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THEME:

“SISTEMA ELECTRÓNICO CON APLICACIÓN IoT DE REUTILIZACIÓN DE AGUAS GRISES DE LA DUCHA HACIA EL INODORO PARA ESTIMAR UN AHORRO DE CONSUMO A ESCALA DE LABORATORIO”

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"ELECTRONIC SYSTEM WITH APPLICATION IoT OF REUTILIZATION OF GRAY WATERS OF THE SHOWER TOWARDS THE WATERCLOSET TO ESTIMATE A SAVING CONSUMPTION TO LABORATOR SCALE"

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Abstract - The present work consists in the development of an electronic system of reuse of gray water from the shower to the toilet to estimate a saving of consumption in laboratory scale. This project will benefit the entire university community of the Technical University of North that makes use of the aquatic complex UTN, because, through this system, it will be possible to reduce the use of drinking water in activities that do not demand the quality of the same as is the case of the toilet, in addition to reducing the consumption of drinking water this will generate both economic and environmental benefits.

The data of the amount of water reused in cubic meters, the economic saving in dollars and the temperature of the CPU are sent by means of a Wi-Fi wireless connection, to the platform for IoT that is ThingSpeak, in this platform the data are shown graphically And the most important thing is that it will be very easy to interpret for anyone, whether or not they have experience with the management of the ThingSpeak platform.

Keywords - Gray water, embedded system, thingspeak, Internet of Things (IoT)

I. INTRODUCTION

Technological advances currently seek the welfare of people, where it becomes technological developments that may be in a future essential for human beings or simply a technology that will remain for oblivion. Currently in Ecuador there are government projects that encourage software and hardware developers to present proposals for technological advances where small ideas can become a future of great social and technological impact.

Water is for the human species a source of life, our future seems to be determined by the scarcity of water, due to the depletion of natural sources, by climate change, the use and misuse of a growing population that demands greater volume. According to data from the World Health Organization (WHO), one in three people in the world does not have enough drinking water to meet their daily needs, 500m3 per year is the recommended amount for a person to lead a healthy and hygienic life. [1]

A water that at first sight may be unusable has a degree of contamination that is relatively low and does not require a greater treatment to be reused where the quality is not necessary as in the cisterns of the baths, the irrigation, among others, through New efficient systems of treatment, storage and distribution that help the environment and the economy can reduce the consumption of drinking water as well as the waste water discharge, reducing the flow to the septic tanks or treatment plants.

This project is oriented to the National Plan for Good Living (PNBV), which in one of its objectives says that all people have the right to basic services such as potable water, light and sewerage, guaranteeing the quality of it. It also guarantees the rights of nature and promotes environmental, territorial and global sustainability. Reducing unnecessary consumption of drinking water in activities that do not require the use of drinking water.

II. THEORETICAL FRAMEWORK

A. *Internet of Things*

Internet of Things (IoT) is becoming a topic of increasingly increasing conversation both in the workplace and outside it [2]. IoT It is a concept that deals with the connection of devices to the Internet, in which objects of daily life will be equipped with microcontrollers, digital communication transceivers, and adequate protocol stacks that enable them to communicate with each other and with users, Becoming an integral part of the Internet.

Currently, IoT is composed of a dispersed collection of different networks and with different purposes as IoT evolves, these networks and many others will relate to the incorporation of security, analysis and administration capacities [3], as observed in the figure 1.

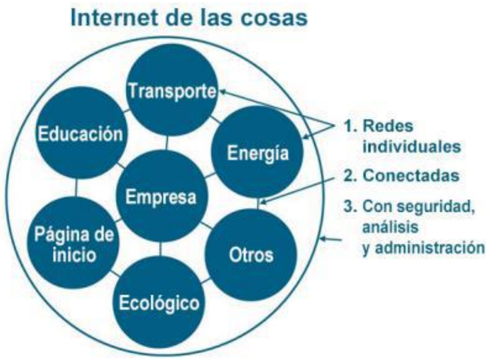

Figure 1.. Scheme of communication of the Internet of the things (IoT)
Source: Evans D. (2011). CISCO IBSG

1) Model of reference to IoT

The trend inclines to give solution to two fundamental problems: to look for a standard form of access to the way and to the devices, and on the other hand to look for the way of integrating the devices to the Internet [4]. The model of reference of the IoT is composed by four caps [5] The model of reference of the IoT is composed by four caps figure 2.

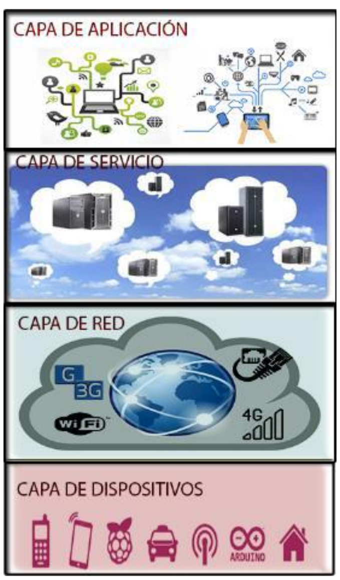

Figure 2. IoT reference model diagram.
Source: Carrez Francois (2013). Internet of Things – Architecture

The device layer connects everything to the Internet and is the key infrastructure for IoT. It consists of a great variety of devices and sensors that allow to obtain data in any place.

The Network Layer mainly provides routing, and congestion control of data (packets of data) from one node to another in the network.

The service layer is defined as cloud computing and already bases its operation on the virtualization of computing services such as Software, development platforms and infrastructure, all over the internet.

The application layer defines the applications and services of the IoT that can be used by the end user.

2) Protocols for IoT

There are a variety of communication protocols that can be applied to the internet of things, within which the most current ones are detailed below.

Constrained Application Protocol (CoAP) is an application layer protocol that has been designed and used across restricted networks such as 6LoWPAN networks. A distinctive feature of CoAP is the use of User Datagram Protocol (UDP) as transport layer protocol instead of TCP [6] [7].

Message Queue Telemetry Transport (MQTT) is an application layer protocol designed for devices with limited resources. MQTT is based on the Transmission Control Protocol (TCP) [6] [8].

B. Hardware and Software

The hardware is the electronic component or any other physical element involved in a system and the software is the logical part that allows to create applications per the needs of the users.

