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Coefficient of Variation of Drinking Water Networks in Residential Urban Complexes

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Abstract- The objective of this paper is to establish a real value of daily and hourly variation coefficients for the design of drinking water networks. Determining the real daily K1 and hourly K2 coefficients of variation of different residential urban complexes, can constitute a reference for the design of future constructions. To be able to size drinking water networks, it is important to know the magnitude of variations in the volume of water that exists and the demands of the population, as the water consumption depends on various conditions and aspects such as: climate, socioeconomic factors population, and for future designs, the global Covid 19 pandemic. The study area will take place in Ecuador, located in the Guayas Province, The Daule city, specifically in the residential urban complexes and called citadels, in the Brillante stage in La Joya and Estelar stage in Villaclub. The macro water meter reading was recorded, 3 days a week, 24 hours a day, in each citadel, then, information was obtained from real water payroll to calculate the coefficients and the impact of the diameter was also calculated with the formula of Hazen Williams. Finally, some real values of coefficients, are not within the range established by current regulations.

Keywords: drinking water networks, coefficients of variation, daily, hourly, water flow.

1. Introduction

For the design of drinking water networks, the Ecuadorian Standards [1] recommend the use of a reference value for the daily and hourly variation's coefficients; otherwise, they established that, based on studies of existing systems, the coefficients of variation can be applied by analogy to the desired project. In an investigation, Delgado & Zorrilla [2] established that the value of the hourly variation coefficient K2 was 2.87, which is not found in the range of values of variation coefficients recommended by the National Buildings Regulations, which recommended that it should be K2= 1.8 – 2.5. They concluded that K2 has a different behaviour in the study area and requires higher demand for water in hours with higher flow. Taking into account the determinants of coefficients of variation, it is important to carry out previous studies to calculate it, as they can give higher or lower results than what is established in the current regulations.

During the process of creating and planning hydraulic investment projects in the urban sector, in our country, difficulties or problems are often found during the execution process, especially in the design of drinking water networks, since this is not exactly known if the values established by the Ecuadorian Institute of Normalization [3] and the values of National Secretary of Water [4], are suitable for its application in the study area because of to the characteristics of each population. The designs of drinking water network can be under or oversized. The system will fail earlier than expected. Other factors that can cause problems include pressure drops, incorrect sizing of pipes, incorrect coefficients of variation, water leaks and ruptures.

2. Theoretical Framework

2.1 Coefficient of Variation

It is a dimensionless value used in the design process of drinking water systems, also defined as a factor that considers a safety margin that compensates for the variations in water consumption that happens during a day. The value of this coefficient decreases as the number of habitants increases, as water flow becomes more heterogeneous. The standards established in Ecuador recommend these values of coefficients of variation:

- Coefficient of Variation Daily K1 = 1.3 to 1.5
- Coefficient of Variation Daily K2 = 2.0 to 2.3

2.2 Endowment

This is the amount of water required to satisfy the needs of the population. The amount of water required varies based on the climate of the area the network needs to supply. According to Secretaria Nacional del Agua [4], they recommended the values of the Table 1, in case of have no data and feasibility studies:

Table 1.- Endowment recommended by Ecuadorian Standards

POPULATION (habitants)	CLIMATE	AVERAGE FUTURE ENDOWMENT (Lt/hab/day)
Until 5.000	Cold Mild Warm	120 – 150 130 – 160 170 – 200
5.000 to 50.000	Cold Mild Warm	180 – 200 190 – 220 200 – 230
More than 50.000	Cold Mild Warm	>200 >220 >230

2.3 Average Daily Flow

It is an average flow of one day during the year or during a set measurement time, its units are volume over time. It is obtained through established Equation (1) by Ecuadorian Standards:

$$QPD = Population * Endowment \qquad (1)$$

2.4 Maximum Daily Flow

It is the maximum flow on a specific day, this depends on the average daily flow and the daily variation's coefficient, as seen in Equation (2):

$$QMD = QPD * K1 \qquad (2)$$

2.5 Maximum Hourly Flow

It is the maximum flow in a specific hour, this depends on the average daily flow and the hourly variation's coefficient, as seen in Equation (3):

$$QMD = QPD * K2 \qquad (3)$$

3. Materials and Methods

3.1 Type of investigation

It is based on an experimental method. This involves the observation, manipulation and recording of variables (dependent, independent, intervention variables, etc), that affect the object of investigation. It has a descriptive – analytical level and quantitative approach.

