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# Dynamic Model of SARS-CoV-2 Spread and Drinking Water Consumption Impact at Universidad de las Fuerzas Armadas ESPE, Ecuador

David Carrera-Villacrés [a, b,*], Camila Bahamonde-Coyago [a], Carlos Mancheno-Criollo [a], Robinson Mena-Castro [a], Josselyn Moreira-Pin [a], María Ordóñez-Ríos [a], Wilson Sailema-Hurtado [a]

[a] *Universidad de las Fuerzas Armadas ESPE. Departamento de Ciencias de la Tierra y Construcción, Sangolquí, 171103, Ecuador*
[b] *Universidad Central del Ecuador. Facultad de Ingenierían en Geología, Minas, Petróleos y Ambiental, FIGEMPA, Av. Universitaria, Quito, 170129, Ecuador*

*Corresponding author: *dvcarrera@espe.edu.ec*

***Abstract*— Since the beginning of the State of Emergency announced on March 17, 2020, caused by SARS-CoV-2 (COVID19), changes have been made due to the strict measures established on the Ecuadorian territory. Also directly affecting the educational field. Universidad de las Fuerzas Armadas ESPE located in the Sangolquí, Ecuador, South América, is one of the many universities in the country that had to adapt to the orders of Secretaría Nacional de Educación Superior, Ciencia y Tecnología. (SENESCYT). This is due to the new situation that had to be faced, and it was indispensable to suspend academic and work activities. One of the consequences of this situation was the decrease in drinking water consumption in the Institution due to the absence of civil and administrative personnel. The objective of this research was to present the dynamic modeling of possible COVID-19 spread scenarios at the Universidad de las Fuerzas Armadas ESPE - Headquarters and the impact it has caused on water consumption during January to July 2020, through official data obtained by the Institution, with the Vensim program. The reincorporation of 25% of the administrative and military personnel could be applied typically, without requiring other sources of supply; if 100% of the university population returned, there would be problems in the future with water resources.**

***Keywords*— COVID-19; drinking water consumption; dynamic model; scenarios.**

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## I. Introduction

Liu and Song [1] describe a method to obtain the variation of potable water demand applicable to buildings based on statistical standards of water consumption, which are used as a guide to accomplish this research model. Regarding environmental health due to COVID-19, some studies have mentioned the essential environmental factors to consider during the quarantine phase to supply stalled works due to little use [2], [3].

The SIR model has been involved where the variations of the three populations (Susceptible, Infected and Recovered) are related through the infection rate and the average infectious period, allowing the job to be done since it was possible to study the variables for modeling [4]–[6]. The analysis of mathematical models that have been investigated for predicting the variations of epidemics in social groups is beneficial for the project because scenarios are being developed through simulation based on variables, which will allow the projection of the experimental scenarios for the present research [7]–[9]. More variables are being analyzed concerning COVID-19 and indicate how the severity of the disease, hospitalization, and symptoms responses shape the dynamics of the pandemic [10]–[14]. Some previous studies have helped to get an idea of the interpretation and analysis of the data in the scenarios of the spread of COVID-19 in Ecuador [15], [16]. The pandemic caused by Covid-19 has made us give a 180-degree turn daily due to society being obligated to quarantine [17].

In Ecuador, drinking water consumption is one of the effects of the quarantine of people in their homes and the increase in the demand for vital liquid [18]. However, the panorama in education institutions is different since it is precisely quarantine that has caused the cessation of face-to-face activities by universities worldwide, causing a reduction in the consumption of these institutions and the decrease in water demand [19].

It should be considered that the situation at Universidad de las Fuerzas Armadas ESPE is different from other universities in Ecuador because it has a considerable number of military students who, due to their functions facing this health emergency, have had to stay within the facilities to provide security in the areas that are required [20]. The University is supplied with water resources through aquifers (underground water) from two wells; its location is shown in Figure 1. The first well has an exit flow of 10 l/s, supplying the facilities during business days, Monday through Friday, due to its better water quality; the second well has a flow of 25 l/s, which supplies on the weekends [21].

