Informador Técnico 84(1) January - June 2020: 100-113 *e-ISSN 2256-5035* *doi:http://doi.org/10.23850/22565035.1756*

Statistical control of water consumption at the Universidad del Atlántico: design of the environmental management monitoring system

Control estadístico del consumo de agua en la Universidad del Atlántico: diseño sistema de monitoreo sistema de gestión ambiental

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Received: 23-08-2019 Accepted: 23-12-2019

How to cite: Ibarra-Montes, Miguel; Herrera-Acosta, Roberto; Ortega-Afanador, Vivianna. (2020). Control estadístico del consumo de agua en la Universidad del Atlántico: diseño sistema de monitoreo sistema de gestión ambiental. *Informador Técnico*, 84(1), 100-113. https://doi.org/10.23850/22565035.1756

Resumen

En los últimos tiempos se ha evidenciado una preocupante disminución en las fuentes de recurso hídrico para el consumo humano, distintos factores son los causantes de su deterioro y elevado consumo en las actividades industriales, agrícolas y de consumo diario en poblaciones grandes, para esta última, la Universidad del Atlántico gestiona este recurso mediante el Sistema de Gestión Ambiental (SGA). El objetivo de este trabajo fue estudiar el control estadístico en el consumo del agua por bloques en la Institución; se realizaron diseños de cartas de control por cada bloque durante un semestre, como datos históricos, los cuales se usaron luego para comparar, mediante las medidas paramétricas usadas en las cartas de mediciones individuales los controles presentes en el consumo de agua. Usando el control estadístico se logró evidenciar alteraciones en el consumo de agua con lo que se realizaron inspecciones de posibles fugas, lo cual justificó las causas de variabilidad a intervenciones de obras en algunos bloques y se dieron recomendaciones de mecanismos a implementar para el control del consumo del preciado líquido.

Palabras clave: monitoreo ambiental; indicador ecológico; gráficos de control.

Abstract

In recent times, there has been a worrying decrease in the sources of water resources for human consumption, different factors are the causes of their deterioration and high consumption in industrial, agricultural and daily activities in large populations, for the latter, the Universidad del Atlántico manages this resource through the Environmental Management System (EMS). The objective of this work was to study the statistical control in the water consumption by blocks in the Institution; Control chart designs were made for each block during one semester, as historical data, which were then used to compare, through the parametric measures used in the individual measurement charts, the controls existing in water consumption. By using statistical control, it was possible to evidence alterations in water consumption with which inspections of possible leaks were carried out, that justified the causes of variability to work interventions in some blocks and recommendations were given for mechanisms to be implemented for the control of the consumption of the precious liquid

***Keywords**:* environmental monitoring; ecological indicator; control charts.

1. Introduction

Recently, environmental issues have taken priority in all types of organizations, accelerated world population growth and socioeconomic factors have contributed to water scarcity around the world, approximately 1/5 of the world's population does not have access to drinking water, and it is predicted that by 2025 more than 3/5 of the world population will face problems of insufficient water (Nieto, 2011), all this sets the standard to identify proposals for technological innovation in its management. The Universidad del Atlántico, being one of the most important for the department of Atlántico, with a population of 23,909 undergraduate students, 504 graduate students and 1,330 teachers, due to its extension and the multiple activities that are developed, generates an impact on the environment. The headquarter object of this study was the main campus of the Universidad del Atlántico North branch, it has a large physical plant of 281,956 m^2 (Universidad del Atlántico, 2019), whose administrative division consists of nine blocks (buildings) eight of them, identified with the following nomenclature: A, B, C, D, E, F, G, H, that are mainly classrooms, but with some administrative offices and dependencies, a block for administrative staff, a coliseum, a sports center and a block under construction at the time of this research: I. Blocks A, B, C (from now on block ABC) are linked and in them classes of the Faculty of Basic Sciences, Engineering and Chemistry and Pharmacy are taught, as well as the Dean´s office of Basic Sciences, the Office of the Vice President for Teaching and Research, the Faculty of Nutrition and Dietetics, the Physics, Chemistry, Microbiology and Engineering Laboratories. Blocks D and F are linked, and classes are taught there from the Faculty of Economic Sciences, Human Sciences, Education Sciences and Engineering, in them there are also computer rooms, the Faculty of Human Sciences, the Faculty of Sciences of the Education, the Faculty of Architecture, the Faculty of Economic Sciences, the Amílcar Guido Jiménez Hall and the Planning Office. In block E there are classes from the Faculty of Educational Sciences, especially from the University Program in Physical Education, Recreation and Sports; block G constitutes the library and block H houses classes from the Faculty of Engineering, Law and Education Sciences. There are seven water meters at the Universidad del Atlántico and in this work, they will be named, according to the original administrative nomenclature.

Due to universities are considered companies and to be sustainable they require conservation and good use of their resources (Rivas-Marín, 2011), the United Nations Environment Program (UNEP, 1977) announced that Higher Educational Institutions (HEI) must have a special responsibility in the protection and management of the environment and, in general, they implement the international environmental regulations ISO 14001, as applied in various universities in Europe, the United States, Canada and some countries in South America. Therefore, in order to comply with these regulations, the impacts of the activities on the environment are considered, and thus develop a plan to reduce the impacts generated by its growing population and the processes that take place there (Rivas-Marín, 2011).