3.2 Population and Sample

According to INEC [3], they mention the percentage of Population density that exists in the study area, which is 3.84 for the canton Daule. To obtain the total number of habitants or persons, the operations of formula (4) are performed:

Table 2.- Calculation of the number of habitants by population density by houses/family

Residential Urban Complex	Number of Houses (A)	Population Density (B)	Number of Population (A*B)
La Joya (Brillante)	480	3.84	1.843,20 pers
Villaclub (Estelar)	368	3.84	1.413,12 pers

4. Analysis and Discussion of Results

4.1 Analysis of Flow Variation Curves

The reading record of the macrometer installed in each complex was made. The days were: 10^{th}November, 12^{th}November and 15^{th}November, 24 hours a day for 1 week.

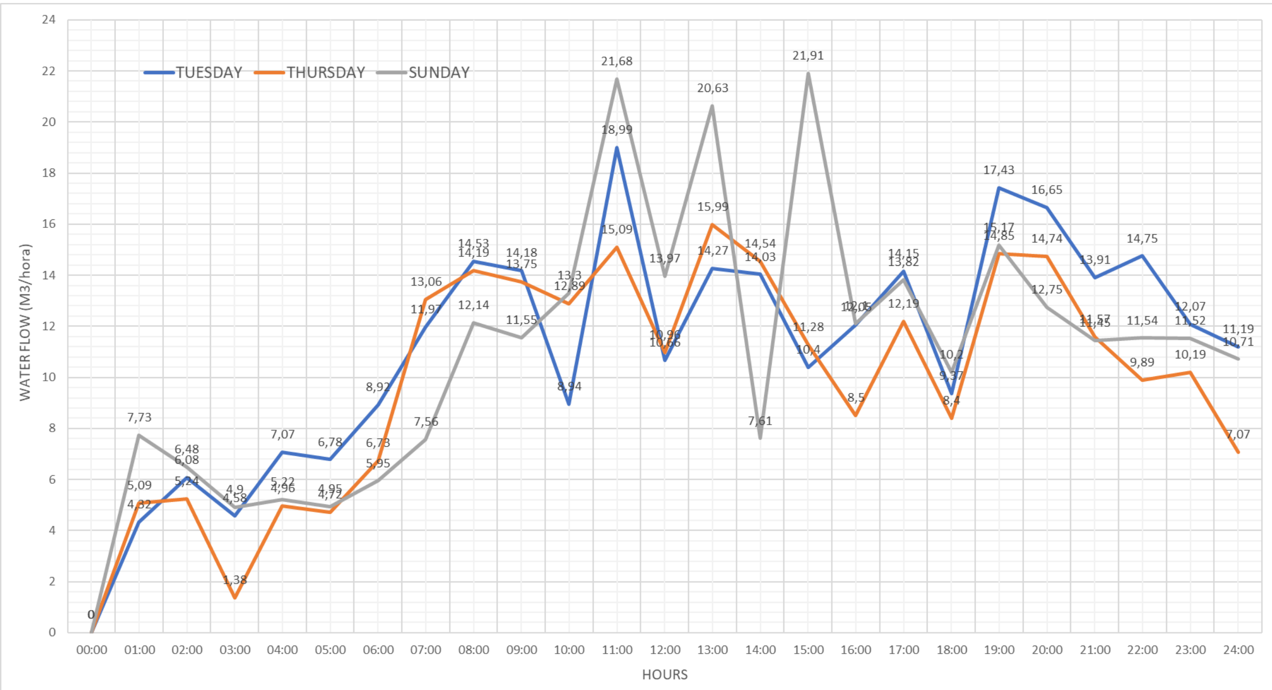

Figure 1.- Behaviour of water flows in La Joya (Brillante)

In summary, the day with the highest water flow was Tuesday, November 10, with a value of 277,29 m^3/day, which is the maximum daily flow. And the hour with the highest water flow, it was Sunday, November 15 at 3:00 pm, with a value of 21,91 m^3/hour, which is the maximum hourly flow.