1) Open Source Hardware (OSH)

The term "open source" is initially applied to software projects with public source code and available for others to modify, improve and compile. Currently, "open source" is also available for projecting hardware and includes printed circuit board designs [9].

2) Open Source Software (OSS)

Open source software is software whose source code is available for modification or improvement. The Source Code is the part of software that most computer users do not always see [10].

3) Cloud platforms for IoT

Advances in the Internet of Things (IoT) have provided a global infrastructure of physical entities in the network, capable of monitoring and controlling their physical state, as well as being exposed through data flows and services through the network. The platforms for IoT allow to virtualize the device, the state of the sensors and actuators. Cloud platforms for IoT applications can be accessed for free or limited depending on the features that the user needs.

C. Gray Waters

Gray water, refers to wastewater generated from domestic uses such as bathing and washing clothes. In many utility systems around the world, gray water is combined with sewage into a single domestic wastewater stream. However, gray water can be of much higher quality than sewage due to its low level of contamination and greater potential for reuse.

1) Characteristics of gray water

The gray water recently generated is not as unpleasant as the sewage, but if it is not handled properly soon, it may become so. Gray water decomposes at a much faster rate than sewage and if stored for as little as 24 hours, bacteria consume all the oxygen and gray water becomes anaerobic and becomes septic.

2) Gray water categories

The wastewater from the bathroom, which, including showers and bathtubs, is called light gray water. The gray water that includes the most contaminated wastes such as dishwashers and laundry and, in some cases, kitchen sinks are called dark gray waters [11].

3) Gray water quality

When gray water has just been produced, it does not usually have any unpleasant odor compared to black water, gray water has a relatively high temperature and readily degradable contaminants. Therefore, it needs to be treated immediately after collection [11]. As previously mentioned gray waters can be classified by their origin as shown in table 1. Each of these gray water sources produces a slightly different composition [12].

Tabla 1.
Composition of gray water from the kitchen, bathroom and laundry room.

Uses	Characteristics of gray water
Kitchen	Gray kitchen waters contain food residues, high amounts of oil and grease, including detergents for dishwashers
Bath	Gray bath waters are considered the least contaminated gray water source within a home. It contains soaps, shampoos, toothpaste and other body care products.
Laundry	Gray laundry waters contain high concentrations of chemicals from soap powders, as well as bleaches, suspended solids, and possibly oils, paints, solvents, and non-biodegradable clothing fibers.

Source: Vilhelmiina Harju (2011). Assembling and testing of laboratory scale grey water

4) Recycling gray water

The gray waters of bathrooms, showers, washbasins and washers have to be collected separately from the wastewater, treated and finally disinfected for reuse as a source of non-potable water. The reuse of gray water can be as cheap and easy (but with the use of lots of labor) as outdoor water troughs, or as complex and expensive (but convenient to use) as the installation, treatment, distribution systems . Advanced systems collect, filter and treat gray water for indoor use such as toilet flushing or laundry.

5) Technologies for treatment of Gray Waters

Gray water has a relatively low content of nutrients and pathogens and therefore, high quality water can be easily treated using technologies for its treatment. Technologies used for the treatment of gray water can be divided into biological systems, physical, chemical, and, or a combination of these [11]. Most of these technologies are preceded by three different stages of treatment: pre-treatment, main treatment, and post-treatment.

Biological systems are generally preceded by a pre-treatment stage of coarse filtration and followed by sedimentation / filtration to remove biosolids or sludge, and a post-treatment stage of disinfection by chlorination or ultraviolet (UV) filters, to remove microorganisms.

Gray water treatment systems include filtration and sedimentation. Filtration as a pre-treatment method includes screen meshes, sand bed filtration, filtration with nylon sock type, metallic strainer or gravel filtration.

Graywater chemical treatment systems include coagulation, flocculation, electrocoagulation, adsorption with granular activated carbon (GAC) and natural zeolites, magnetic ion exchange resin (MIEX), activated carbon powder (PAC) and advanced oxidation processes (AOP), such as ozonation and photocatalysis. These systems are effective for use with light gray water and, in some cases, gray laundry waters.

Natural gray water treatment systems are systems that use natural means for filtration and biological degradation (eg, soil and plants).

6) Gray water reuse systems

Gray water systems require a separate transmission system to detect gray water and the distribution of water from drinking water [13].

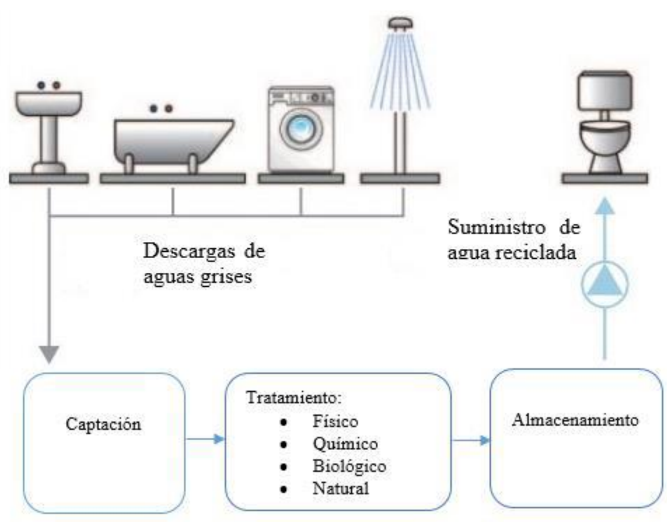

Figure 3. Gray water reuse system.
Source: Dietmar Sperfeld, FBR (2012). Grauwasser-Recycling

As shown in Figure 3, gray water passes through different types of stages, for example, in re-use in toilets, it means that the gray water collected passes through a transmission system until a collection system for prefiltration, then proceed to the treatment stage in which the different treatment technologies such as physical, biologic, chemical or natural will be applied and then transferred to the storage stage for use in the toilet.

