the lack of planning in urban development and the lack of investment in network infrastructure represent some of the challenges the country faces regarding the drinking water supply service. Considering the above, an important aspect to address the water supply issues is to understand the behavior of drinking water consumption, in particular at the residential level, who consume more than 70% of the water billed by IDAAN (Instituto de Acueductos y Alcantarillados Nacionales, by its acronym in Spanish). The objective of this research paper is to carry out a preliminary analysis of the water consumption corresponding to the residential sector with the information available from the monthly water bill. The study was carried out through digital surveys. The average daily consumption per person according to the data collected is 48.67 ± 32.18 gallons per person per day (gppd). However, the per capita consumption reported in 2021, analyzed by region, ranges between 69 and 137 gppd. The design value (100 gppd) according to the IDAAN regulations is 2.05 times greater than the estimated average consumption per person. These values highlight that a more in-depth study of water consumption must be carried out, including analysis of factors such as geographic region, income, number of residents, among other factors.

Keywords– Drinking water, residential consumption, monthly billing, drinking water management, water measurement.

I. INTRODUCTION

Panama has an abundant water resource that is sustained by its high rainfall, which reaches an annual average of 8,305.5 gallons of rain per square feet Another example of this water wealth is presented with its multiple hydrographic basins which provide a water availability of 31,572 billion gallons. It is highlighted that in the country 92.5% of the population has drinking water supply services, supplied through public aqueducts by the national water utility company (IDAAN) or by the Health Ministry. However, only 70% and 76% of the population receiving potable water supply have 24-hour access throughout the dry and rainy seasons, respectively [1]. This situation directly affects the population and is reflected in the reflected in the multiple water cuts suffered in certain areas, being more common in sectors inhabited by low-income populations (Fig. 1).

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Climate change and rapid population growth are very important factors to take into consideration with water demand. Water supply is considered one of the most important infrastructure assets of a community, so proper planning, design and management of infrastructure is essential [2].

For potable water management, there are two key parameters for the planning and sizing of supply systems and the production and storage capacity of drinking water, these are: daily and hourly demand; and daily and hourly extreme values [3]. To evaluate these parameters, detailed consumption information with daily and hourly resolution is required. However, current records only show the volume consumed at the end of the month.

Panama currently has 56 drinking water treatment plants (DWTP) nationwide where seven: Miraflores, Monte Esperanza, Laguna Alta, Antonio Yepes de León, Mendoza, Río Gatún and Federico Guardia Conte, extract 405.5 million gallons per day (MGPD) of Gatun and Alhajuela Lakes. These water treatment plants are responsible for supplying the metropolitan area and surrounding cities that are home to approximately 55% of the country's population. Among other plants to mention are those of Howard and Gamboa which are in the process of construction. These plants will have a production capacity of 40 MGPD, expandable to 60 MGPD, in the case of Howard, 65 MGPD, expandable to 85 MGPD, for Gamboa [1], [4], [5], [6], [7]. In addition, expansion works are being developed for Federico Guardia Conte, Mendoza, and Laguna Alta DWTP. These extended modules will have a production capacity of 15, 20 and 5 MGPD, respectively, increasing the water load over the Gatún and Alhajuela lakes [8]. The volume of extractions to produce drinking water is considered important and represents a significant stress to the Panama Canal's hydrographic basin that could compromise the availability of water for the operation of the interoceanic waterway. In 2023, the water used for human consumption and lock operations was 12.4% and 65.5% (TABLE I), respectively [9].