The Management Report of the Universidad del Atlántico for 2018 speaks of a total consumption of drinking water billed of 195,427 m^3 (Universidad del Atlántico, 2018), which contrasts, for example, with the consumption presented by the Universidad del Norte, located in the same geographical area, which was 151,122 m^3 for the same year on its main campus (Universidad del Norte), that is, that waste is evident. Therefore, an efficient management of the resource is required at the Universidad del Atlántico, having with which to detect problems such as damage to the network infrastructure and propose immediate solutions, would be very useful, in addition, this process requires the participation of all the stakeholders, as stated by the Dublin principles: Water management must be inspired by an approach based on the participation of users, planners and decision-makers at all levels.

Water plays an important role in ecosystems; therefore, it is necessary to extend the construction of knowledge in lines that allow addressing the comprehensive management of water resources for sustainable development (Hernández-Pasichana; Posada-Arrubla, 2018). The Integral Management of Water Resources (IWRM) seeks to guide the development of public policies on water resources, through a combination of economic and social development and the protection of ecosystems, according to the guidelines of the Ministry of the Environment, while technical-scientific knowledge is a valuable resource that must be created and managed to promote the development of sustainable production (Lagos; Vargas, 2003). For this reason, tools such as the "Water Footprint" have been created for water resources, which assesses the sustainability of resources, measuring the total volume of water used by the inhabitants of specific regions (Tolón-Becerra; Lastra-Bravo; Fernández-Membrive, 2013), but it does not allow continuous monitoring that leads to immediate actions; the control chart produces an evolution in that sense, the theory is simplified and its graphical utility provides speed in the analysis (Álvarez, 2018). Despite this and the expansion of its use in the industrial field, they have focused on improving leak detection and monitoring systems (Gutiérrez; Pérez-García; Izquierdo; Herrera, 2010); the use of control charts has not been explored in this topic, although there must have a considerable amount of data to use control charts, but in many cases only samples of size n = 1 can be taken at each time, due to the process characteristics. The control chart for individual data or Chart X is used for this type of cases and, in addition, it monitors the middle level of the process.

Recent studies have shown that it is robust enough to detect changes in the mean and in the dispersion of the process, since when an individual measurement is triggered, it directly affects the two moving ranges in which it participates, that is why it can be used as the only measurement control chart for a process, but, on the other hand, it has been shown to be sensitive to the assumption of normality. The general objective of this work is to monitor water consumption measurements at the Universidad del Atlántico and through the analysis of its statistical behavior, using control charts and thus obtain valid conclusions that lead to the implementation of mechanisms that allow the rationalization of water consumption.

2. State of the art

As higher education institutions, universities have a significant impact on society and can play a key role in providing sustainability. In particular, "green" universities are expected to contribute to sustainability to a greater extent (Dagiliūtė; Liobikienė; Minelgaitė, 2018). It should be noted that the average monthly consumption/dwelling in hot areas nowadays is between 15 and 16 m^3, according to the compilation of standards of the Commission for the Regulation of Drinking Water and Basic Sanitation; on the other side, strata 4, 5 and 6 currently have an average consumption of 20 m^3 (El Heraldo, 2017).

Farina; Maglionico; Pollastri; Stojkov (2011) in their research integrate quantitative data on water consumption through the measurement of water and historical data on building users, analyzing data collected over time and arriving at an approximation of water use in public schools connected with their occupants adjoining buildings. There are two main categories of water-saving measures to reduce its use: technical measures include network improvement, leak repair, development of water-saving appliances; and non-technical measures that include information, education and awareness that can change consumer habits (Yang *et al.*, 2017).

Otaki; Ueda; Sakura (2017) investigated methods to promote water conservation through feedback on the level of long-term water consumption. This study, conducted in Tokyo, where there is a concern about water shortages, and consumers were provided with four types of feedback on the level of water consumption in their community. These included actual consumption, average consumption, consumption range, and emoticons with written information. Feedback was sent every two (2) weeks over a twenty-four (24) week period. The results indicated the effectiveness of the comments in high and low consumers, setting a standard in research on water conservation.

Bhakar *et al.*, (2015) analyzed the water supply, its consumption, recycling, and related energy consumption in an Indian university, located in a semi-arid zone. In total, 2,038,722 L of water/day of consumption on campus for irrigation and 1,481,424 L of water for irrigation/day were estimated. It was concluded that tap water in academic and residential buildings was the main source of impact.

Cedeño-Viteri; Rodríguez-Aguilar; Sánchez (2012) presented a new statistical control methodology for a sewage treatment plant operating in the original variable space. This study focuses on the performance of the detection stage, which applies the Mahalanobis distance of 2 orders as a statistical test, concluded that the computational load of the identification stage guarantees real-time results for the faults found.