7) Advantages of gray water reuse

- Reduction of total water demand
- Reduction of hydraulic and organic loads in the municipal wastewater system
- Reduction of water bills
- Replenishment of groundwater contributing to a healthy water cycle
- Protection of aquatic ecosystems due to the decrease in freshwater diversion

8) Disadvantages of gray water reuse

- Cannot be stored for more than 24 hours (since nutrients break down and cause bad odor).
- Biodegradable soaps and detergents may also present a problem over a period when using gray water for irrigation.
- Contains fats, oils, grease, hair, lint, soaps, cleansers, fabric softeners, and other chemicals that are harmful to plants.

III. DEVELOPMENT OF GRAY WATER REUSE SYSTEM

Using the V-Model for software development, an orderly and structured process will be performed to determine the requirements of this project, based on the IEEE 29148 standard to section the electronic elements that best fit the system requirements.

A. V-shaped development model for embedded systems

The proposed model is based specifically on the V development model, since it is an improvement to the cascade model that allows a sequential work in phases closely connected to the development with its due feedback and adequate documentation, on the other hand, for the analysis Initial and system requirements is working with the IEEE 29148 standard that allows adequate work.

B. Analysis of Electronic Requirements by IEEE 29148

The ISO / IEC / IEEE 29148 standard for the Software Requirements Specification of 2011 allows for the selection of several parameters and specific requirements by evaluating them.

1) Purpose of the system

The main purpose of the system is to measure the amount of water reused in cubic meters, the economic savings generated in pain, and send these data to the platform for IoT, through an Internet connection.

2) Scope of the system

The project will use an electronic system, which will consist of a development board with the following characteristics; That you can connect different sensors, that can store data in a text file, that I have an internet connection and that I have input / output ports..

3) Perspective of the system

The electronic system consists of the following phases as shown in Fig. 4. The block diagram will consist mainly of a storage vessel for collecting the water from the shower, in which the sensors will be installed, which will oversee Send the information to an electronic board, which will process them for activation and communication with the application of the system which is the toilet tank and the IoT platform.

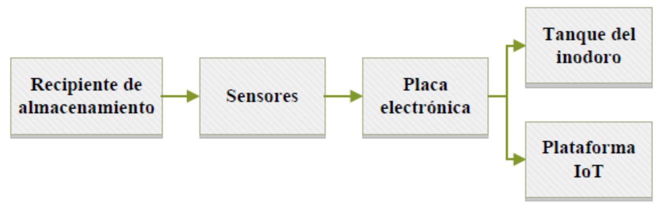

Figure 4. Block diagram of the gray water reuse system from the shower. Source: Authorship

The storage vessel has a filtration and purification method that best suits the gray water reuse needs.

The system has the following elements: a water flow sensor, two water level sensors, an electrovalve and a submersible water pump.

The electronic board stores the data obtained from the water flow sensor in a text file for later upload to the IoT platform and obtain reuse statistics in cubic meters and the economic saving in dollars.

4) User characteristics

This electronic system can be used in a simple way, since it will be configured to operate automatically. Users can view; The monthly amount of water reused in cubic meters, and the economic saving in dollars, on a platform in the cloud.

5) System Restrictions

- Use wireless communication between the development board and the router.
- The storage container should be subject to the physical conditions of the place.

6) System Requirements

For the requirements, will be considered the people that interfere directly or indirectly in the development of the system.

Common interfaces requirements

Within the common requirements of the interfaces of the system are contemplated certain parameters that will contribute to the proper functioning of the same. As are the interfaces of; User, hardware and software.

Functional requirements

Within the functional requirements that the software must perform are; Receive the information, process it, and produce results.

Non-functional requirements

Functional requirements are requirements that impose constraints on design or implementation. They are properties or qualities that the system must have.

C. Analysis of requirements for choice of software and hardware

The analysis of the requirements is the next step in choosing the software and hardware that best suits and meets the stakeholders needs, and for this will be based on the previously established requirements, which will be assigned a relevant valuation in each case.

The scores assigned are one for when the requirement is met and zero when the requirement is not met.

D. Grises Greywater Reuse System Hardware

The system hardware consists of two water level sensors, a water flow sensor, water pump, solenoid valve, storage vessel, electronic board and an Access Point.

1) Raspberry Pi 3 Development Board Model B

The electronic plate Raspberry Pi has the characteristics that make it ideal in the design of the gray water reuse project which they are; Input and output pins for sensors, wireless internet connectivity, processing capacity of 1.2 GHz, storage capacity greater than 4 Gb using a micro SD card, file handling since this board is considered a mini computer.

2) Water flow sensor FY-S201

The water flow sensor YF-S201 has a hall effect sensor that emits an electric impulse with each revolution, has an operating range of 1 to 30 liters per minute, supports a water pressure of up to 2.0 MPa, The Hall effect sensor is sealed allowing you to stay safe and dry. The sensor sends a train of pulses that take the value of a logic one (1L), with voltages greater than 4.5v and zero logic (0L) with values smaller than 0.5v. The flow rate can be calculated by the following formula per the manufacturer's specification:

$$Pulsos = 7.5 * Q \qquad (1)$$

Where Q equals the flow in liters per minute with an accuracy of +/- 3%.

3) Float type flow sensor

The float level sensor is ideal for level detection applications in tanks, operates in two normally open (NA) and normally closed (NC) states. Its main advantage is that it is based on magnetic proximity sensors so they do not have wear elements nor do they have jamming problems, which make it ideal for the project.

4) Submersible Water Pump

The pump has a delivery pressure of water flow of up to 1000 liters per hour. It works with a constant flow of water where it can be regulated per the need of the user. Excellent quality and very long life, withstand 24 hour work.

5) Solenoid valve

A solenoid also known as solenoid valve, is a valve that opens or closes the passage of a liquid. The opening and closing of the valve is effected through a magnetic field generated by a coil.

E. Design of the gray water reuse system from the showerhead

The design phase allows us to represent the operation of the system in a structured way, considering the conditions for the system to operate in the best way: power supply, location of sensors, installation of water pump and installation of the storage tank.

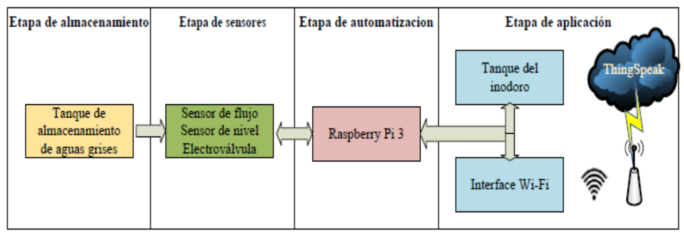

Figure 5. Block Diagram System Reusing Water from the shower
Source: Authorship.