According to data from the Inter-American Development Bank (BID for its acronym in Spanish), it is estimated that the average water consumption per person in Panama is 133.94 gppd [4]. Meanwhile, the average consumption for Latinamerica and worldwide are 44.1 gppd [10], [11] and 49.9 gppd [4], respectively. IDAAN's technical regulations establish a design consumption value of 100 gppd [12]. The per capita consumption, analyzed by region, ranges between

TABLE I
WATER USAGE OF THE PANAMA CANAL HYDROGRAPHIC BASIN
FOR DRINKING WATER AND LOCK OPERATION

Year	Available water (MG)	Lock operations		Drinking water		Ref
		(MG)	%	(MG)	%	
2023	1,163,149	761,872	65.5	144,238	12.4	[9]
2022	1,605,902	927,772	57.8	145,295	9.0	[13]
2021	1,534,839	928,300	60.5	146,087	9.5	[14]
2020	938,603	635,598	67.0	144,766	16.0	[15]
2019	1,029,742	706,396	68.0	145,295	14.0	[16]
2018	1,056,477	850,475	81.0	148,861	14.0	[17]



Fig. 1 Evidence of the lack of water in Panama. Multiple citizens are observed obtaining water from tanker trucks [18], [19], [20].

69 gppd (Eastern Panama and Darién) and 137 gppd (Colón). The national average is 97 gppd, 101 gppd in Panama City and 102 gppd in Panama Oeste [21].

The distribution of drinking water is overseen by IDAAN in the case of communities of more than 1,500 habitants. A monthly invoice is issued corresponding to the volume of water consumed per home, using meters located in each residence or by applying a fixed rate. A correct determination of consumption per residence is essential to evaluate the performance of the water supply. The measurement can be affected by the following factors: status of the meter, number of inhabitants per home, area of residence (urban or rural), error when taking readings in the meter and condition of the aqueduct system. According to IDAAN's statistical bulletin from 2022, the amount of drinking water distributed nationwide is 194,389 million gallons (MG), of which 142,123 MG are through the IDAAN's network, so that this institution has been responsible for 73.1% of production. In 2022, the amount of water billed by IDAAN was 117,146 MG. Of this value, 76.81% is consumed by the residences, 13.51% by the commercial sector, 0.08% by the government sector and 1.31% by industry. Of the amount of water billed, it can also be mentioned that 17.7% correspond to direct measurements from the meter, 53.9% measurements averaged according to standard consumption rate and 28.4% without measurements (TABLE II) [22].

TABLE II
DISTRIBUTION OF BILLED CLIENTS FROM 2013 THROUGH 2022

Year	Total volume (MG)	Read meters	Average usage	Without meters	Ref
2022	117145.7	17.7	53.9	28.4	[22]
2021	115096.4	19.2	52.2	28.6	
2020	114390.9	12.8	58.7	28.5	
2019	114306.9	47.7	24.1	28.2	[23]
2018	112295.4	47.1	24.2	28.6	
2017	110498.2	47.1	23.7	29.2	
2016	106936.5	49.2	20.6	30.2	[24]
2015	103460.5	47.7	19.1	33.1	
2014	100162.2	43.2	19.9	36.9	
2013	96229.2	36.2	20.4	43.4	

Considering the above, the importance of accurate measurement of drinking water consumption at the residential level is highlighted. The objective of this research is to carry out a preliminary evaluation of the drinking water demand in the province of Panama and Panama Oeste using the available monthly information, individual home water bills. This, in turn, supports the sustainable development objective SDG 6 (Clean Water and Sanitation), as well as SDGs 9, 11 and 13, which refer to the planning and construction of sustainable infrastructures, in the presence of the climate change phenomenon.

II. MATERIALS AND METHODS

A. Methodology

The analysis of drinking water consumption at the level of population, housing, and other data of interest, consisted of the preparation of a digital survey, which was distributed and designed through the Google Forms platform. This platform was preferred over others of the same type, due to its ease of use with the data obtained and its greater degree of reach when used.

The survey was launched at 11:00 am on April 27, 2023, and was promoted both in person (Universidad Tecnológica de Panamá, Campus Víctor Levi Sasso), using QRL, and virtually through social networks such as: WhatsApp, Twitter, Instagram, and Outlook. Participation in the survey was voluntary. It remained open for 5 weeks, closing on June 1, 2023.

B. Used Resources

The survey was designed through multiple sections created in the Google form, with the aim of making links between them and thus being able to obtain the respondent's information with greater order and ease. Most of the sections were dedicated to obtaining a complete regional location (province, district and jurisdiction) according to the territorial order established in the address of the billing receipt.

