A student journey of social impact and technological advancement for drinking water in schools and communities in Ecuador

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Abstract: In this project, student teams from Universidad San Francisco de Quito and Delft University of Technology worked together to provide safe drinking water in Ecuador. We used M-100 chlorinators from the company WaterStep, donated by Water Ambassadors Canada, to chlorinate water in schools and communities. The journey involved testing water quality, setting up the chlorination systems, and learning how to work in different communities. The key to success was testing water properly and setting up the system carefully. Learnings about working with local communities and organizations are included as well as the importance to understand each community's needs to make a real difference.

Keywords: Safe Drinking Water, Chlorination System, Water Quality testing, Community Engagement

Resumen: En este proyecto, equipos de estudiantes de la Universidad San Francisco de Quito y la Universidad Tecnológica de Delft trabajaron juntos para proporcionar agua potable segura en Ecuador. Utilizamos cloradores M-100, proporcionados por WaterStep, para clorar el agua en escuelas y comunidades. El viaje incluyó pruebas de calidad del agua, instalación de los sistemas de cloración y aprendizaje sobre cómo trabajar en diferentes comunidades. La clave del éxito fue probar correctamente el agua y configurar el sistema con cuidado. Se incluyen aprendizajes sobre el trabajo con comunidades y organizaciones locales, así como la importancia de entender las necesidades de cada comunidad para marcar una verdadera diferencia.

Palabras clave: Agua Potable Segura, Sistema de Cloración, Pruebas de Calidad del Agua, Participación Comunitaria

Introduction

The collaborative team from the student chapter of Engineers Without Borders at Universidad San Francisco de Quito (USFQ) and students from Delft University of Technology (TU Delft), took the initiative to ensure drinking water in schools and communities of Ecuador. The project entailed the integration of water chlorinators in an existing water system with the aim of providing safe drinking water for those in need.

Through the process of installing water chlorinators and conducting extensive water testing, the group dived deep into the complexities of water quality in Quito as well as its surrounding regions. The journey presented challenges to overcome; navigation through social barriers, logistical challenges, and the need for a precise chlorinator setup to ensure security. The valuable lessons learned and the impact of each challenge transformed them into stepping stones toward success.

This work will present different aspects of the project, from the initial testing and setup of the chlorinators, to interactions with various schools and communities, as well as the social and logistical challenges faced. The aim is to provide an insightful look into the world of humanitarian engineering and reflect on the full journey, the impact made, and the valuable lessons learned in the fields of water quality improvement and community engagement.

Materials and methods

The system that is provided by USFQ is the M-100 chlorinator [2]. Four chlorinators were gifted to USFQ to realize the project and provide safe drinking water to those in need. The M-100 uses salt (sodium chloride, or NaCl) and direct current (DC) electricity to produce chlorine gas ($Cl2$) and sodium hydroxide (NaOH). In more detail through the process of electrolysis, the M-100 creates chlorine gas from salt water. The chlorine gas, which evenly distributes throughout the water, kills waterborne bacteria within two hours [1, 2]. The chlorinator is connected to a closed off water tank. The tank takes the contaminated water with a hose, injects the water with chlorine gas and pumps water – chlorine gas mixture back into the water tank. As contaminated water circulates through the tank, water - chlorine gas mixture is injected into the water and is mixed with the contaminated water. The circulation of the water is due to a submerged pump in the water tank that is connected to either a battery or a battery converter. Due to the battery the system does not have to be connected to the grid and can be a good solution for remote communities.