For the study of this project, a request for numerical data was sent to the Institution's authorities, and we received a whole bunch of information about the population of military, administrative, and maintenance personnel who are still working in person. The university has strict control of the permanent staff of the plant, which enters to work, likewise, the flow of water that is used. The information is reliable because the ESPE operates like a military unit collecting the information every day.

Considering that the military and administrative personnel are relatively smaller concerning the students who are not currently attending the university campus, the most significant reduction in drinking water consumption is caused by the absence of students [20]. On the other hand, there is also a decrease in drinking water consumption by military and administrative personnel who currently go to the facilities, and if they get infected, they will have to quarantine. Therefore, they stop consuming water within the facilities.

In the present research, the consumption data that existed before, during, and a possible return were compared, thus evaluating the Institution's drinking water consumption [22]. There are four possible scenarios for the spread of the virus that have been proposed for the development of this research, comprised of two models: Dynamic model of propagation during quarantine, where three projections of the partial population are considered, so 25 %, 50% and 100% of the military, administrative and maintenance personnel; Epidemic model with reactivation of face-to-face activities where 100% of the university community is considered, in addition, to evaluate the impact generated by the consumption of water resources in the University.

The actual number of people on campus was tabulated based on the data months since the beginning of 2020. Therefore, the objective of the present work was to accomplish the dynamic model of the spread by COVID-19 and the impact caused in the consumption of water at Universidad de las Fuerzas Armadas ESPE during the sanitary emergency, through the use of the Vensim software, related to the different scenarios that would be presented to study the variation in the consumption of drinking water resources experienced by the University during the health emergency.

## II. Materials and Method

### A. Study Zone

The study area corresponds to the campus of Universidad de las Fuerzas Armadas ESPE, Sangolquí headquarters, located in the province of Pichincha, Ecuador, South America. It is located spatially at 0º18'53" South latitude, 78º26'36" West longitude, covering 48.2 hectares [23]. Figure 1 shows the study area.