Romano; Woodward; Kapelan (2017) presented their data analysis methodology to determine the approximate location of a leak within a piping system, Measured Area (DMA). This methodology is based on the statistical process control (*Statistical Process Control - SPC)* and the leak location system (LLS) that automatically processes the night data recorded every minute. It was mainly concluded that LLS allows to substantially reduce operational costs by reducing leak search area and reducing the number of unnecessary leak repairs, improving customer service through more proactive and informed communications, and reducing the number/duration of supply interruptions and low-pressure situations.

Kofinas; Spyropoulou; Laspidou (2018) generated data on water consumption at home, the work took place in two case studies, Skiathos, Greece and Sosnowiec, Poland, exhibiting significant differences in water consumption patterns, showed effectiveness in reducing gaps between the data and missing values, the approach used can constitute a potential basis for building a tool that will support tasks that demand large series of water consumption data.

Gutiérrez *et al.,* (2010) analyzed the variations in water quality in a distribution network. For this, statistical process control techniques (*SPC)* were used, in order to detect and measure significant mismatches of the desired variable over time. Using control charts, the response of the network to a theoretical entry scenario for a pollutant, as a first approach to establish possible alert states and the definition of potentially critical points within the network. It was mainly concluded that statistical process control techniques, despite being originally created in industrial processes to verify the quality of products and reduce potential failures in production, can be applied to other types of events, in which, demand the detection of changes or mismatches in a variable, in this case being anomalies in the quality of the water in a distribution network. The approach presented allowed that, by means of a control chart, the magnitude and intensity of the variations due to the intrusion of the pollutant studied was detected and monitored.

Statistical control charts allow to monitor processes periodically, the speed of their response is evaluated through the Run length or Average Run Length, (ARL) this is decisive in the search for a chart that fits the production characteristics (Quintana; García; Casal, 2011) and is defined as the number of points plotted on a control chart until the first out-of-control signal appears. Theoretically, a control chart under ideal characteristics of normality has an ARL of 370 (Lagos; Vargas, 2003). The charts of individual measurements and mobile path are particularly suitable for the study of batch processes (Juran; Gryna; Bingham, 2005), these are diagrams for variables of the continuous type applied to slow processes, where there is an important period between one measurement and another, for example, water consumption (Gutiérrez; De la Vara, 2013). In destructive processes where it is only possible to have one measurement at a time, preceding the construction of the chart for individual observations, their normality must be tested, since otherwise, the results could be equivocal (Mustafa; Rodríguez; Chauvet, 2002) because of the sensitivity to the assumption of normality that this chart presents. In this work, the Anderson-Darling normality test was used, because it is one of the most powerful normality tests (in particular, the most powerful in the statistical packages used), the sample size, its effectiveness in extraordinary or aberrant cases (*outliers*) (Marques, 2011) and the importance it gives to distribution queues, which leads to a better fit; In addition, this test provides a better detection capacity in small samples (Pedrosa; Juarros-Basterretxea; Robles-Fernández; Basteiro; García-Cueto, cited by Marques, 2011).

$$A^2 = -n - (\frac{1}{n}) \sum\left[(2i-1)Ln\left(p_{(i)}\right) + (2n+1-2i)Ln\left\{1-p_{(i)}\right\}\right] \quad \textbf{(1)}$$

An alternative to the Anderson-Darling test is the Kolmogórov-Smirnov test, considered less powerful than the Anderson-Darling test, however, it shows great efficiency in detecting non-normality in medium sample sizes (n200) (Pedrosa *et al.,* 2015), the Kolmogórov-Smirnov statistic is defined as (Llinás, 2017):

$$D_n = {}^{max}_{\;\;x}|F_n(x) - F\ (x)| \quad \textbf{(2)}$$

Where, $F_{(n)}$ (x) = sample cumulative distribution function and F (x) = hypothetical cumulative distribution function.

The control chart X is defined as follows (Lagos; Vargas, 2003) (Equation 3, 4 and, 5):

$$\text{LCS} = \bar{X} + \frac{3\,\bar{R}}{d_2} \quad \textbf{(3)}$$

$$\text{LC} = \bar{X} \quad \textbf{(4)}$$

$$\text{LCI} = \bar{X} - \frac{3\,\bar{R}}{d_2} \quad \textbf{(5)}$$

$$\text{Where } \bar{X}\ \sum_{i=1}^{n}\frac{x_i}{n}, \sum_{i=1}^{n}\frac{|R_i|}{(n-1)}$$

Hitchin and Knight (2016), in their work, explained and illustrated some of the characteristics that are specific to air conditioning systems and described how energy signatures that take them into account can be applied to produce benchmarks, control charts and information for diagnosis, emphasizing the use of energy signatures originating from the daily energy consumption of the measured system. They found that the daily control charts provide warnings, but do not provide meaningful diagnostic information on specific faults and that this type of information can be provided by a sub-hourly power signature and by sub-hourly interval residual values, providing reports of exception.