The rest of the sections were used to consult data such as:

- Volume of water consumed
- Days of consumption
- Existence or not of a meter
- Billing with IDAAN or other entity
- Number of people per residence

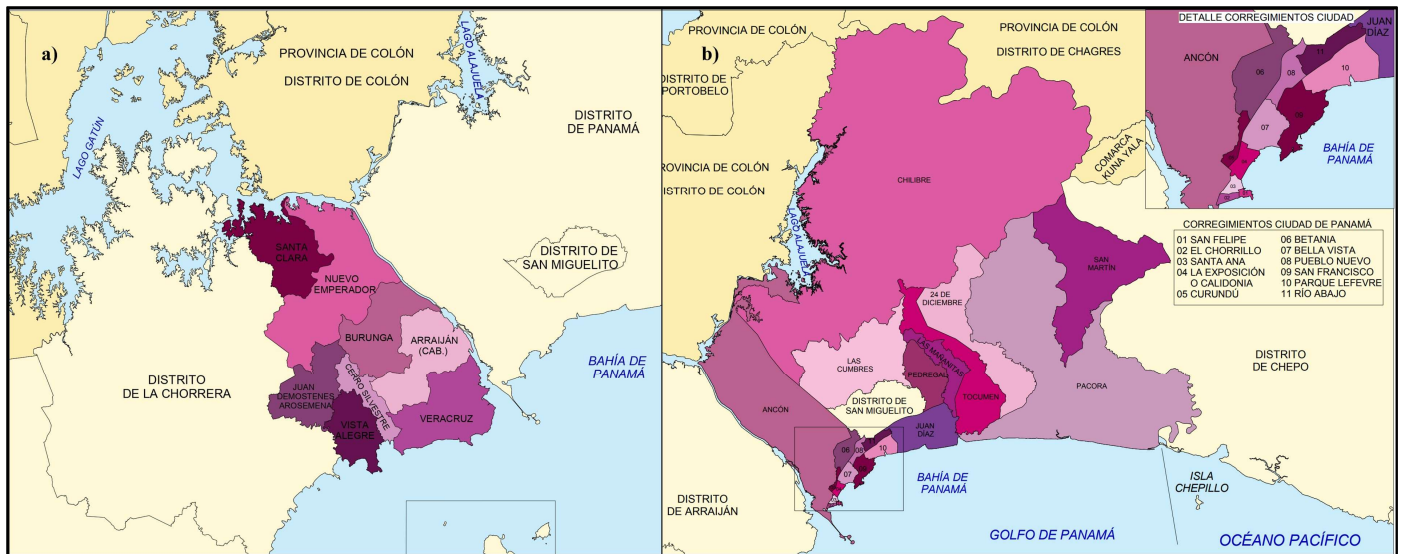


Fig. 2 Political-administrative division of the districts and jurisdictions of the provinces of a) Panamá Oeste and b) Panamá [25].

- Residence type: apartment or house
- Opinion on the current water rate

From the consulted data in the survey, the essential data for the analysis of water consumption were the volume of water consumed per residence, days of consumption, number of residents per home and regional location. To carry out the analysis of domestic water consumption and the rest of the analyzes, the Microsoft Excel tool was used. This was used to organize, filter, and calculate the data of interest at the time of carrying out each study.

To create the graphs, Microsoft Excel was used to generate the domestic water consumption graphs (box whiskers, box and whiskers graph), and the online application Canva was used for the graphs corresponding to the rest of the data obtained in the survey (pie chart).

III. RESULTS AND DISCUSSION

A total of 233 surveys were received. 174 responded that they do receive a water bill from IDAAN. The 59 responses that do not receive a water bill could be due to: 1) the residence is part of a building that has a common meter for the entire infrastructure, 2) the water service is not managed by IDAAN, 3) the residence does not have a meter. Approximately, 80% of the responses that do not receive a water bill from IDAAN are found in the provinces of Panamá and Panamá Oeste.