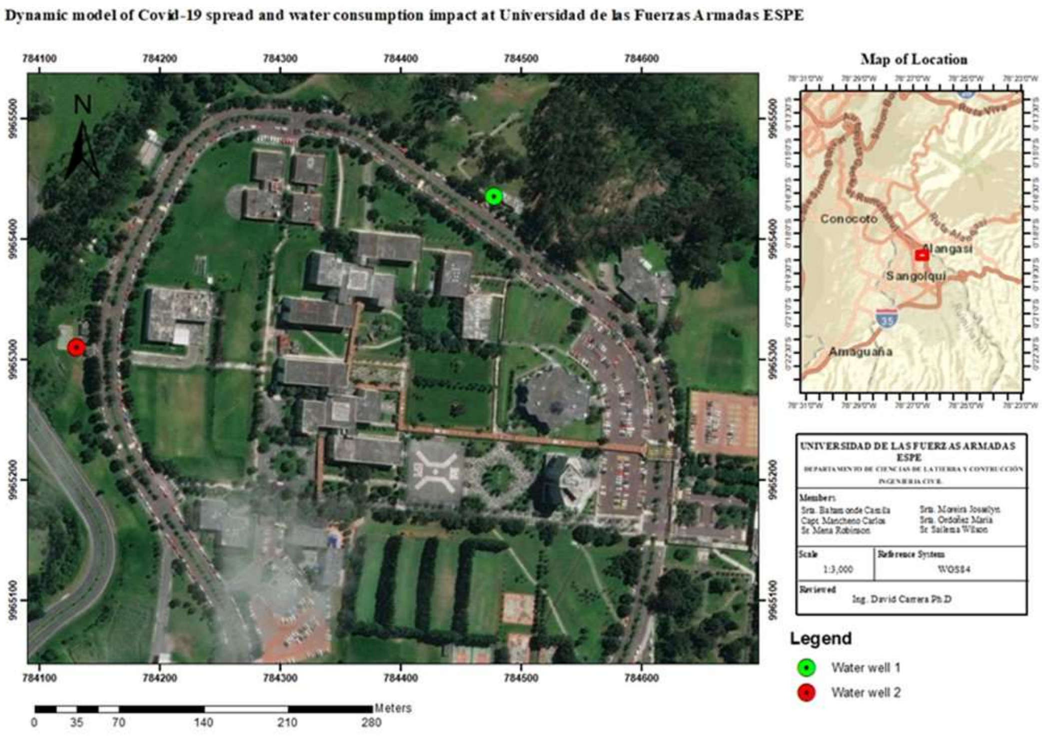


Fig. 1 Study zone at Universidad de la Fuerzas Armadas ESPE

*B. Experimental Design*

The information of the university population can be tabulated without error because nobody enters or leaves without going through a checkpoint of the military police. Likewise, plant personnel are periodically tested for covid. The population was divided into groups depending on the functions they performed. With this, better control of the population was carried out within the University. With the data obtained, it was possible to determine the number of people who attended in the months of January-February, March, April, May, June, July 2020. Thus, to determine the drinking water consumption based on those months [22]. This was possible to analyze the water consumption that has occurred during these months and the model of the infected population at the University ESPE.

*C. Procedure*

During this year, it can be confirmed that, until the end of January 2020, the entire university community was finishing off the academic period usually; Holidays begin at the start of February 2020, for this reason, the student population decreases, although the administrative staff continues with their job [24].

Universidad de las Fuerzas Armadas ESPE has 137 military students in the current period, distributed by their specialization [24]. In 2020, the number was permanent, and it was expected that everyone would usually attend classes; on March 17, 2020, the State of Health emergency caused by SARS-CoV-2 (Covid19) is issued by the Minister of Defense, Gral. Oswaldo Jarrín orders the Joint Command to mobilize its troops to control the state of exception decreed by the President of the Republic of Ecuador. For this reason, the military students at the Universidad de las Fuerzas Armadas ESPE proceeded to comply with the order given [25].

This order caused the military personnel to get divided into two groups. One for control operations distributed throughout the country of Ecuador and another group to remain at the university as a reaction force; By order of the Minister of Defense on Friday, May 15, all military students are obligated to return to the University to start the new academic period, scheduled to begin on May 18, 2020, the same ones who kept on receiving online classes in the classrooms of the University [24].

After reincorporation, some military students presented symptoms, resulting in 14 confirmed cases that were infected of Covid-19; thus, the decision was made to reestablish new biosecurity protocols [24]. Currently, the new protocols allow a limited number of militaries, administrative, and maintenance personnel to walk within the facilities, which has caused a notable reduction in the water consumption curve within the University. Table 1 indicates the updated figures.

TABLE I
UPDATED DATA OF COVID-19 INFECTIONS WITHIN THE INSTITUTION [26]

| Data | COVID – 19 |
|---|---|
| 39 | Confirmed cases |
| 227 | Home isolation |
| 14 | Confirmed military personnel |
| 25 | Confirmed administrative personnel |

On the other hand, the administrative staff and the teachers and maintenance personnel are made up of 1996 people who attended the Universidad de las Fuerzas Armadas ESPE, Campus-Sangolquí, to achieve their administrative activities and daily functions. In February 2020, the academic period ended; for this reason, the administrative staff and teachers, due to their paid vacation schedule, began to work with this planning, having 998 people within the University by March [24].

This happened until, on March 17, 2020, the President of the Republic of Ecuador, Lenin Moreno, declared a state of exception, caused by the health emergency SARS-CoV-2 (Covid-19) [25], consequently, the directors of the Universidad de las Fuerzas Armadas ESPE, in compliance with this decree, adopted new mechanisms for prevention measures. The members that make up the university population were ordered to work online, complying with the days of quarantine from their homes [20].