Smeti; Koronakis; Golfinopoulos (2007) in their research constructed control charts for the data obtained from the daily toxicological analysis of the treated water (water that has already been used for human consumption) from the treated water tanks of the Water Supply and Sewerage of the Athens Corporation. The basic idea of the control charts was to test the hypothesis that there are only common causes of variability *vs.* the alternative that there are special causes. The charts were designed and evaluated under the assumption that the process observations are independent and identical normally distributed. It was mainly concluded that typical control charts are ineffective, due to the existence of autocorrelation in the toxicity data for the three treated water tanks. The large amount of autocorrelation that was present in the data drastically reduced the performance of the charts, giving a large number of false alarms when estimated through the MR average range of motion and covering the actual alarms when *s* was estimated through the sample standard deviation *s*.

3. Methodology

Statistical control of drinking water consumption was carried out at the Universidad del Atlántico with the support of the Environmental Management System (EMS) through its Efficient Water Management Program (PGEA), performing the statistical analysis and design of the control chart for individual data or Chart X, from specific historical data to a semester and per block.

3.1 Sample collection

Water consumption was measured in cubic meters (m^3) by reading 7 water meters of the Universidad del Atlántico campus, these measurements yielded a sample size of n = 1 at each time for each drinking water meter. For data analysis, the STATGRAPHICS Centurion XVI.I and Minitab 18 software were used.

For the design of the control chart, readings were made four times a week, obtaining the water consumption from Monday to Thursday during the month of August until November of the immediately preceding year; taking the academic period where classes were being taught normally, completing 58 measured data per block, with which the statistical evaluation of the stability of the process was carried out and the control chart was designed. To control monthly water consumption, readings were made for two weeks, measuring consumption three times a week, thus completing a total of six data.

For the statistical analyses, the normal activities of each building were taken into account, the blocks that consume the most water were the ABC, due to its natural activity as a science block, where the laboratory practices are linked, which require additional water consumption, Block I is inherent to the research and it is its function, however, it is lower, since the research groups have not yet moved to it, followed by the Administrative Block and Block H by the number of staff that stays there and its capacity, respectively. Those that consume the least are the coliseum and the Sports Center, since they have few bathrooms, they are small and the population that enters there is less, in addition, the irrigation of the sports complex's fields is carried out with treated wastewater.

3.2 Phase I - Process control design

3.2.1 Anderson-Darling normality test

To test the normality hypothesis of the population, an Anderson-Darling normality test was performed.

3.2.2 Initial study

This phase consisted mainly of estimating the process parameters, trying to establish whether the process is under statistical control by using the individual letter in this case.

First, an initial study control chart was made to obtain the process parameters for each variable, μ and σ.

3.2.3 Debugging

Following the initial study, we proceeded to verify atypical data and detect the assignable causes within the process.

Once the causes of variability had been detected, the data considered atypical was eliminated to stabilize the process control chart.

3.3 Phase II - Operation control

Phase II of the study was continued after the purification of the data set, to monitor future observations, for which online monitoring was carried out, taking four data for each block in one week.

Independent charts were made for each block, considering that the activities carried out are different, in addition, that the exact date of each plotted point must be recognized for the control to be effective.

3.3.1 Implementation of statistical control

After determining the statistical model that the data set followed, the statistical control was carried out based on individual control charts and moving range, that is, monitoring if the data variation is within the expected limits for a process without relevant changes, all this, considering the defined settings in phase I.

In this phase, the chart was used to determine if the process is under control when future samples are drawn, that is, an inference. No samples were used in phase I (initial study).

4. Results

4.1 Normality test

Using the Anderson-Darling test procedure, performed with Minitab 18 software, the cumulative distribution function observed for each variable was compared with the determined theoretical distributions (see Table 1).

Table 1.

Anderson-Darling normality test for each data set

Block	P-value	Block	P-value
Adm.	0.019	I	0.294
ABC	0.025	Coliseum	0.0048
D	0.011	Sports center	0.007
H	0.0047	--	--

Source: own elaboration.

Since the P-value obtained from the Anderson-Darling test (in most cases) is less than or equal to 0,05, according to (1), the idea is that all blocks come from a normal distribution with 95 % confidence. However, taking into account the sensitivity of Chart X to the assumption of normality, it was decided to perform another normality test, the Kolmogórov-Smirnov test, with great efficiency for the study sample size and the results obtained are concentrated in Table 2.

Table 2.

Kolmogórov-Smirnov normality test for each se of data

Block	P-value	Block	P-value
Adm.	0.419366	I	0.674798
ABC	0.514932	Coliseum	0.0543713
D	0.510508	Sports center	0.330186
H	0.232474	--	--

Source: own elaboration.

Since the smallest P-value obtained for the data set of the Kolmogórov-Smirnov test performed is greater than or equal to 0,05, according to (1), cannot reject the idea that all blocks come from a normal distribution with 95 % confidence.

In view of the contradictory results between the applied normality tests, a comparison test of alternate distributions was carried out, which resulted in gamma and binomial distributions, from the parameters obtained it was possible to determine that they approximated the normal distribution in all cases, so it was assumed that all data sets followed a normal distribution.