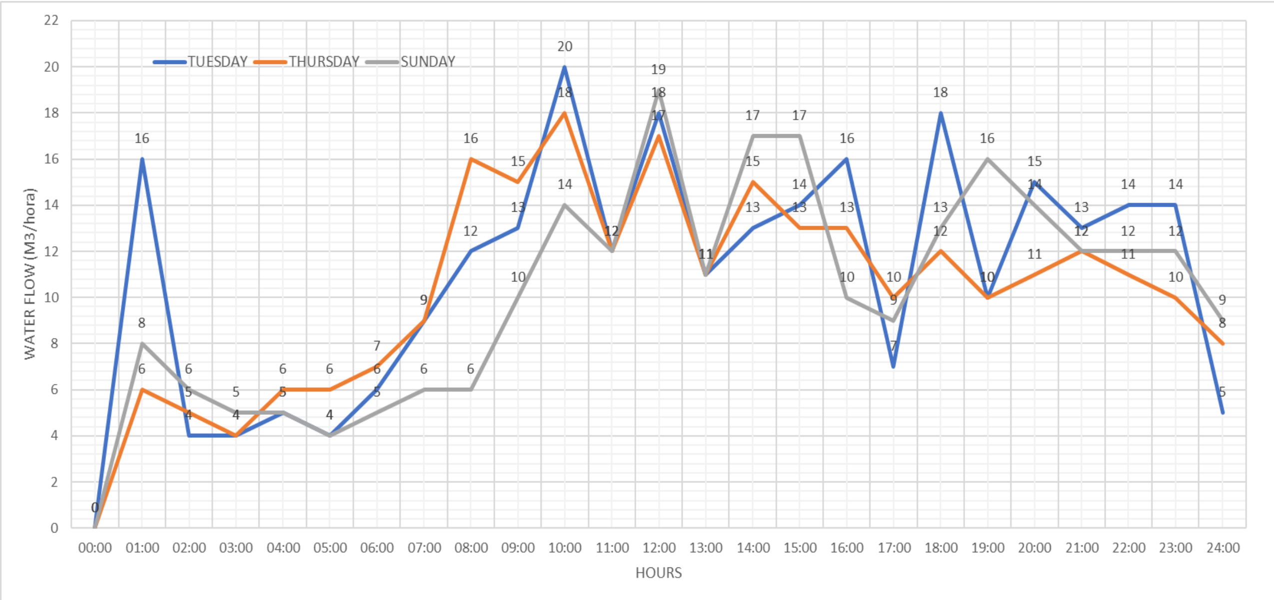

Figure 2.- Behavior of water flows in Villaclub (Estelar)

In summary, the day with the highest water flow was Tuesday, November 10, with a value of 273,00 m^3/day, which is the maximum daily flow. The hour with the highest water flow was Tuesday, November 10 at 10:00 am, with a value of 20,00 m^3/hour, which is the maximum hourly flow.

4.2 Calculation of Coefficients of Variation

Information was obtained from the water payroll of families residing in each complex and Average Endowment per year was established, which is the total sum of the water consumption values of all the water payrolls; however, for calculation, the Endowment per day per person is required, then, the values obtained are detailed in the Tables 3 and 4.

Table 3. - Summary of results obtained to calculate coefficients of variation in La Joya (Brillante)

ITEM	DESCRIPTION	FORMULA	RESULT	
A	Maximum Daily Flow	Analysis	277,29	m^3/day
B	Maximum Hourly Flow	Analysis	21,91	m^3/hour
C	Maximum Hourly Flow	B * 24	525,84	m^3/day

D	Annual Endowment Year 2020	Water payroll	178,00	m^3/family - year
E	Average Monthly Endowment Year 2020	D / 12	14,83	m^3/family- month
F	Average Monthly Endowment per family	E / 30	0,49	m^3/family - day
G	Population Density	Data INEC	3,84	
H	Average Daily Endowment per person	G / H	0,13	m^3/person - day
I	Average Daily Endowment per person	H * 1000	128,76	litres/person - day