Of the 174 responses that reported that they do receive billing, 116 provided monthly consumption volume data used in the analysis. That is, 58 responses reported a consumption volume of zero. This could be due to 1) the meter is damaged, 2) there is a flat rate charge, 3) there was no reading in the reported month. Approximately, 89% of the responses that reported zero consumption are found in the provinces of

Panamá and Panamá Oeste. In Fig. 2 political-administrative division of the district of Panamá along with the surrounding districts.

A. Data distribution at the province level

Fig. 3 shows the distribution of responses obtained with the survey at the province level. Of the 10 provinces established in Panamá, volunteers residing in 9 provinces provided a response. Of these, 87.7% of the participation was centered in Panamá (74.4%) and Panamá Oeste (13.3%). Followed by provinces such as Chiriquí, Veraguas, and Los Santos. The provinces of Herrera, Bocas del Toro, Coclé and Colón were the ones that contributed the least amount of data for the analysis.

B. District-level data distribution

Fig. 4 presents the distribution of data obtained with the survey at the district level. The greatest contribution of data was provided by the districts of Panamá, San Miguelito, (both part of the province of Panamá) and Arraiján (province of Panamá Oeste) which represent 97.1% of the responses that were considered for the analysis. In the background are the districts of La Chorrera, San Carlos, and Chepo with 2.9 %.

C. Water consumption analysis (2023)

Fig 5 presents the results of the water consumption analysis carried out based on residential water consumption obtained in the period from the end of April to the beginning of June 2023. According to the information collected in the surveys of the water bill of IDAAN.

The average value, standard deviation and median of water consumption per residence is 48.67 ± 32.18 gppd and 52.14 gppd, respectively. The design value (100 gppd) is 2.05 times greater than the average value and the value

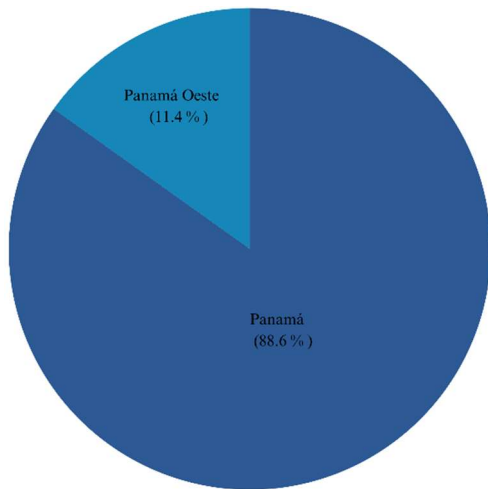


Fig. 3 Distribution of responses obtained at the province level.

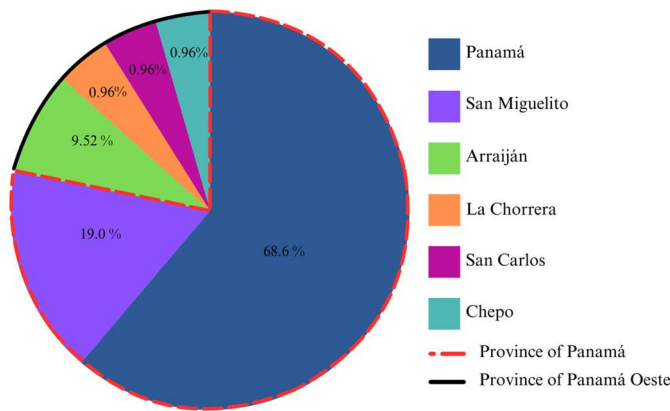


Fig. 4 Distribution of responses obtained at the district level.

estimated by IDB reports is 2.73 times greater [4]. The estimated minimum and maximum value are 1 and 148 gppd, respectively.

In the analysis, 96.23% of the consumption values obtained were below the design value (100 gppd) and only 3.77% were above.

D. People per household

Fig 6 shows the percentage distribution of people per household in the residences surveyed. For this analysis, only residences that receive a water bill were considered (103). More than 75% of the responses have between 3 to 5 residents per home, with the mode being 4 residents. The highest percentages were 36.8% (4 people), 19.8% (3 people), 21.7% (5 people), and 13.3% (2 people). The average number of inhabitants per home was 3.84. For comparison, the average value of inhabitants per residence reported by the National Institute of Statistics and Census (Instituto Nacional de Estadística y Censo) is 3.8 [26].