4.2 Control design for the process

The design of the control charts per block was carried out to determine the established parameters of drinking water consumption for each block (see Figures 1 to 7):

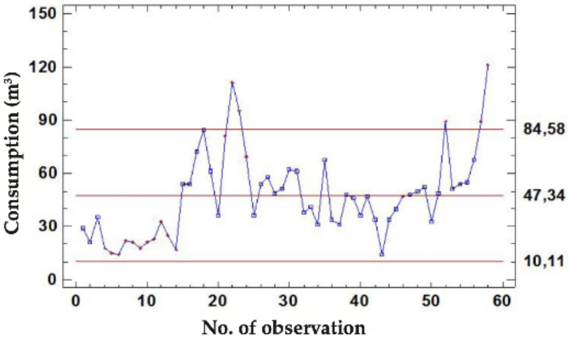

Figure 1. Individual Control Chart for Administrative Block
Source: own elaboration.

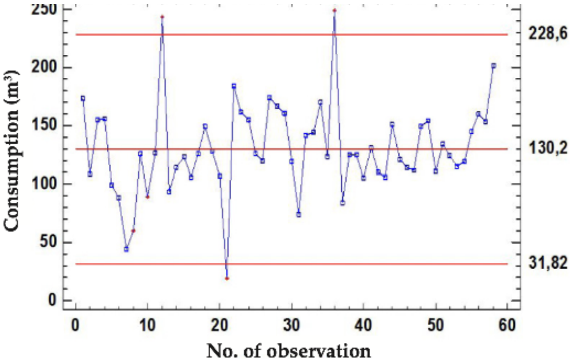

Figure 2. Individual Control Chart for Block ABC
Source: own elaboration.

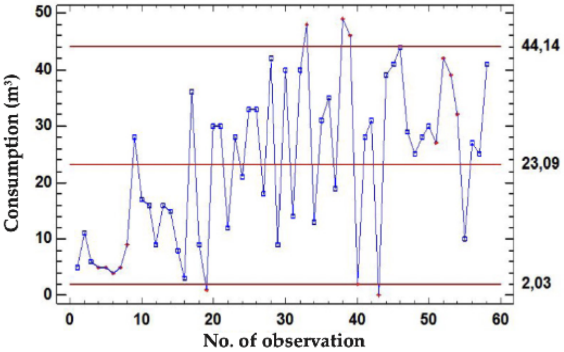

Figure 3. Individual Control Chart for Block ABC
Source: own elaboration.

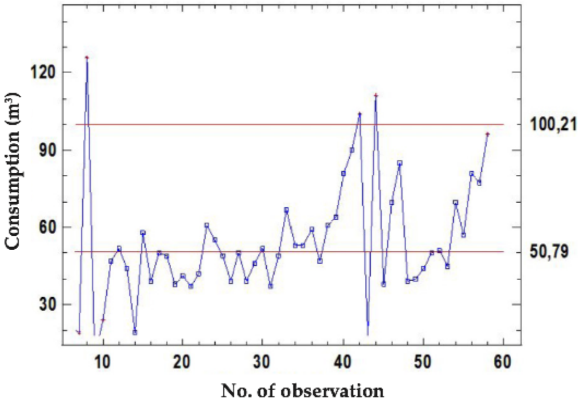

Figure 4. Individual Control Chart for Block ABC
Source: own elaboration.

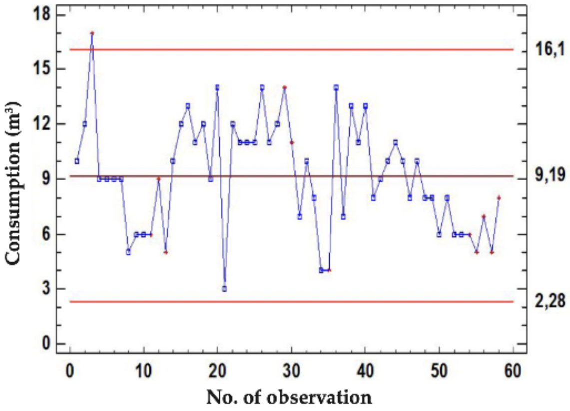

Figure 5. Individual Control Chart for Block ABC
Source: own elaboration.

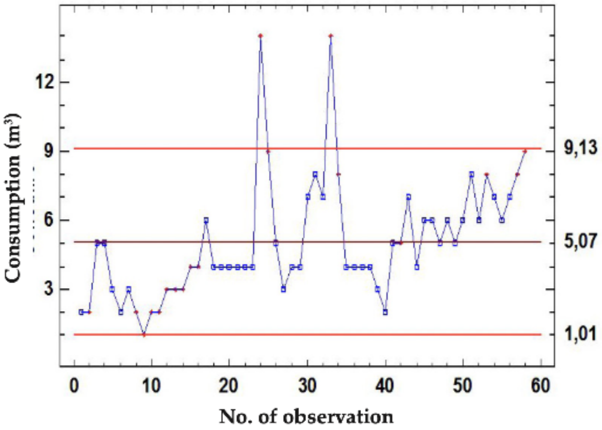

Figure 6. Individual Control Chart for the Coliseum
Source: own elaboration.