At the end of March and start April, only around 20 people were required to attend University in-person to carry out specific functions. After approximately 60 days of mandatory quarantine that Ecuador had to comply with, the National COE authorized 25% of the administrative personnel to return to their daily work, with fewer hours and just specific days [24].

The entry of approximately 80 people was registered, and in June they increased to 150 being the highest number reached; therefore, the main problem was the increase in people infected by Covid-19 in different work areas, which led to the Institution deciding to reduce the administrative staff to 20 people [24].

Studied scenarios: For the development of this research, four possible scenarios were considered against the spread of the virus, including them in two models: Dynamic model of propagation during quarantine, where three projections of the partial population at 25% were considered, 50 % and 100% of the military, administrative and maintenance personnel; Epidemic model with reactivation of face-to-face activities where 100% of the university community was considered. In addition, evaluate the impact generated by the consumption of water resources in the University.

## III. RESULTS AND DISCUSSION

*A. System Stability*

The submitting Figure 2 shows the cause-and-effect diagram where the possible causes of spread are identified.

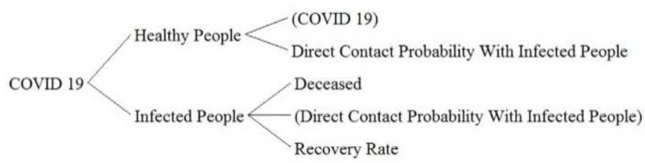


Fig. 2 Diagram cause and effect with variables

In Figure 3, the design of the dynamic model of Covid-19 propagation at the Universidad de las Fuerzas Armadas ESPE is shown, from which four possible scenarios were obtained, presented in two models that are detailed below.

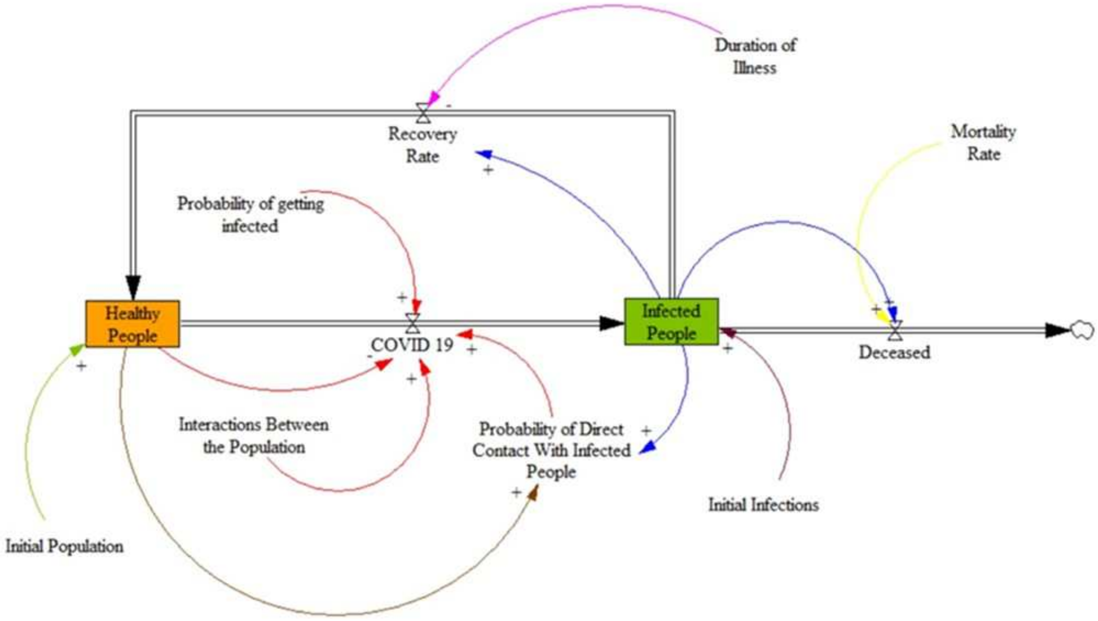


Fig. 3 Dynamic spread model for Covid-19

It is worth mentioning that to consider the interactions between the university population, administrative personnel, teachers, or students, it was necessary to consider the number of people who enter a classroom, department, or office, reaching an average of 25 people in the same place. Table 2 shows the variables that have been considered to make the dynamic model.