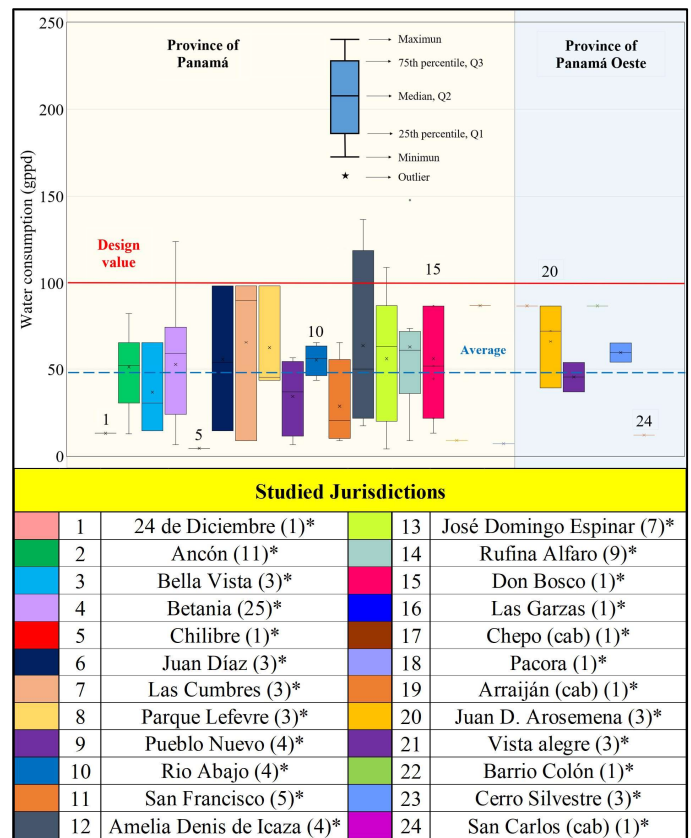


Fig. 5 Domestic drinking water consumption (2023) by jurisdiction. Note: the numbers inside the symbol “(*)” indicates the amount of data gathered from each jurisdiction.

E. Surveyed residences

From the results obtained, it can be observed that more than 65% of the data used in the analysis of water consumption is from houses, this being 66.7% while the apartments contributed 33.3% of the data. Making this distinction is important, since apartment-style residences generally do not have backyard areas and recreation areas are common. Performing the data analysis taking only those provided by houses, an average value and standard deviation of 55.43 ± 32.77 gppd was obtained and median of 55.40 gppd. In the case of those provided by apartments, an average value and standard deviation of 46.87 ± 28.05 gppd was obtained and median of 49.97 gppd.

F. Meters in residences

For this analysis, all the responses received in the survey (233) were considered. From the results it was obtained that approximately half of the responses sent do not have a meter.

The data taken for this analysis was inferred through possible cases posed to the respondent such as:

- Whether or not you have IDAAN billing
- It has always had equal water consumption 0
- Has had water consumption different from 0
- The residence meter is damaged
- The residence does not have a meter

G. Users' opinion on the water rate

Considering the daily situation to which users are subjected with the drinking water supply service, one of the questions in the survey refers to the opinion about the rate. Fig. 7 shows the percentage distribution of the opinions of the respondents regarding the monthly rate billed by IDAAN. For this analysis, only residences that receive an IDAAN water bill (174) were considered.

Most respondents agree with the current rate of 72.4%, 8% would prefer it to go down and only 19.5% think the rate should go up. It should be noted that Panamá has one of the lowest rates in the region. This has been maintained for more than 40 years [1], [27]. The rates currently used are those defined in 1982 [27], [28].