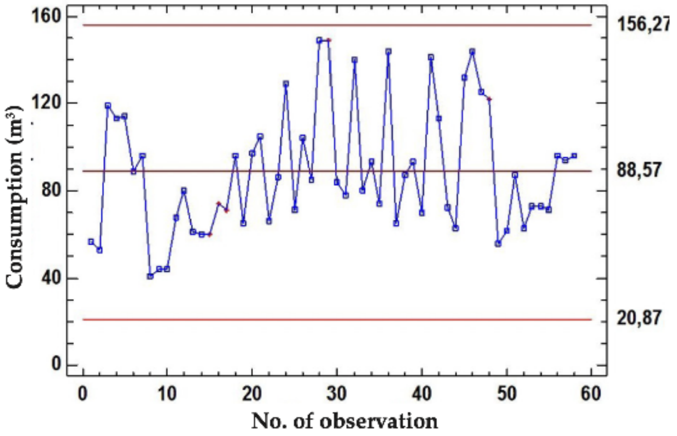

Figure 7. Individual Control Chart for the Sports Center
Source: own elaboration.

The previous figures show the stabilized control charts, since the points that go outside the limits calculated through (3) and (5) do not have assignable causes, due to the population variation that cannot be quantified by blocks. Due to the robustness of the aforementioned Chart X, this analysis is useful, since the mean of these data will vary as the years go by, thanks to the increase in population, which is proportional to drinking water consumption. Table 3 shows the parameters assigned to each block after the stabilization of the control charts.

Table 3.
Parametric data of each control chart per block in water consumption of the Universidad del Atlántico

	Administrative Block		ABC block	Block D
μ		47.3448	130.224	23.0862
σ		12.4113	32.8014	11.6959
Median	Block H	Block I:	Coliseum Block	Sports center
μ	50.7931	9.18966	5.06897	88.569
σ	16.4707	2.30185	1.35312	22.5675

Source: own elaboration.

4.3 Phase II - Statistical control

For the data measured in the control, a statistical analysis was performed for each block, controlling the parameters of the charts resulting from Phase I and an analysis of causes was performed to find causes assignable to the obtained *outliers*, as a result, a stable consumption was found for the Administrative, ABC, H, Sports Centre and Coliseum buildings, the latter having a single point out of control, due to some works that have been carried out; Figure 8 shows the control of the ABC blocks, since it is the most important for the Universidad del Atlántico, due to the high consumption of drinking water due to the very same activity of the practices in the laboratories and the number of classrooms they have.

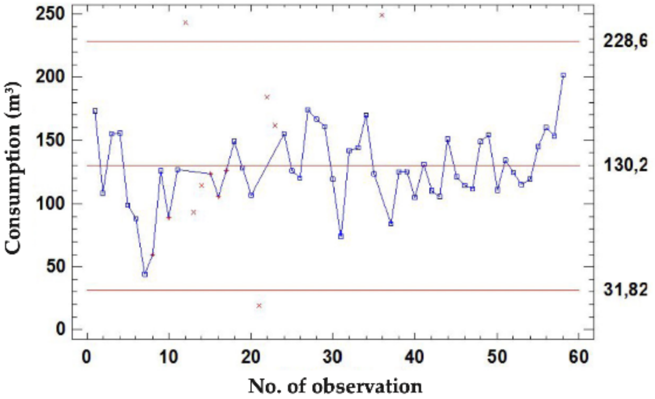

Figure 8. Control of water consumption in Block ABC
Source: own elaboration.

According to Figure 9, the consumption in block I is in statistical control, this may be because the block is not in operation and the water consumption is limited to standardized activities, such as the incorporation of air and gas lines.

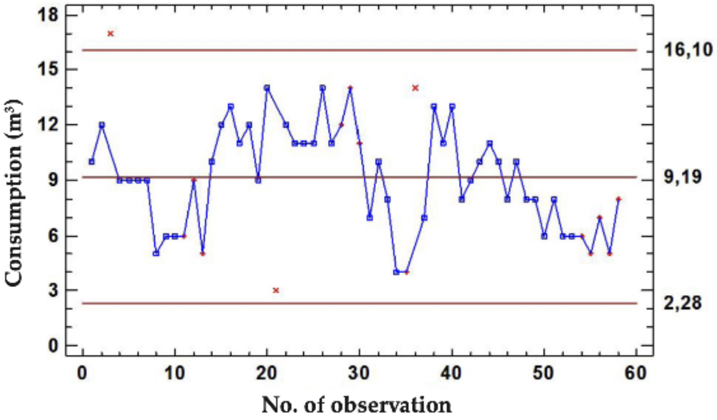

Figure 9. Control of water consumption in Block I
Source: own elaboration.