FIGURE 1: Chlorinator M-100

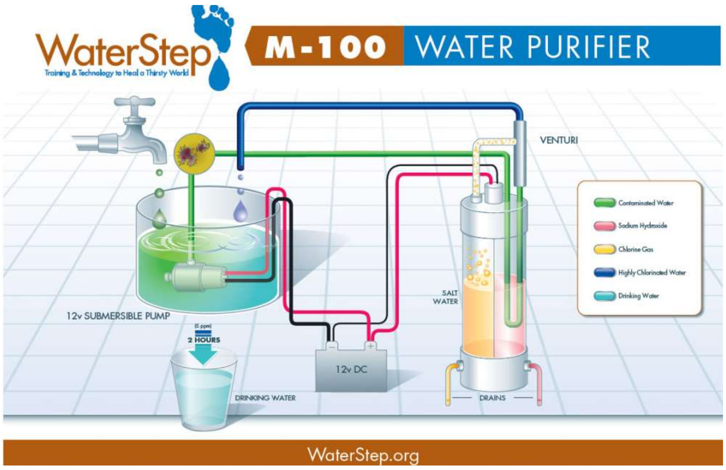

FIGURE 2: System overview [3]

Initially testing of the chlorinator was set up in the hydraulics lab of USFQ. In the lab the primary testing as well as the initial arrangements of the system were made. The primary arrangement of the Chlorinator, tank and battery can be seen in Fig. 2.

The chlorinator works in the way that chlorine eliminates disease-causing organisms and bacteria in water. It does not kill all viruses [2]. This stated, it is of utmost importance to know the contamination of, the potentially to be treated water, before starting the chlorination process. It is essential to test the water in the first step and make sure that the contamination of the water "only" contains organisms that can be killed by chlorine. In the case of water contamination that cannot be eliminated by chlorine the system is not suitable. This is the basis of the in-depth community selection that was conducted.

The following paragraphs present the method of community selection that was developed throughout the process. It is proved to be crucial in achieving the primary goal of improving water quality in Ecuador.

When starting the project, the first objective was to improve water quality in Quito region and its surroundings. The initial assessment revealed a surprising reality, many areas near Quito, including schools that were visited in Lumbisi and Yaruqui (Fig. 3), already have chlorinated water and the chlorination levels were within the Ecuadorian standards. This finding was reinforced by discussions with the local authorities and the conclusion that these communities would not benefit from an additional chlorination system was made.

Therefore, the focus shifted to a more in-depth community selection process to find a community that can benefit most from a chlorination system. This selection process included a questionnaire at first with basic questions about their water supply as well as a site visit to the possible installation point. During the process of getting in touch with different communities, criteria were established to find out if the community is suitable for an installation of the chlorinator.

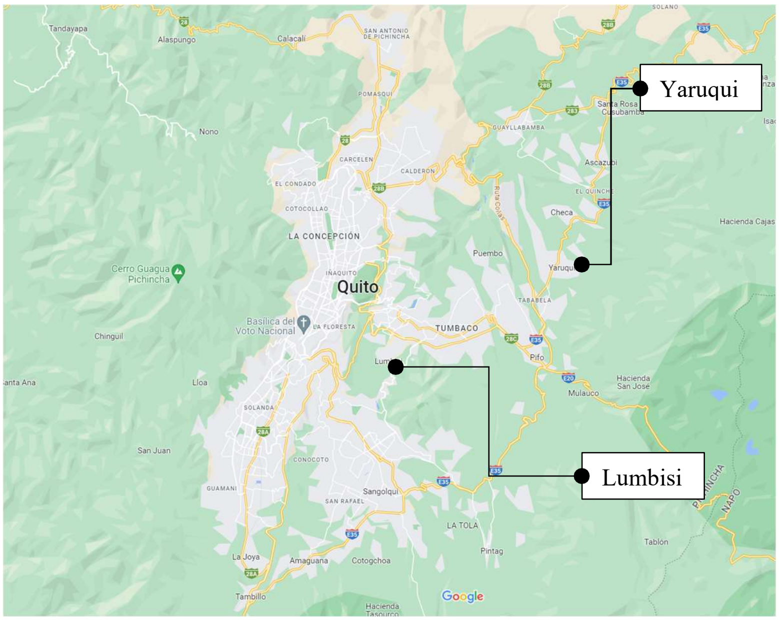

FIGURE 3: Map of Quito incl. Lumbisi and Yaruqui [4]