Considering the initial infections in the modeling with the partial population at 25%, 50%, and 100%, a numerical number of 39 people is expected [26]. Regarding the initial infections for modeling with the total population at 100%, it is assumed from the arrival of one person.

TABLE II
VARIABLES FOR THE DYNAMIC SPREAD MODEL FOR COVID-19 [22]

| Name | Equation | Unit |
|---|---|---|
| Initial population | Partial university population 25%: 499<br>Partial university population 50%: 998<br>Partial university population 100%: 1996<br>Total university population 100%: 10235 | people |
| Healthy people | Recovery rate-COVID 19 | people |
| COVID 19 | Healthy people · Contact probability with infected people · Interaction among the population · Probability of having the disease | people/days |
| Infected people | COVID 19-Deaths- Recovery rate | people |
| Recovery rate | Infected people / Period of the disease | people/days |
| The time of the disease | 0.175 [6] | days |
| Probability of getting infected | 0.8 [27] | % |
| Interactions between the Population | 25 | 1/days |
| Probability of Direct Contact with Infected People | Infected people/(Infected people + healthy people) | People/people |
| Initial infections | Partial university population: 39 [26]<br>Total university population 100%: 1 | people |
| Mortality rate | 0.003 [27] | 1/days |
| Deaths | People infected *Mortality rate | people/days |

## *B. The dynamic model of the spread during quarantine*

The information presented in Table 3 has been evaluated to show the first study model, where a decrease in the university population is visualized, considering that only military, administrative, and maintenance personnel were present.

TABLE III
NUMERICAL AMOUNT OF THE UNIVERSITY POPULATION [22]

| | 2020 List | | | | | | |
|---|---|---|---|---|---|---|---|
| **ITEM** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** |
| Pre-grad | 8064 | 35 | 137 | 45 | 137 | 137 | 35 |
| Postgraduate | 175 | | | | | | |
| Administrative and teachers | 1996 | 1996 | 998 | 20 | 80 | 150 | 20 |

For this dynamic model, it was necessary to mention that three projections or scenarios were done:

*1) The dynamic model with 25% of the university population*: Figure 4 shows the curve of the spread of Covid-19 with the reincorporation of 25% of the personnel.

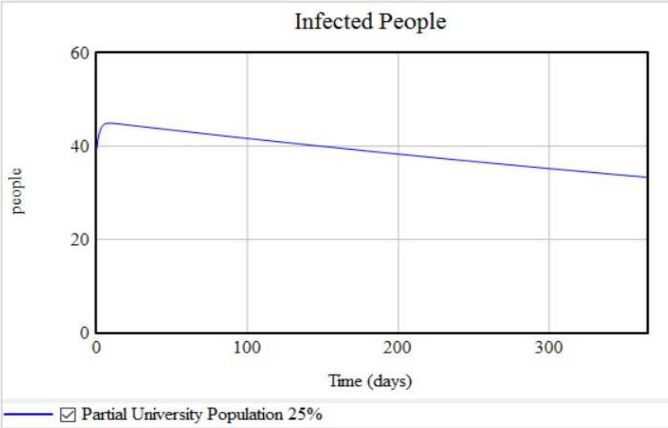


Fig. 4 Spread projection of Covid-19 to 25% of partial population

For this projection, the personnel allowed to attend in June by order of the National COE were considered, so around 287 administrative people and 137 student military personnel ended up appearing. As can be visualized in this curve, the amount reached is around 45 to 50 people within the first 30 days. Under these conditions, the model would stabilize around 39 people, controlling the spread of contagion over the next few months.