This control chart will continue to be measured in the coming months to show the real water consumption and the acceptance that the use of the control charts may have. It can be observed in the control charts obtained a lot of variability in maximums and minimums coming from a present attributable variation. It should be taken into account that the population increased in the second half of the measurements, since this corresponded to a different academic semester, in addition to the diversity of activities carried out in each block, consequently, the collection of water consumption data must be carried out in a different way to allow the use of another type of control chart, for example, the moving average chart that allows obtaining information for mass analysis, in addition, the process (water consumption) must be thoroughly investigated considering external factors such as the weather, and internal factors such as routine and/or extraordinary activities, special events, student load assigned in classes, etc., since due to their variability it does not serve as a basis for forecasting, however, this research lays the foundations to generate consequence in the alma mater, since the attributable variation can easily be associated with waste, lack of maintenance and adequacy of the pipeline network.

In order to be able to conclude on more relevant results, an analysis of all the possible causes of measurable consumption variation must be carried out, firstly, it is recommended to use analysis to detect breaks in the university's water distribution network such as the one proposed by Martínez (2015), which allows formulating pressure management that leads to a reduction in the probability of pipe ruptures based on the relationship of the water pressure indicators, with the pipe ruptures and the distinction of the indicators of greater significance in breaks. Other external factors of possible influence can be obtained through a complete cause analysis, and these can be measured simultaneously with water consumption, this to find which variables are the most relevant and can best explain the variability of water consumption, for this task the recommended statistical tool is the Principal Component Analysis (PCA), as cited by Flórez-Vergara, *et al.*, (2018). Another valid strategy to implement this statistical control is the day and night flow measurement, in this way much more precise data on consumer culture can be obtained.

5. Conclusions

With the use of statistical control applied to the water consumption of the Universidad del Atlántico, control charts were obtained in which the great attributable variation (not common) that could be appreciated, which makes it clear that water consumption of many different activities and which is also being affected by external factors that require a more rigorous investigation, evidencing the need for a monitoring system that allows actions to be taken, for which powerful statistical tools were recommended as implementation strategies. It has been deduced from the multiple activities necessary to implement statistical control of water consumption in the university and its complexity, it requires the appointment of an implementation committee, with suitable knowledge and the design of an action plan, where it is contemplated the form of data collection, the inspection procedure, the choice and implementation of the control charts and the actions to be followed based on the results obtained, all this in order to measure the effectiveness of this statistical control and the measures adopted based on it.

5. References

Alvarez, Antonio (2018). Cambio organizacional y cambio en los paradigmas de la administración. *Revista de Ciencias Sociales y Humanidades. UAM Iztapalapa.*, *48*, 11–34.

Bhakar, Vikrant; Sihag, Nitesh; Gieschen, Rebekka; Andrew, Stefan; Herrmann, Christoph; Sangwan, K. S. (2015). Environmental impact analysis of a water supply system: Study of an Indian university campus. *Procedia CIRP*, *29*, 468–473. https://doi.org/10.1016/j.procir.2015.02.061

Cedeño-Viteri, Marco; Rodriguez-Aguilar, Leandro; Sánchez, Mabel (2012). Statistical Monitoring of Water Systems. *Computer Aided Chemical Engineering*, 31, 735–739. https://doi.org/10.1016/B978-0-444-59507-2.50139-6

Dagiliūtė, Renata; Liobikienė, Genovaitė; Minelgaitė, Audroné (2018). Sustainability at universities: Students' perceptions from Green and Non-Green universities. *Journal of Cleaner Production*, *181*, 473–482. https://doi.org/10.1016/j.jclepro.2018.01.213

Farina, Marco; Maglionico, Marco; Pollastri, Marco; Stojkov, Irene (2011). Water consumptions in public schools. *Procedia Engineering*, 21, 929–938. https://doi.org/10.1016/j.jclepro.2018.01.213

Flórez-Vergara, A.; Díaz-Mercado, J.; Ibarra-Montes, M.; Olivero-Verbel, R.; García-Correa, L. (2019). *Propiedades Físicas de nidos de Acromyrmex rugosus y su efecto sobre el crecimiento de Zea mays L.* Editorial Universidad del Atlántico, Barranquilla.

Gutiérrez, Humberto; De la Vara, Román (2013). *Control estadístico de la calidad y seis sigma.* México, D.F.: Mc Graw Hill.

Gutiérrez, Joanna; Pérez-García, Rafael; Izquierdo, Joaquín; Herrera, Manuel (2010). Análisis de eventos de contaminación en redes de abastecimiento de agua con técnicas de control estadístico de procesos. En *I Seminario Iberoaméricano de la red IT-AGUA.* Grupo FluIng - IMM - UPV, Valencia España.

Hernández-Pasichana, Sandra; Posada-Arrubla, Adriana (2018). Avances de la investigación sobre la gestión integral del recurso hídrico en Colombia. *Revista U.D.C.A Actualidad & Divulgación Científica*, *21*(2), 553-563.
https://doi.org/10.31910/rudca.v21.n2.2018.1079

Hitchin, Roger; Knight, Ian (2016). Daily energy consumption signatures and control charts for air-conditioned buildings. *Energy and Buildings*, *112*, 101–109.
https://doi.org/10.1016/j.enbuild.2015.11.059

El Heraldo. (2017). *Barranquilla reduce su consumo de agua un 30,7%*. Recuperado de:
https://www.pressreader.com/colombia/el-heraldo-olombia/20170322/281509341008800 1/1.