One key aspect is that the communities have their water supply as a non-continuous system. This means water flow is not constantly coming in and going out and the chlorination can be made during the time without any in and outflow to prevent the mixing of treated and untreated water. This set up can particularly found in smaller centralized locations like schools where a separate tank can be integrated without the need of a continuous water flow. Non-continuous systems we discovered only to be feasible in as school in Santo Domingo, as well as in some communities and schools we visited close to Pedernales (more in the section “Results”). In contrast to a non-continuous system are continuous systems, these are more likely to occur at more established communities that have a constant water supply. The chlorination system M-100 is not compatible with such continuous water systems as the process of water in and out flow will have to be interrupted during chlorination. In those cases where continuous systems were discovered such as in, Simjatug, Niebli and Nanegalito (see section “Results”), our advice is to install a continuous chlorination system such as the system of the local Ecuadorian company CLORID S.A. Some of our partners already took on the advice and are planning to include this system in communities with a continuous water system.

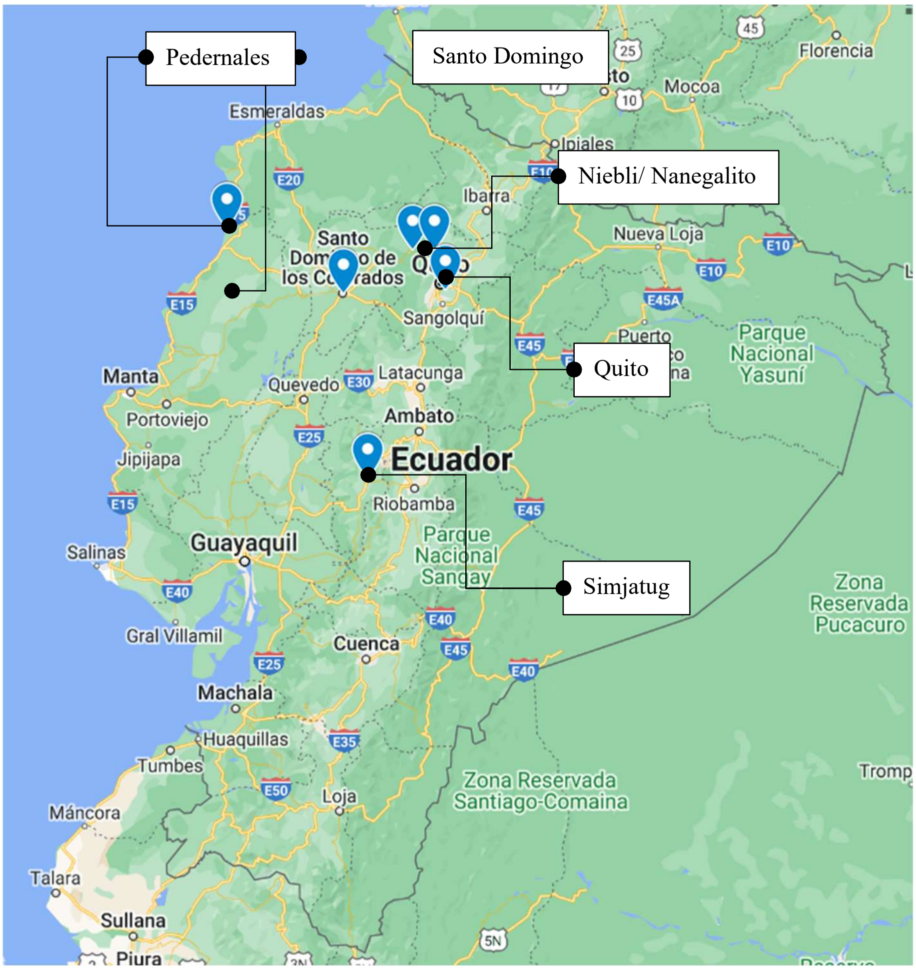

FIGURE 4: Map of Ecuador with locations of site visits [4]

Additionally, the presence of a responsible and trustworthy supervisor for the maintenance of the system is a key aspect. It is important that this person is dedicated to check the chlorine level, redo the process if the chlorine level drops as well as check the system on a regular basis. This aspect is vital for the sustainability of the chlorination system and the long-term impact on improving water quality.