As shown in Figure 5. The block diagram shows a graphical representation of the fundamental parts for the design of the gray water reuse system from the shower, in addition, it shows us the way of connecting the Hardware and the communication to be used. The gray water reuse system has four main stages:

1) Storage stage

The storage container will be placed under the shower, which will have a water filtration system to prevent solid particles from entering the container, it will also help filter the rest of the soap, shampoo or grease. The filter will be located on the container, which is made of gravel, activated charcoal and filter cotton.

2) Sensor stage

In this stage the sensors are used; Of flow of water that will allow to know the amount of water reused which will be located to one side of the toilet, of water level which will allow to activate the pump to fill the tank of the toilet when it is empty and whenever there is water in the Storage container.

3) Automation stage

At this stage is the Raspberry Pi 3 plate to which all sensors are connected to their respective GPIO pins, to send and receive information from them. In this stage is also the electronic board with its respective elements as resistors, diodes, led diodes, transistors and relays.

4) *Application stage*

Inside the application stage you have: the wireless interface and toilet tank. The wireless interface is for information output to the internet, giving the system an IoT application and the toilet tank will be filled with purified filtered water in the storage container.

F. *Programming*

Raspberry Pi 3 uses the Python programming language by default, this is a high-level programming language which predominates because of its ease and the great contribution of thousands of developers.

1) *Flow diagram of water flow sensor*

Flow chart to measure the amount of water reused.

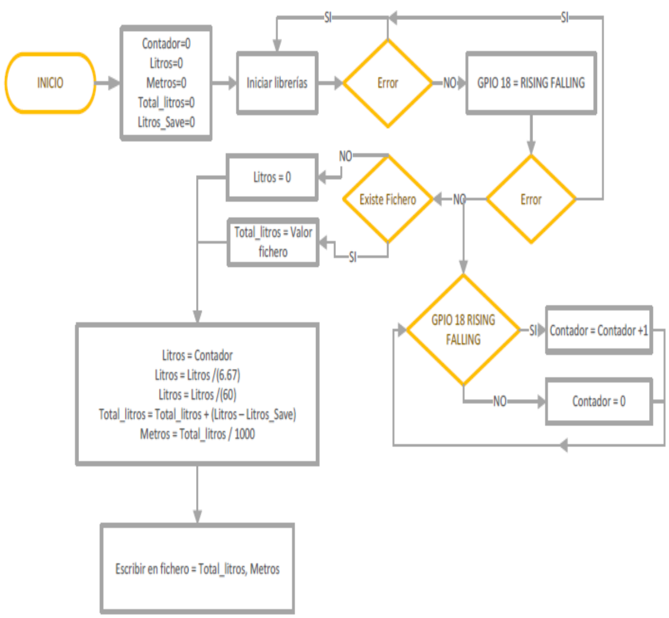

Figure 6. Diagram flow sensor reused water flow
Source: Authorship

Figure 6 shows the flow chart corresponding to the sensor reading. The water flow sensor delivers a pulse train that is proportional to the flow of water flowing through it at that time, which is calculated with equation 1. The value obtained with the equation is given in liters per minute, for this you should convert it to liters and cubic meters, then store them in a file to back up the information in case there is a power cut and the moment the power is read, the file is retrieved, the data is stored and Cumulatively add the amount of water reused.

2) *Water level sensor flow diagram*

The flow diagram of the level sensors indicates the operation of the submersible water pump and the solenoid valve.

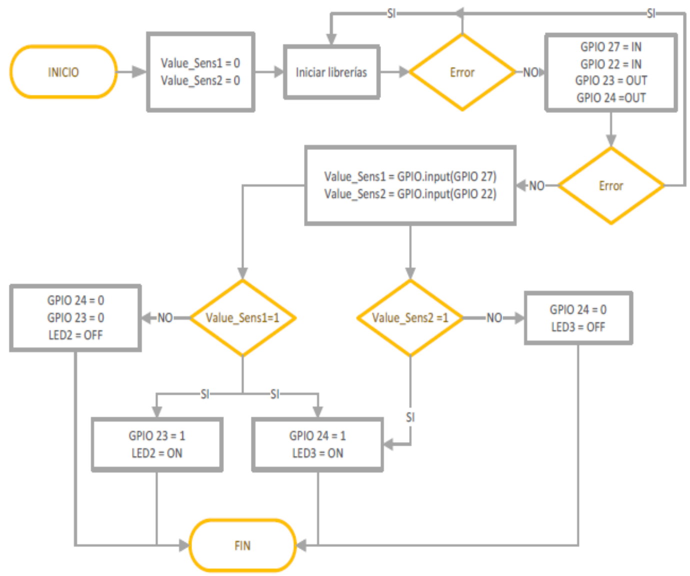

Figure 7. Diagram flow sensor water level.
Fuente: Authorship.

Figure 7 shows the flow diagram of the water level sensor, where the reading of the sensors is stored in the corresponding variables. The sensor 1 and sensor 2 perform a comparison of their values to activate the pump if the storage vessel contains water and the toilet tank is empty. If these conditions do not match, the pump will not activate. The sensor 1 in the storage tank deactivates the solenoid valve to close it, avoiding the entry of drinking water, if there is reusable water.

3) *Flow diagram for sending data to the ThingSpeak platform*

The ThingSpeak platform is oriented to the internet of things. In this platform, you can visualize graphically: the amount of water reused in the toilet in cubic meters and the economic saving in dollars

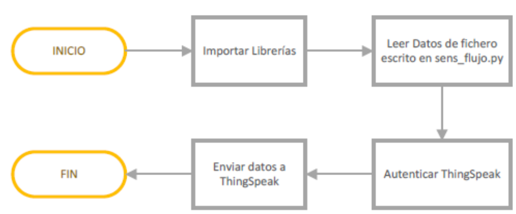

Figure 8. Flowchart for ThingSpeak data to the platform.
Source: Authorship

In figure 8. The flow diagram of the data sent to the ThingSpeak platform is shown.