J	Population of the urban complex		1.843,02	person
K	Average Daily Flow	J * H	237,31	m^3/day

L	**COEFFICIENT OF VARIATION DAILY**		**1,17**	
M	**COEFFICIENT OF VARIATION HOURLY**		**2,22**	

Table 4.- Summary of results obtained to calculate coefficients of variation in Villaclub (Estelar)

ITEM	DESCRIPTION	FORMULA	RESULT	
A	Maximum Daily Flow	Analysis	273,00	m^3/day
B	Maximum Hourly Flow	Analysis	20,00	m^3/hour
C	Maximum Hourly Flow	B * 24	480,00	m^3/day
D	Annual Endowment Year 2020	Water payroll	323,00	m^3/family - year
E	Average Monthly Endowment Year 2020	D / 12	26,92	m^3/family- month
F	Average Monthly Endowment per family	E / 30	0,90	m^3/family - day
G	Population Density	Data INEC	3,84	
H	Average Daily Endowment per person	G / H	0,23	m^3/person - day
I	Average Daily Endowment per person	H * 1000	233,65	litres/person - day
J	Population of the urban complex		1.413,12	person
K	Average Daily Flow	J * H	330,18	m^3/day
L	**COEFFICIENT OF VARIATION DAILY**		**0,83**	
M	**COEFFICIENT OF VARIATION HOURLY**		**1,45**	

4.3 Impact of Coefficients on the Diameter of Pipes

To find the impact of the coefficients on the diameter of the pipes, the formula of Hazen Williams was used, which is to find the load losses. The analysis focuses on determining a similar value of load losses used in the maximum hourly flow, considering the theoretical and real coefficient of variation and interacting with the Diameter of pipes until a similar load losses value is get. For this calculation, the formula of Hazen Williams (4) was used.

$$hf_{(m)} = 10{,}67 * \left(\frac{Q_{\left(\frac{m3}{seg}\right)}}{C} \right)^{1{,}852} * \frac{L_{(m)}}{D_{(m)}^{4{,}87}} \quad (4)$$

Therefore, the differential values correspond to water flow and Diameter; for this case, the water flow applied is the maximum hourly flow; the value of C = 150 is keep, which is a function of the pipe material, and the length “L” was used of a constant of 1.000 meters.

Table 5.- Diameter comparison results as a function of Variation's Coefficients

Description	Dairy flow (average)	Coefficient of Variation Daily K1	Coefficient of Variation Hourly K2	Diameter	Load Losses
	m^3/sec			m	mca
La Joya	0,00275	1,17	2,22	0,15	1,0645
Comparison with literature		1,5	2,3	0,15	1,0642
Villaclub	0,00382	0,83	1,45	0,14	1,2509
Comparison with literature		1,5	2,3	0,17	1,2506

5. Conclusion

In the analysis of the water flow curves, in La Joya, the day with the highest flow was Tuesday, November 10, with a value of 277,29 m^3/day and for Villaclub, the day with the highest flow was also Tuesday, November 10, with a value of 273,00 m^3/day.

For La Joya, the coefficient of variation daily K1=1,17 and hourly K2=2,22, in comparison with the actual regulations establish for the K1= 1,3 to 1,5 and K2= 2,0 to 2,3, only the coefficient hourly K2 is in the range. For the case of Villaclub, the coefficient of variation daily K1=0,83 and hourly K2=1,45, anyone is not in the range of Ecuadorian Standards.

To calculate the impact of the coefficients of variation in the Diameter of the pipe, in the case of La Joya, it is shown that there is not impact, while for Villaclub, the Diameter varies from 0,14 m with a real coefficient and 0,17 m with a theoretical coefficient.

6. References

[1] Instituto Ecuatoriano de Normalizacion. (1992). Normas para estudio y diseño de sistemas de agua potable y disposición de aguas residuales mayores a 1000 habitantes. Quito.

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[4] Secretaria Nacional del Agua. (2014). Normas para estudio y diseño de sistemas de agua potable y disposición de aguas residuales para poblaciones mayores a 1000 habitantes.