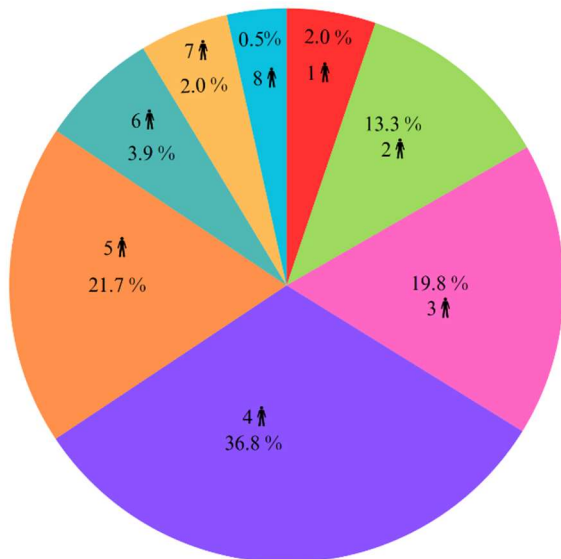


Fig. 6 Distribution of the number of people per home.

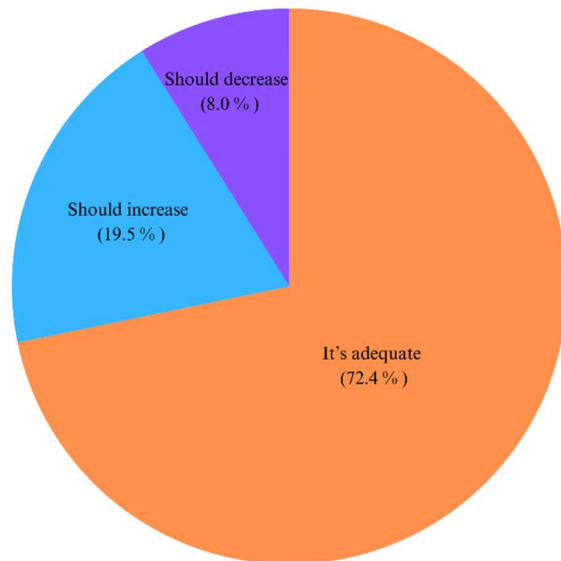


Fig. 7 Distribution of opinions regarding the IDAAN monthly rate.

H. Data comparison (2002-2020 vs 2023)

The data collected was compared with a previous database of water consumption. This database consists of more than 300 observations collected in activities of the water treatment course between 2002 and 2020. From the analysis of these data, it can be highlighted that the average value of water consumption per person is 61.20 ± 28.58 gppd with a median of 57.65 gppd.

To achieve a comparison between the data obtained for the first and second analysis, only the common areas in both databases were considered. Fig. 8 shows the comparison between both databases and the areas considered for the comparison.

By performing the calculations again for each data group, an average water consumption value of 48.14 ± 32.48 gppd (2023) and 60.91 ± 24.44 gppd (2002-2020), a median of 52.14 (2023) and 58.66 (2002-2020), was obtained. The minimum consumption values were 1 (2023) and 4 gppd (2002-2020), and the maximum values were 148 (2023) and 130 (2002-2020) gppd. In both cases, water consumption per person is significantly lower than the design value (100 gppd) according to the areas evaluated. The average consumption value reported by the IDAAN is 95 gppd at the national level, 98 gppd in Panamá Metro and 99 gppd in Panamá Oeste [29]. In a previous study, average consumption for single-family homes was reported between 48.86 and 102.76 gppd depending on the region or neighborhood [30].

IV. CONCLUSIONS

- It can be concluded that a significant percentage of the responses collected did not provide consumption values (33%) since they reported zero consumption. This can be said to be due to one of the following factors: the meter is damaged, or the residence does not have a meter.
- According to the results obtained for the consumption analysis and the comparison between them, it is concluded that the design value (100 gppd) is 2.05 times greater than the consumption per person at the level of the studied areas.
- The evaluation of water consumption is an important factor in the management of water resources and operation of the supply network and should be studied in more detail. The sample size must be expanded, and an evaluation must be carried out at the regional or neighborhood level.
- Given the problems that the population suffers with respect to the supply of drinking water, more in-depth studies of water consumption must be carried out, including at the level of geographic sectors to provide useful information to technical personnel based on scientific evidence that supports the network operation.