G. *Integration*

The integration phase is very important where we validate our design with our functional program.

1) *Design and simulation software*

The simulation of the electronic circuit is done in the Proteus simulation software, to check the reaction of the electronic devices with their programming.

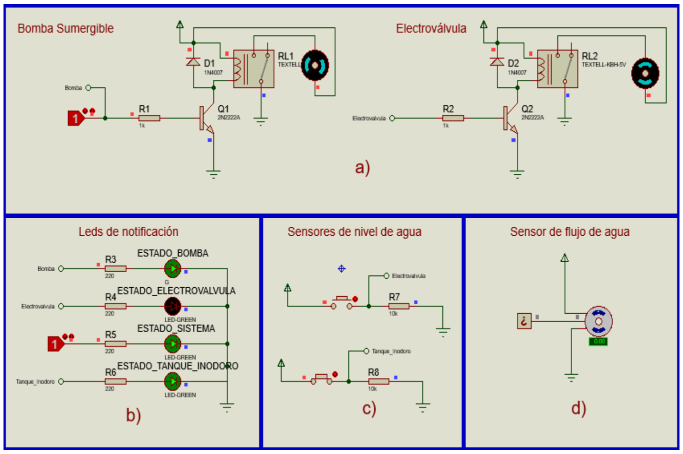

Figure 9. Simulation of the electronic system
Source: Authorship

Figure 9 shows the simulation of each part of the electronic system such as: Circuit for the activation of the submersible water pump, and the solenoid valve, status check leds for each selected electronic element, level sensors have the pull-down configuration as the water level sensor operated as a switch and the hall effect water flow sensor that measures the amount of water flowing through it and sends the data to Raspberry Pi 3 plate.

To diagram the connection of the Raspberry Pi 3 plate with the different sensors, the Fritzing software was used as shown in figure 10.

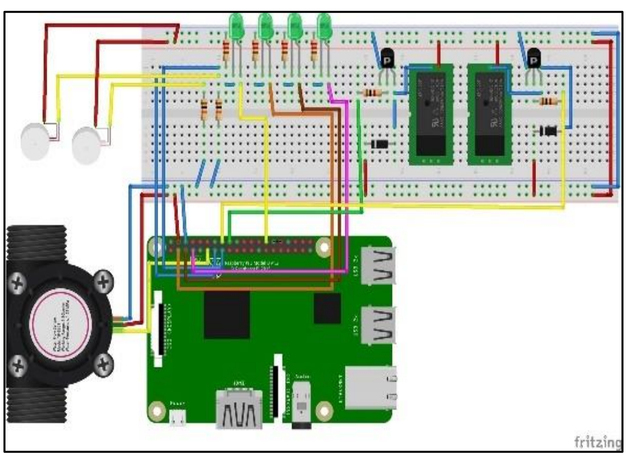

Figure 10. Connections System Simulation
Source: Authorship

The design of the electronic board was realized in the software Eagle. In the figure. 11, we can observe the design realized for the connection with the plate Raspberry Pi 3.

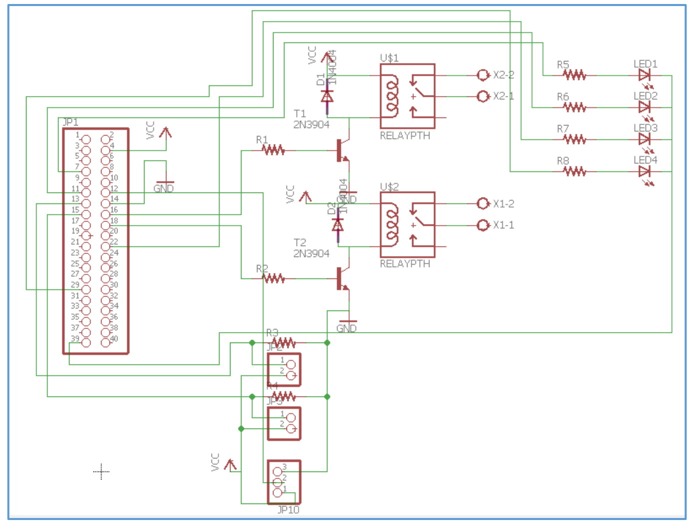

Figure 11. Design of the electronic board at the Eagle software
Source: Authorship

In figure 12, it is possible to observe the electronic board already made the routing of the tracks, for its later printing in the plate or Bakelite of glass fiber.

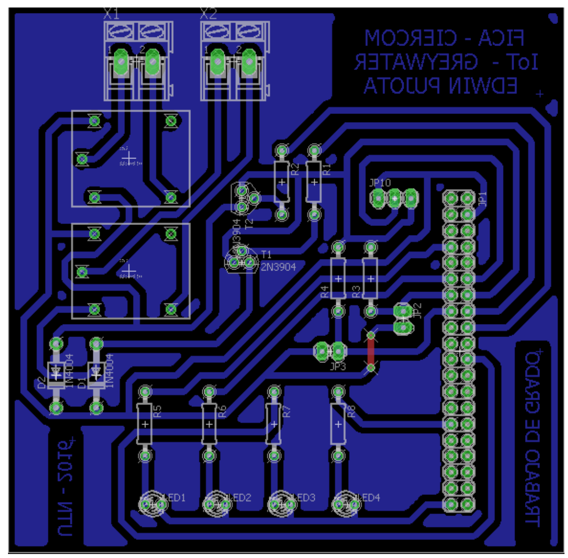

Figure 12. circuit design for electronics
Source: Authorship

H. *Implementation of the system*

The implementation process is the final phase of the model where once verified the entire system can be put in place at its location.

1) *Current situation of the aquatic complex UTN*

The Universidad Técnica del Norte has a semi-Olympic swimming pool which consists of; Sauna, turkish bath, whirlpool, polar pool. The aquatic complex UTN has 5 showers (orange color) and 5 bathrooms (Green color) which are located as shown in figure 13.