*2) The dynamic model with 50% of the university population:* In Figure 5, a slight increase in the spread of Covid-19 can be analyzed; in this scenario, the face-to-face participation of 50% of administrative personnel, including military students, was considered.

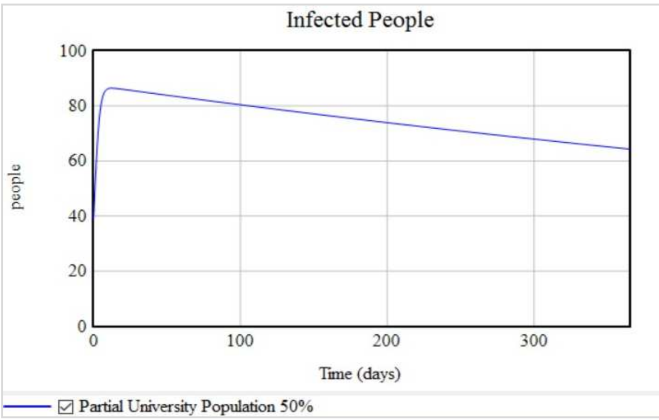


Fig. 5 Spread projection of Covid-19 to 50% of partial population

It can be inferred that the number of spread reaches around 90 people during the first 20 days. After this, the spread curve is kept around a range between 65 to 70 people.

*3) The dynamic model with 100% of the university population:* In Figure 6 shows the projection of spread by Covid-19. To accomplish this scenario, the active presence of the entire administrative, military, and maintenance population was considered.

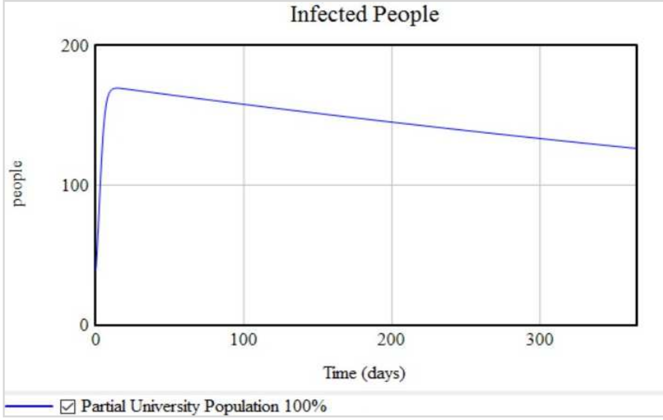


Fig. 6 Spread projection of Covid-19 to 100% of partial population

This curve allows us to compare that the spread had a rapid increase in a short period, thus having an amount that goes up to 180 people infected during the first 15. To stabilize the spread, it is necessary to manage biosecurity controls that can identify and isolate the infected individuals for their speedy recovery, maintaining a range of around 130 to 140 people.

### *C. The epidemic model with the reaction of face-to-face activities*

The second study model, the university population's total reincorporation, has been evaluated, resulting in a higher spread rate as represented in Figure 7.

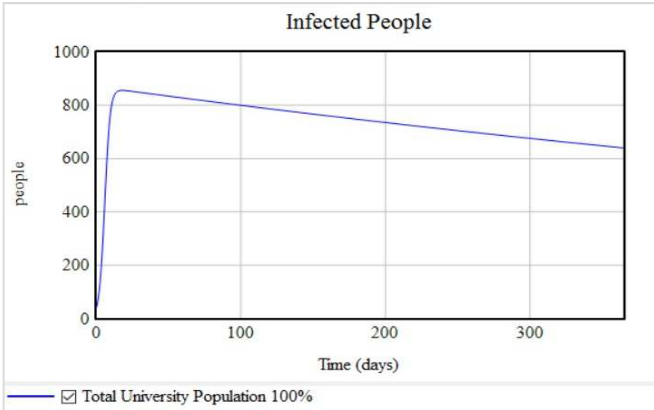


Fig. 7 Spread projection of Covid-19 to 100% of the total population

For this model, congruent results were obtained with the previous model, so the phenomenon's behavior will be similar, but it reaches the highest point of spread due to the increase in the population. This scenario becomes the most critical of all because there is a greater number of people in the facilities, with a spread that ranges from 840 to 860 people approximately 27 days after starting the modeling. There is a small flattening, and later, a decrease in infections until the curve becomes stylized in approximately 641 infected [28].