Fundamental factors for possible installation are the different water quality parameters. Various water tests were conducted to ensure that the water quality is suitable for chlorine disinfection as well as will be potable water after adding chlorine. As mentioned before the first test was always a chlorine test. Once the choline test is negative the presence of Coliform, E.Coli, nitrates and sodium chloride was tested to secure the safety of drinking water after chlorination. These tests were conducted in the environmental lab by the help of knowledgeable professors. There are different guidelines on the possible concentration of each substance seen in Table 1. The Ecuadorian law for potable water [5] has been taken into account to define the concentrations of substances.

TABLE 1: Requirements for water quality

Substance	Test	Outcome needed for installation
Chlorine	WaterStep colour test and numerical testing	< 0,1 ppm
Coliform/E.Coli	Petrifilm Coliform testing	Coliform or E.Coli present
Nitrate	Testing in the Chemical lab	< 50 mg/l
Salt	Testing in the chemical lab (conductivity test)	Sweet water

The selection process also considered safety aspects. Suitable locations need to insure secure installation points. In case of schools to keep children away from any harmful residues. Logistics of selection communities for the chlorination system presented a different point to be considered. It is important to ensure safe and secure transportation as well as knowledge on the remote communities and contact to them. This necessitates local partnerships with a local contact person. This individual serves a great link between the project team and the community. Their knowledge of the location of the community as well as the local water system is very valuable. This local person also played a critical role in ensuring the team's safety within the community. In addition to the transportation challenges, the tank size can play a crucial role in the community selection process. Managing the logistical complexities of transporting equipment like water tanks requires not only strategic planning but also careful financial planning. Balancing these budget constraints with the need for safe transport can be an essential aspect of ensuring the project's viability and success.

Results

Upon arrival in Ecuador the project team had little to no knowledge of a chlorination system. Contact with students that previously installed the same chlorination system set off a great start to gathering knowledge.

The location for the installation of the first chlorinator had to be determined. The objective was to look at the water quality at two schools close to the university. The water qualities would then be compared in order to find out which school would benefit the most from installing a water chlorinator. Two communities were preselected by our colleagues from USFQ. On Thursday the 15th of September the first field trip to the two schools took place.

The first school that was visited was named ”Colegio Pedro Echeverria Teran” in Lumbisi, Quito, and the second school was ”Escuela Victor Emilio Estrada” near Yaruqúi, Quito.

While visiting the first school ”Colegio Pedro Echeverria Teran” in Lumbisi (hereafter called ”School 1”), we discovered that the school has access to the general water supply from Quito and even possesses a pressurizing system to redistribute the water across the school’s facilities. The second school that was visited ”Escuela Victor Emilio Estrada” near Yaruqúi (hereafter called ”School 2”) did not possess a pressurizing system but has access to the general water distribution system of Quito as well.

During the visit, water samples of both schools were taken and brought to the environmental engineering laboratory of USFQ for further analysis. Results of the tests were a free chlorine content of more than 0.1 ppm and no coliform or E. coli in the water (Fig. 5). In the below shown coliform tests it can be seen that there are no black or blue dots visible in the red areas, which indicates that neither coliforms nor E. coli are present in the water. These two tests did not meet our installation criteria and thus were not selected as a possible location.