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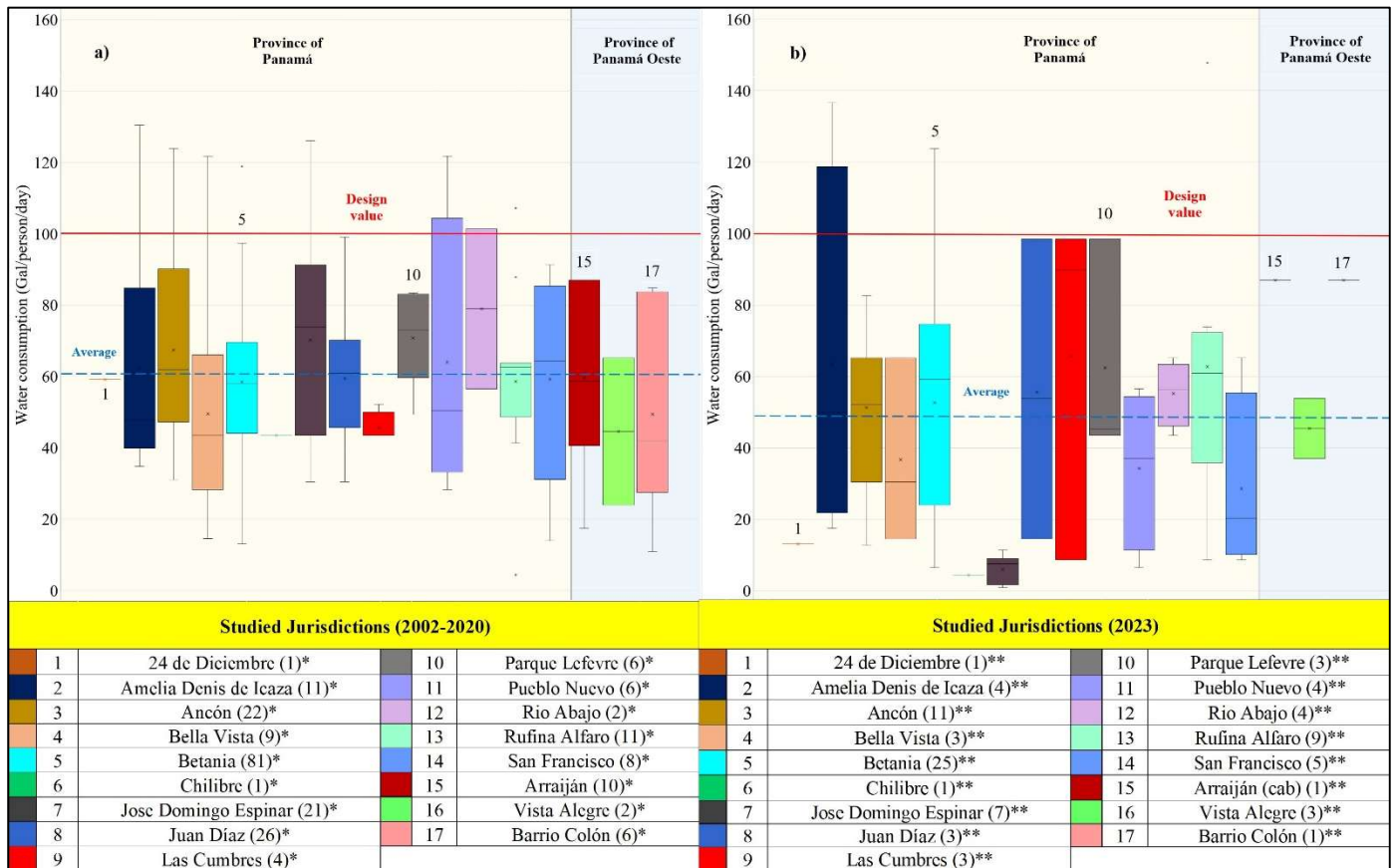


Fig. 8 Comparative graph of water consumption a) 2002-2020 vs b) 2023. Note: the symbols “()” and “()**” corresponds to the amount of data gathered from the jurisdictions of the years 2002-2020, and 2023, respectively.

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