### *D. The real endowment of the university population*

Table 4 shows the results obtained from the endowment that is delivered to the university population, considering the two wells which supply the Institution and with the percentage of 35% of water not accounted (WNA) for according to Senagua 2015 [29]:

TABLE IV
REAL ENDOWMENT OF THE UNIVERSITY POPULATION

| Water Well | Population | Flow l/s | Net end l/hab-day | WNA 35% [29] | Real End l/hab-day |
|---|---|---|---|---|---|
| 1 | 10235 | 10 | 84.42 | 0.35 | 54.87 |
| 2 | 10235 | 25 | 211.04 | 0.35 | 137.18 |

Before quarantine, the Universidad de las Fuerzas Armadas ESPE population occupied an endowment of water resources of 55 [l / habitant-day] from the first well. It is located in the Postgraduate sector. The operation is constant during working days, while there is the presence of students, since their water has good organoleptic properties. On the other hand, the second well located around the Mechanics labs was activated on weekends, generating a supply of 137 [l / habitant-day]. Currently, given the reduction in their consumption, the wells are activated alternately every two days to match the endowment generated by them.

According to the NEC 11 [27], the necessary water supply for universities is 40 to 60 [l / habitant-day]. For offices, it is 50 to 90 [l / habitant-day] as indicated in Table 5; it can be seen that both the first and second wells provide adequate staffing for the personnel who occupy the facilities regularly and also supply floating population generating a perfect functioning of the Institution.

TABLE V
ENDOWMENTS OF BUILDINGS FOR SPECIFIC USE [28]

| Type of building | Unit | Endowment |
|---|---|---|
| Offices | l/habitant/day | 50 a 90 |
| Universities | l/habitant/day | 40 a 60 |

Once we obtained the data on the water resources required during the health emergency, the water consumption for January to July, between 2019 and 2020, was compared for both administrative staff and students. We were noticing this way the great change in water consumption due to the current situation in our society. The values reflected in Figure 8 of the relationship between drinking water consumption and students; indicate the significant decrease in its use, considering that only a group of military students remained inside the facilities. There is an increase in May and June due to the reincorporation of their day-by-day activities to start the academic period and a slight decrease caused by implementing biosecurity protocols.

The curve representing a relation between water consumption, administrative and maintenance personnel in Figure 8 presents a similar view regarding the decrease in water consumption in the facilities, this due to the sudden end of activities in the coming months. There was a slight increase due to the partial face-to-face reinstatement of staff. On the one hand, the necessary staffing during June, which reflects the maximum consumption of the reinstatement of 25% of administrative personnel, maintenance personnel, and military students, shows a relatively low flow, which, in the long term, would keep the operation of the wells, without the need for new prevention measures or new resources to supply the facilities typically.

On the other hand, in the possible scenario in which the university population rejoins their normal face-to-face activities, it will be necessary to implement under strict control the new security protocols in which it is essential to use continuous personal sanitation care, for which it was considered that each student would access 100% of their endowment. Regarding this scenario, in which the entire university population returns. It would be necessary to use the total endowment generated by the wells. Increasing consumption would put the utility of the well to the limit, which would cause long-term difficulty due to continuous demand, it will require a longer recharge time and better maintenance to continue normally supplying in the future. During drinking water consumption, January–July 2019, constant consumption of the vital liquid can be observed within the Institution, both in the administrative staff and the students. The previous information can be verified in Figure 8.