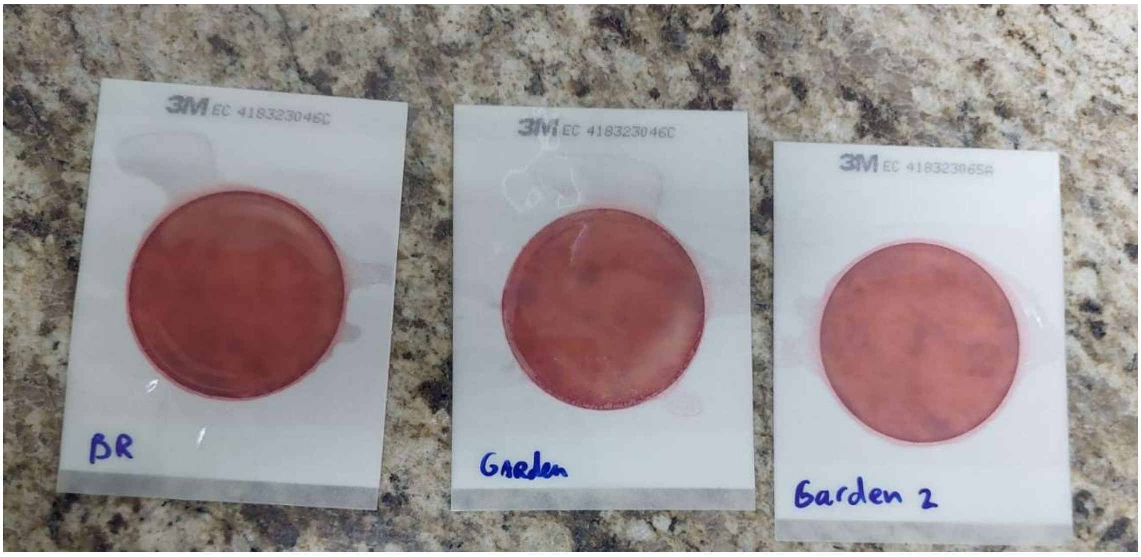

FIGURE 5: E.Coli tests from Schools in Lumbisi and Yaruqúi

There was no further contact with communities in Ecuador in need of a chlorination system. In order to get in contact with local communities, information about these communities was needed. As students in a foreign country there was no knowledge upfront of the existing communities in Ecuador. From all the communities, only communities that meet specific conditions are of importance for the project. For this reason, a connection with companies and NGO’s was established to gather information on the communities in need. The contacted companies are active in the field of installing chlorination systems, maintaining water supply or social interventions in Ecuador.

To learn more about the technical difficulties and social issues on installing a chlorination system, contact was made with an organization which had installed a chlorination system in the past. The organization in the municipality of Quito that has experience in this field is called FONAG [6]. The organization collaborates with communities for preservation and conservation of water sources in the municipality. Together with FONAG the community training and social problems would be discussed. This helped a lot with the development of a manual as well as the understanding of the social implications.

A visit was made to a community in the mountains near Quito. In this community a Clorid system had been installed. The Clorid system functions on a continuous system, a system with constant in- and outflow. It was interesting to see the difference between the two systems. The inflow and outflow of the Clorid system must be regulated because the added chlorine must be within defined boundaries. This makes that the system only must be checked on a daily basis, whereas the Waterstep M-100 system must be monitored more closely whilst in operation.

Contact was established with the company CRISFE [7]. A private non-profit organization that carries out social interventions in Ecuador. CRISFE has been working on projects in Ecuador for years and has contact to communities in need of potable water. Together with CRISFE a trip to visit these communities was organized.

The first visit was to a school named “Escuela San Gabriel de Guachapeli” in the city Cañaveral. The school was connected to the water supply of Pedernales. After testing the water there was little to no coliform formed in the samples. No need for installation in the school. Driving to the second site in Cañaveral, a small community with 30 families, was a challenge since the roads were barely accessible. In this community the water used for drinking, washing and showering was bought from a truck called ‘tanquero’. This truck pumps water from a river further away and delivers it to remote communities.