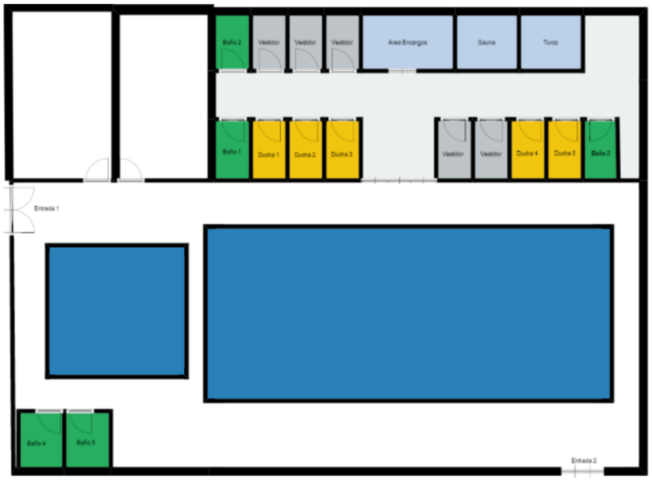

Figure 13. Map of location of showers and baths in aquatic complex UTN
Source: Authorship.

All showers at the UTN Aquatic Complex have the following measures:

- Height from floor to shower 1.92 meters.
- The width of 1.10 meters.
- The length is 2.10 meters.
- The REA for showering is 1.10 meters by 80 cm

The shower area is because there is a small wall to place personal objects as shown in figure 14.

Figure 14. 3D view of the shower of the aquatic complex UTN
Source: Authorship

2) Installation of the electrical system

Since the bath does not have an alternating current supply, the installations of two outlets, ie outputs for the connection of up to four devices, are realized, as shown in figure 15. In our project, three outputs will be used, the first one to be for feeding the Raspberry Pi3 plate, the second that will be for the operation of the water pump and the third that will be for the solenoid valve.

Figure 15. Installing the power supply for electronic devices.
Source: Authorship

3) Installation of the operating system for the Raspberry Pi 3 plate

The Raspberry Pi 3 does not have any internal storage interface (except the firmware that is stored in the GPU), therefore it is necessary to boot the operating system from a MicroSD card. This requires a MicroSD card 16GB Class 10 Kingston as shown, because its transfer rate is, 10MB / s, therefore, has a higher throughput which is easily verified when the operating system and run was used the programs.

4) Remote connection using SSH protocol

SSH remote connection is the best way to connect with the Raspberry Pi 3 uses this port 22 and allows access to a remote host and send commands through a shell. To do this we need to know the IP address that is assigned on the local network to the Raspberry Pi 3. It is preferable for the Raspberry Pi 3 assign a static IP to not be consulting the IP at every moment. No need to log in as root to the system because the user "pi" has the same root privileges for any command that requires root privileges only must prefix sudo.

5) Storage container

The sizing of the storage container it performed by the different site conditions, ie the height of the shower floor, the width of the tub, the number of users, the ability of the toilet tank and daily toilet flushes. Per the height obtained, the storage vessel must have a maximum height of 15 cm, length must be less than 110 cm and smaller width to 80 cm.

In the number of users is identified if they are male or female, because in the case of men use 15 to 16 liters, while women use of 16 to 18 liters of bath water as shown in table 2.

Tabla 2.
Number of liters of water used to bathe men and women

N. Tests	mens	Women
1	15.63 Liters	16.53 Liters
2	15.1 Liters	17.6 Liters
3	16.03 Liters	17.96 Liters

Source: Authorship

To determine the number of users an observation of how many people use the showers in the weekday and a weekend was performed as shown in table 3.

Tabla 3.
Number of users who use the showers daily

	Showe r 1	**Showe r 2**	**Showe r 3**	**Showe r 4**	**Showe r 5**	**# Users**
Monday	12	8	9	9	7	45
Tuesday	13	9	10	10	8	50
Wednesd ay	10	11	9	9	8	47
Thursda y	12	10	9	11	7	49
Friday	11	8	10	8	9	46
Sáturday	15	13	10	11	12	61
Sunday	17	14	14	13	14	72

Source: Authorship

With this data results in a storage vessel with a height of 15 cm, width 60 cm and length 80 cm, this gives us a storage capacity of 36 liters of water which supplies us 6 downloads per container.

Moreover, the storage vessel contains a physical / chemical filter made from gravel (physical), activated carbon filter and cotton (Chemical) as shown in figure 16. The filter gravel and cotton prevent solid particles from entering the container storage, while the activated carbon will act as the water purifier.

Figura 16. Container storage with physical / chemical filter
Source: Authorship

The storage container is located under the shower, as shown in Figure 17, this would capture the water while the user bathes. The storage container inside contains a submersible water pump and the water level sensor.

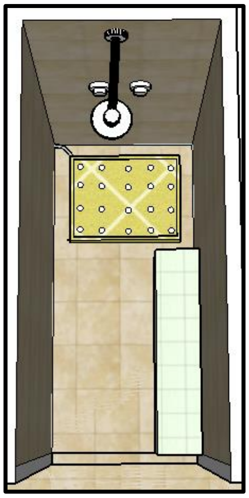

Figure 17. Installing the storage container
Source: Authorship

Due to the location of the storage container showers it will be in each of the showers with a connection of all storage containers through a half-inch hose. In figure 18, the connection between each shown.

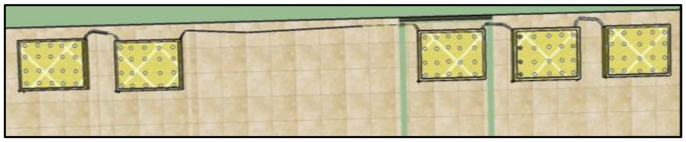

Figure 18. Installing the storage containers.
Source: Authorship

6) Installation of water flow sensor

The flow sensor is located to one side of toilet as shown in figure 19.