Kofinas, Dimitris; Spyropoulou, Alexandra; Laspidou, Chrysi (2018). A methodology for synthetic household water consumption data generation. *Environmental Modelling and Software*, *100*, 48–66.
https://doi.org/10.1016/j.envsoft.2017.11.021

Lagos, Iingrid; Vargas, José (2003). Sistema de familias de distribuciones de Johnson, una alternativa para el manejo de datos no normales en cartas de control. *Revista Colombiana de Estadistica*, *26*(1), 25–40.

Llinás, Humberto (2017). *Estadística Inferencial.* Barranquilla, Colombia: Editorial Universidad del Norte. 278.

Marques, María. (2011). *Estadistica Basica Un enfoque no parametrico*. México D.F.: UNAM, 42.

Martínez, Ángela (2015). *Metodología de análisis estadístico de roturas en redes de distribución de agua* (Tesis doctoral). Universidad Politécnica de Madrid. Madrid, España.

Mustafa, Ana; Rodríguez, Norma; Chauvet, Susana (2002). Control de calidad : Cartas de control por variables. En *Congreso regional de ciencia y tecnología NOA.* Universidad Nacional de Catamarca, Argentina. 1–17. Recuperado de
http://editorial.unca.edu.ar/Publicacione%20on%20line/CD%20INTERACTIVOS/NOA2002/Control%20Calidad%20Cartas.pdf

Juran, J. M.; Gryna, F.; Bingham, R. S. (2005). *Manual de Control de Calidad*. Barcelona, España: Revertré, 946.

Nieto, Nubia. (2011). La gestión del agua: tensiones globales y latinoamericanas. *Política y Cultura*, (36), 157- 176. Recuperado de 2019, de
http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0188-77422011000200007&lng=es&tlng=es.

Otaki, Yurina; Ueda, Kazuhiro; Sakura, Osamu (2017). Effects of feedback about community water consumption on residential water conservation. *Journal of Cleaner Production*, *143*, 719–730.

https://doi.org/10.1016/j.envsoft.2017.11.021

Pedrosa, Ignacio; Juarros-Basterretxea, Joel; Robles-Fernández, Adán; Basteiro, Julia; García-Cueto, Eduardo (2015). Pruebas de bondad de ajuste en distribuciones simétricas, ¿qué estadístico utilizar? *Universitas Psychologica, 14*(1), 245-254. https://doi.org/10.11144/Javeriana.upsy14-1.pbad

Programa de las Naciones Unidas para el Medio Ambiente. (1977). *Conferencia Intergubernamental sobre Educación Ambiental, Tbilis*i. URSS, 14-26 de octubre de 1977: informe final. Recuperado de https://unesdoc.unesco.org/ark:/48223/pf0000032763_spa

Quintana, Alicia; García, Liliana; Casal, Ricardo (2011). Variabilidad lateral para evaluar la velocidad de lateral. *Revista Ingeniería Industrial 10*(2), 31–48.

Rivas-Marín, María (2011). Modelo de sistema de gestión ambiental para formar universidades ambientalmente sostenibles en Colombia. *Gestión y Ambiente*, *14*(1), 151-162. Recuperado de https://revistas.unal.edu.co/index.php/gestion/article/view/25453/39275

Romano, Michele; Woodward, Kevin; Kapelan, Zoran (2017). Statistical Process Control Based System for Approximate Location of Pipe Bursts and Leaks in Water Distribution Systems. *Procedia Engineering*, *186*, 236–243. https://doi.org/10.1016/j.proeng.2017.03.235

Smeti, Eleni; Koronakis, Demetrios; Golfinopoulos, Spyridon (2007). Control charts for the toxicity of finished water-Modeling the structure of toxicity. *Water Research*, *41*(12), 2679–2689. https://doi.org/10.1016/j.proeng.2017.03.235

Tolón-Becerra, Alfredo; Lastra-Bravo, Xavier; Fernández-Membrive, Victor (2013). Huella hídrica y sostenibilidad del uso de los recursos hídricos. Aplicación al Poniente Almeriense. Estudios previos y medidas de eficiencia. M+A. *Revista Electronic@ de Medio Ambiente*, *14*(1), 56–86. Recuperado de http://revistas.ucm.es/index.php/MARE/article/view/42123/40102

Universidad del Atlántico. (2013). *Infraestructura de la Universidad del Atlántico*. Recuperado de https://www.uniatlantico.edu.co/uatlantico/node/1709

Yang, Lili; Yang, Shuang-Hua; Magiera, Ewa; Froelich, Wojciech; Jach, Tomasz; Laspidou, Chrysi (2017). Domestic water consumption monitoring and behaviour intervention by employing the internet of things technologies. *Procedia Computer Science, 111*, 367–375. https://doi.org/10.1016/j.procs.2017.06.036