The community is dependent on the water truck, which costs a lot compared to the income of the locals. Together with CRISFE an idea was proposed to install a rainwater catchment, to generate a free water source for the community. The installation of a rainwater catchment is out of the scope for this project. Focus will be on the installation of the chlorinator on a large tank, located in a public place in the community.

After the visit to the school, we visited the nearby community La Bonilla. The community does not have access to any running tap water (neither potable nor non-potable) and has to buy its water supply from trucks that deliver water, called tanqueros. Each household has its own water tanks in which they store the water from the tanqueros. According to a community representative, the water supply by the tanqueros is neither consistent nor reliable and the community is often left without water. In La Bonilla, CRISFE is already working on a project to connect the community to the water distribution system of Pedernales and to implement a chlorination system within the next 4-5 months.

From the visit at the community La Bonilla, we concluded that a temporary solution to overcome the time until the water supply project from CRISFE is completed would be very helpful. The idea would be to install a central tank in the community, that gets filled by the tanquero for which the households in the community would pay cooperatively. The water could then be chlorinated and redistributed to the households that paid for the filling of the tank. However, in this solution the primary problem will be the fair redistribution of the chlorinated water (how to make sure every household gets the amount they paid for), and the feasibility of the distribution of the water, since many households do not have cars or means to transport the water. Furthermore, the safety and the organization of responsible people to handle the chlorination and the distribution of the water is an important issue which would take time to resolve, and which makes it inefficient as a temporary solution.

Our next contact was the REDNI [8] organization, with whom we visited a community near the town Simjatug. RENDI is an organization that specializes in child malnutrition. The organization helped us looking for a location to install the chlorinator where a large number of children would benefit from the installation. The location near Simjatug however did not meet the requirements for possible installation. There was a large cistern (about 50.000 m3) with a constant inflow of water from the mountains and a constant distribution of water to the community. The constant inflow induced a problem, since the inflow needs to be stopped when the chlorination process has started. A solution could be a separate tank, connected to the big cistern, that can be closed off during the process of chlorination. Due to the size of the community, consisting of 600 people, and the corresponding large walking distances to the tank this would be difficult for people to access. Moreover, the main issue reported by the locals is in the water supply. The water supply is from the mountains and not constant over the year. An advice was given to look into the Clorid system, which is a chlorination system that functions on a continuous system (unlike the Waterstep M-100 used in this project).

Another organization that we established contact with is the organization Engineers in Action [9]. Together with members from this organization one community from a list of communities in need was visited. The location entailed a school in Santo Domingo, which will be covered in the next chapter. At this location the first installation took place.

First visit – investigation:

On the 3rd of October we made our first visit to a school called 'Unidad Educativa Julio Jaramillo Laurido bloque 1' located in Santo Domingo. The purpose of this visit was to see if this was a possible location for our first installation of a chlorination system. On first arrival at the school, we were welcomed by two local community members, whom both work at the school and explained us how their water system works and showed us around. They take their water from a well (Fig. 6) and pump it into a cistern which can take up to 16000 liters (Fig. 7). From there it is distributed around the school to the toilets and taps. The water is not meant to be used as drinking water, but unfortunately some of the children do drink the water when they do not have money with them to buy drinking water.

FIGURE 6: Well at school in Santo Domingo

FIGURE 7: Cistern at school in Santo Domingo

To determine if it is a possible location for installation, we took several water samples from different locations around the school area. Those samples would later be used to test the presence of Coliform, E.Coli, Nitrates and Conductivity in the environmental laboratory at USFQ. The chlorine level was tested in-situ, which can be seen in Fig. 8. The chlorine level in the water turned out to be 0, which is the first step of determining a possible location.