Figure 19. Installing the water flow sensor.
Source: Authorship

Reading data water flow sensor is one of the main programs of the system so it should be run whenever the Raspberry Pi 3 initializes. To do an initialization script is created in the /etc/init.d/ directory with the command "sudo nano /etc/init.d/agua". In figure 20 lines of code that must have the script indicated.

```
#! /bin/sh
### BEGIN INIT INFO
# Provides:          greywater
# Required-Start:    $local_fs $remote_fs $network $syslog $named
# Required-Stop:     $local_fs $remote_fs $network $syslog $named
# Default-Start:     2 3 4 5
# Default-Stop:      0 1 6
# Short-Description: Start/stop greywater
### END INIT INFO
case "$1" in
        start)
                echo "Arrancando programa"
                # Aquí hay que poner el programa que quiere
                #sudo ./sens_flujo.py
                /usr/bin/python /home/pi/IoT_GreyWater/sens_flujo.py
                ;;
        stop)
                echo "Deteniendo programa"
                ;;
        *)
                echo "Modo de uso: /etc/init.d/sens_flujo.py {start|stop}"
                exit 1
                ;;
esac
exit 0
```

Figure 20. File program began meter water flow.
Source: Authorship

The executable file must be as follows:

- sudo chmod 755 /etc/init.d/agua

And finally, you must activate the automatic start:

- sudo update-rc.d defaults water

7) Installing the water level sensor

The project consists of two water level sensors; the first is located within the storage tank and the second gray water inside the toilet tank as shown in figure 21, These sensors serve to activate the water pump and the solenoid valve.

Figure 21. Location of water level sensors.
Source: Authorship

Reading data from water level sensor is another major system programs so it should be run whenever the Raspberry Pi 3 initializes. To do an initialization script is created in the /etc/init.d/ directory with the command "sudo nano /etc/init.d/electrónica". In figure 22, the lines of code that must have the script indicated..

```
#! /bin/sh
### BEGIN INIT INFO
# Provides:          raspberry
# Required-Start:    $local_fs $remote_fs $network $syslog $named
# Required-Stop:     $local_fs $remote_fs $network $syslog $named
# Default-Start:     2 3 4 5
# Default-Stop:      0 1 6
# Short-Description: Start/stop raspberry
### END INIT INFO
case "$1" in
        start)
                echo "Arrancando programa"
                # Aquí hay que poner el programa que quiere
                #sudo ./electronica.py
                /usr/bin/python /home/pi/IoT_GreyWater/electronica.py
                ;;
        stop)
                echo "Deteniendo programa"
                ;;
        *)
                echo "Modo de uso: /etc/init.d/electronica.py {start|stop}"
                exit 1
                ;;
esac
exit 0
```

Figure 22. File program began meter water flow.
Source: Authorship

The executable file must be as follows:

- sudo chmod 755 /etc/init.d/electronica

And finally, you must activate the automatic start:

- sudo update-rc.d electronic defaults

When you restart the Raspberry Pi 3, the program runs automatically.

8) Filling the toilet tank

Filling the toilet tank it performs by using the submersible pump is located inside the storage container shower number 1, and hose ½ inch transporting water from the storage vessel to the toilet tank as It is shown in figure 23.

Figure 23. Hose connection with the toilet tank.
Source: Authorship

9) ThingSpeak Sending data to the ThingSpeak platform

ThingSpeak provides an open platform for data services, including database and analytical chronological series, being accessible through a standard API with support for different devices.The purpose of using ThingSpeak in this project is to interact with statistics monitoring services in the cloud that is able to access data from the Internet that are generated locally.

To communicate the Raspberry Pi 3 with the ThingSpeak platform it is necessary to create an account where the data is stored. In addition, some libraries should be installed in the Raspberry Pi 3 before you start writing the code in Python. For SSH terminal writes:

- sudo apt-get install python-pip
- wget-O Geekmanpythoneeml.tar.gzhttps://github.com/geekman/pythoneeml/tarball/master

The first command installs pip which is a package manager that is used to install and manage software packages written in Python. The second command is downloaded from a repository Github the EEML tool used to model basically based on a hierarchical layer structure it is that we will use to send data to ThingSpeak systems.

A text document with extension ".py" where the Python code that allows read data from the file where the values of the amount of water in cubic meters reused in the toilet are be staying is created. Once you have all the data ThingSpeak authentication is performed and proceeds to send the data to the platform.

To send the data monthly to the platform ThingSpeak the cron tool is used.

- 00 00 1 * * python /home/pi/IoT_GreyWater/ThingSpeak.py #The program will run the first of each month.

I. Functional tests

The prototype measuring functioning properly recycled water seven days a week. If some sort of power outage occurs the values are not lost and when the energy service values previously consumed cubic meters will be recovered and can proceed with measurements is restored.

1) *Calibration of the ag flow sensor.*

To check the correct operation of the water flow sensor the following tests for calibration was performed. We run the program and note the number of pulses obtained in one liter of water. Three tests were performed with 1000ml and obtained the following results as shown in table 4.

Tabla 4.
Calibration data of water flow sensor

Test No.	Quantity	Pulses
1	1000 ml	398
2	1000 ml	400
3	1000 ml	399

Source: Authorship

Then we can say that for every liter of water that passes through the sensor get about 400 pulses. This means that for each pulse that gives the sensor is equivalent to 2.5 ml (milliliters).

2) *Raspberry Pi 3 Plate*

Raspberry Pi electronic plate 3 is the core of the system as it processes the information it receives from the sensors; this raises the temperature to 65 °C. For this purpose, a fan installed on the electronic board as shown in figure 24.

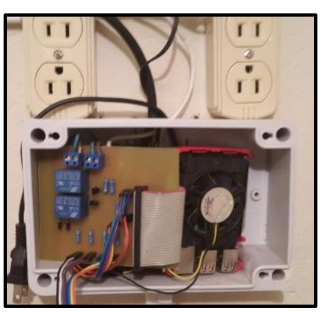

Figure 24. Installation of the plate Raspberry Pi 3 with its fan.
Source: Authorship

3) *ThingSpeak Platform*

The purpose of using ThingSpeak in this project is the IoT where application using this platform we can see the data on the amount of reused water in cubic meters, the cost savings in dollars and the temperature of the CPU from anywhere that has access to Internet. In figure 25, we can see the data in ThingSpeak platform.