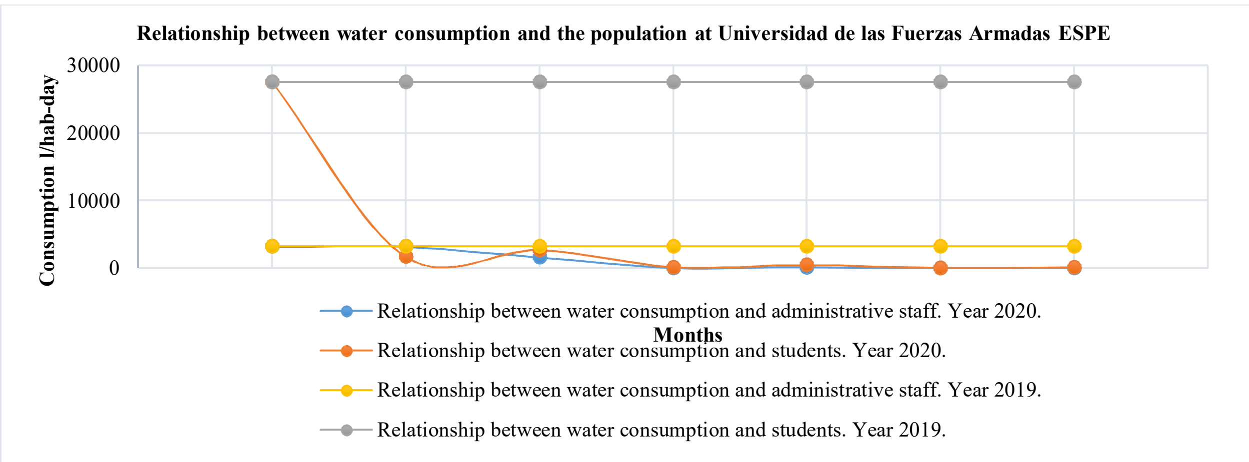


Fig. 8 Representation of water consumption affected by Covid-19

Data were collected at the beginning of the year when the pandemic did not spread or needed mandatory quarantine. In this case, it can be seen in Figure 8 that the month of January begins with a water consumption similar to the one presented in the year 2019. In February, the consumption curve descends because students begin the academic recess. In March, it was planned to return to the classrooms. Therefore, the curve denotes a small increase in water consumption, the same that begins to descend rapidly because on March 16, 2020, the health emergency was decreed in the country, and the majority of university personnel begin with the online modality, until at the end of June 25% of administrative, military and maintenance personnel return to work in person, which causes a slight increase in consumption. In July, isolated cases of covid-19 appear, so online activities are renewed, and a decrease in water consumption is again denoted.

## IV. Conclusion

According to the reviewed evidence, it has been shown that right after receiving the order to reincorporate 25% of the administrative and service personnel during June. There was an increase in reported cases, which again led to the implementation of the online modality. Likewise, the consequences of returning to 50% and 100% of the personnel could be unsolvable since at least 9% of the population could become infected, despite the biosecurity measures applied. However, it could be recommendable to resume face-to-face activities with up to 25% of the population if biosecurity measures are strict and adequately controlled to prevent the spread of the virus, allowing personnel to transit through the facilities.

It can be observed that drinking water consumption in the University is inversely proportional to the number of people infected by Covid-19 due to the increase in the number of sick people. It could be necessary for them to quarantine from their homes. The normal use that is normally applied decreased, which resulted in an eventual saving of the resources from which the Institution is supplied.

One of the psychological impacts caused by fear of getting infected in the population is making an effort to reduce the spread of the virus. It has led to the development of new personal sanitation habits, generating considerable demand for water. For this reason, the analysis of this project has considered the real endowment that was 55 (l/habitant-day) to which each person has access within the University facilities. Once it is allowed to resume face-to-face activities, the water sources supply will certainly be affected by endless use and the great demand required from Monday to Friday to fulfill biosafety protocols. Thus, it has alternatives to equalize their operation and avoid an excessive decrease that causes the search for new sources of water supplies.

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