FIGURE 8: Chlorine testing of cistern water

After reviewing the tests in USFQ we concluded that, regarding the water quality, the school could be helped by installing a chlorination system. It was up to us to decide if it was also possible and how we could install such a system. Our first idea was to install a system directly into the cistern, this would mean that the school would have only drinkable water in the whole school. A full cistern of 16000 liters of drinkable water that would be used to drink, cook, wash your hands and even to flush the toilets. This might feel like a bit of a waste (flushing the toilets with clean drinking water), but we knew that it does not waste any more resources compared to a smaller tank. However, there were some downsides to this idea, for example it would mean that the chlorinator system had to run for quite a long time, approximately 8 hours + 2 hours waiting time. And on top of that, the water could not be used during the time that the chlorination process is running.

Although there were some difficulties to the plan, we still thought it was worth it and proposed the plan to the responsible people at the school. This is where we learned a very important cultural difference. They told us that they did not like our plan at all and for the following reasons: first, it would mean that the students would have to drink the water directly from the tap. This could lead to them not using it, because all their life they have been taught that the tap water is not safe to drink. Of course, we want to install a system that will actually be used, so this was a good reason to reconsider our plan. Secondly, in case the children did trust the system and would use it, they could now be convinced that the water from the tap is safe to drink everywhere, which could lead to them drink the unsafe water from the tap at home. This can of course lead to dangerous situations, so we decided that our initial plan was not that suitable for this location anymore.

After some discussions with the locals, we came up with a new plan. This plan consists of a separate and smaller tank which will only be used for drinking water. As the school already had a suitable tank in their possession, this plan was received very well by them. In the end we decided to work this out and come back to install such a system.

<u>Second visit – installation week:</u>

One week later, from the 9th until the 11th of October we packed our toolbox and many Plastigama parts and went back to Santo Domingo to realize our first installation! The installation week not only consisted of installing the system, but also of training the local supervisors and teaching the children about the chlorinator and clean drinking water. In Fig. 9, the finalized system that we came up with is shown.

FIGURE 9: Final drinking water tank

The tank has a separate inlet on top for the untreated water coming from the cistern. Then there are two openings besides that inlet where the two hoses of the chlorinator are connected to. Then there are two holes at the bottom of the tank, one is the outlet where the children can tap their clean drinking water. Here we installed a tap that lets the water come out very slowly, to minimize the spillage. The second hole is used to install a clear hose, to show the water level of the tank. This is shown in Fig. 10.

FIGURE 10: Water level indicator

The positive aspect about this location is that it gave us the possibility to install all the important parts inside a building, which will be locked for the students. This ensured it to be safe and keeps the children away from the toxic residues of the chlorinator. This also gave us the opportunity to create a more permanent solution for the connection to the power supply. Instead of using the battery clamps we decided to connect the chlorinator and the pump directly to the adaptor and sealing it safely in an electrical box. This design can be seen in Fig. 11.

FIGURE 11: Electrical box

After the installation it was time to test the effect of the chlorinator and while doing that, we took the opportunity to teach the supervisors, how they can operate the system. The test results of the Coliform and E.Coli tests are shown in Fig. 12. Here on the left side, it can be observed that the water before chlorinating contains a lot of Coliforms. Halfway through the process the water already shows no remaining Coliforms as can be seen on the test in the middle. On the right test it is shown that after the process and 2 hour waiting time the water is still free of Coliforms and safe to drink.