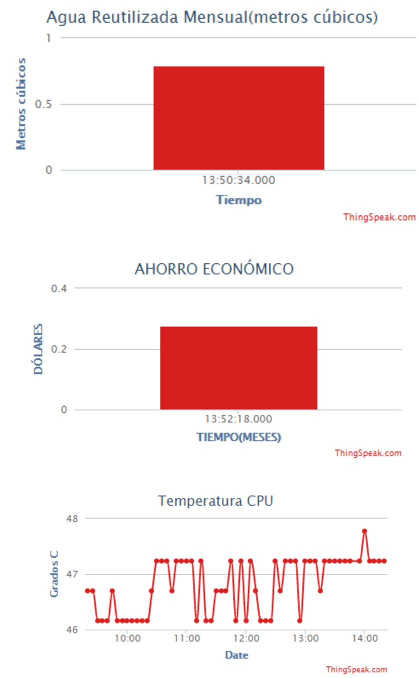

Figure 25. Data on the platform ThingSpeak
Source: https://thingspeak.com//

J. Results

Once done checking the correct operation of each of the sensors and electronic devices, we proceeded to use the system greywater ie electronic board and all attached devices.

In table 5, you can see the amount of potable water used throughout the UTN aquatic complex and the amount of water used in the showers by users each month.

Tabla 5.
Data monthly consumption of drinking water in the UTN aquatic complex.

	Drinking water consumption (m3)	Water used in the shower (m3)
April	424	25.024
May	423	24.82
June	425	25.024
July	372	24.208
August	421	25.16
Septemb er	111	12.75

Source: www.emapaibarra.gob.ec/index.php/consulta-planilla.html.

Per data obtained must be the month in aquatic complex UTN consume up to 25 cubic meters of potable water only using the shower.

In table 6, the amount of water and reused month reuse rate generated by the electronic system gray water reuse is shown.

Tabla 6.
Number of reused water monthly.

	# Users per month	**Water used in the shower (m 3)**	**Water amount reused (m3)**	**% Reuse**
April	1472	25.024	17.664	71%
May	1460	24.82	17.52	71%
June	1492	25.364	17.904	71%
July	1424	24.208	17.088	71%
August	1480	25.16	17.76	71%
Septembe r	750	12.75	9	71%

Source: Authorship

Table 7, the monthly cost savings generated by the system of reuse of gray water is shown. To calculate the savings, consider the market value per cubic meter of water in the city of Ibarra.

$$Saving = Amount\ of\ water\ reused\ (m^3) * 1.15 \qquad (2)$$

- The amount of water reused in meters' Cubic's is the amount of gray water used in the toilet.
- 1.15 is the commercial value in d or dollars it costs per cubic meter of drinking water in the city of Ibarra.

Tabla 7.
Monthly Cost savings generated by the system

	Reused water quantity (m3)	**Monthly cost savings (dollars)**
April	17.664	$22.96
May	17.52	$22.78
June	17.904	$23.28
July	17.088	$22.21
August	17.76	$23.09
September	9	$11.70

Source: Authorship

In figure 26, you can see a bar graph of the amount of reused water and economic savings generated by using the system of reuse of gray water from the shower.

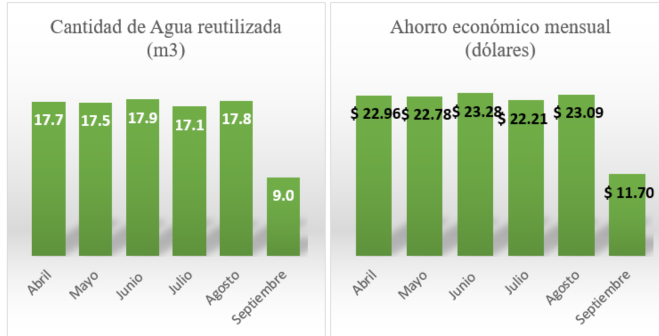

Figure 26. Bar chart the amount of recycled water and generated economic savings.
Source: Authorship

The electronic system of reuse of gray water from the shower saves a year an estimated 193.87 cubic meters of drinking water. What causes us an approximate savings of $ 222,95 a year.

This system will fulfill one of the objectives of the National Plan for Good Living (PNBV), where all people have the right to basic services such as clean water, ensuring the quality of it. It also guarantees the rights of nature and promotes environmental, territorial and global sustainability. Where this project aims to reduce unnecessary consumption of drinking water in activities that do not demand the use of drinking water

IV. CONCLUSIONS

an electronic system with IoT applications greywater from the shower to the toilet to estimate a saving of consumption of drinking water laboratory scale in the aquatic complex at the Technical University of the North, complying with all the requirements developed in the design.

Considering the consumption of drinking water in the UTN aquatic complex, by implementing the electronic system for reuse of gray water an approximate cost savings will come from $ monthly consumption of drinking water $ 20, because of the 25 cubic meters of gray water that they occur in the shower only 71% of this is reused, namely only approximately 18 cubic meters of gray water in toilets 5 having the UTN water complex is reused.

The Raspberry Pi 3 to be a mini computer has the ability to operate complex systems, therefore, this electronic board through its GPIO pins allow connection of all electronic devices that were used in the electronic system and using wireless connectivity Internet allows you to upload the data to the ThingSpeak platform for later viewing.

The storage container uses a physical / chemical filter designed based gravel, activated carbon and cotton filter which reduces the amount of contaminants and bacteria proliferation that generate malodor.

Power consumption by the electronic system of reuse of gray water from the shower is low, which does not generate higher costs in the payment of the return of consumption.

The electronic system of reuse of gray water from the shower manages to reduce water consumption, generating savings of approximately 193.87 cubic meters of potable water per year, benefiting the environment and a growing population where demand for potable water is increasing.

V. RECOMMENDATIONS

You must change the filter if it is intended to integrate the gray water from the shower, bathroom sink or kitchen, because the amount of water and chemicals contaminate found in them.

Reuse of gray water has different applications; the garden watering and car washing, it is recommended to use another type of filter to minimize chemical agent's greywater.

The maintenance of the storage container and the filter is performed every month, also it must be emptied every day because the gray water stored last 24 hours begin to produce odors due to soap scum and bacteria staying in the container.

For the correct operation of the plate Raspberry Pi 3 must perform updates both the operating system and libraries which work with different applications. The Raspberry Pi 3 to be a mini computer uses a CPU to perform all operations so you must install a fan to cool the CPU and prevent damage from it.

The operating system must be installed on a MicroSD category 10 to obtain a better operating system performance due to the features that you have this type of MicroSD cards.

To update the operating system of the Raspberry Pi 3 recommended to use a remote SSH to reduce resource consumption of the plate avoiding overheating of the CPU connection.

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