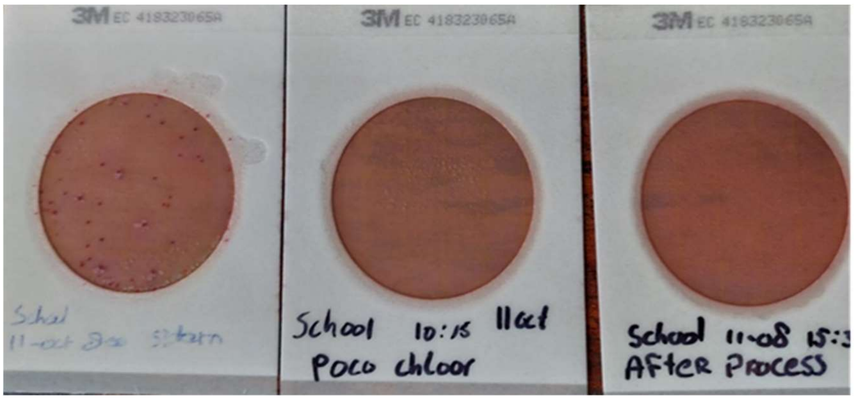

FIGURE 12: Coliform tests during chlorination

Concluding the installation, this means that we can proudly say that the installation has been a success and how to celebrate that better than by all sharing a nice glass of clean drinking water together with the students (Fig. 13).

FIGURE 13: Successful installation

Discussion

In the following section, we discuss and reflect on the lessons learned and experiences made throughout the project.

One key takeaway we experienced during the first visit to the school in Santo Domingo, when our proposed design, as mentioned earlier, was rejected and we had to change it to a technically less efficient design.
From this experience we learned that the solution that might technically the best, most efficient, or most optimal solution might in practice not be the best solution for the community that the solution is installed in. Due to cultural differences and a different level of education and technical understanding a solution that is technically less efficient but easier to understand for the people using it might be more suitable, if the people using the solution have more trust in it. The key point here is, that a solution that is technically optimal, but that is not trusted by the community can become worthless, if it is then not actually used by the community due to a lack of understanding and trust. This realization is from time to time difficult for us as engineers to understand, since we have an engineering background, technical understanding, and a more analytical way of thinking.
Not acknowledging these differences in education, technical knowledge and trust-culture is one of the main mistakes that are made in humanitarian engineering interventions. It can lead to a not-sustainable project outcome, in which a solution is not socially accepted by the community and therefore not used in the long run [10].

Another lesson that we learned during our visits, is that the information that the people in the communities give us have to be verified by ourselves and should not blindly be taken as facts. Since we entered the communities as engineering students from Europe, the people living in the communities immediately had very high expectations towards us and hoped for us to solve all their problems, even though that was far beyond the scope of our project. At the same time, we discovered, that it is very difficult to get reliable information regarding technical and social aspects from the people in the communities, which also stems from cultural differences. Rather than admitting to not knowing a certain thing, we encountered multiple times, that we were given wrong information regarding technical or social aspects by the people living in the communities that we would potentially work with. The main reason for this is, that the people in the communities of course want us to help them with their needs and problems, which is why they naturally try to convince us that their community is suitable for our project, even though that might be untrue or not the case. This as well was something that we had to learn during our time working on the project, since coming from western European culture, we initially tended to naively believe everything we were being told to be a fact.

During the installation of the chlorinator, as well as throughout the whole planning and community selection process, we encountered an unexpectedly high degree of readiness to help, and spontaneity of the people involved. For example, during the installation of the chlorinator in the school in Santo Domingo the teachers were very involved in the process and happy to help us where they could, be it with welding works, plumbing/ piping or creating an opening through a wall. This went hand in hand with the high level of spontaneity and informality that we generally experienced. While in western Europe a higher degree of formality in the planning and execution of projects is typical, we were able to get things done much quicker than we were used to. While we are for example used to the organization of meetings not taking place spontaneously but rather through iterations of e-mail communication, we were able to organize meetings and trips in a rather informal and spontaneous way through WhatsApp. This way, it was possible for us to generally save a lot of time and to react quickly on new findings and even make spontaneous changes to our plans.

Another point that needs to be addressed is the responsibility and ethical implications, that came with the installation of the chlorinator. During most of the professional or academic work that each of us had carried out in the past, our responsibility was always limited to a certain degree. We were used to always have somebody check our work, or at least some safety or review mechanism in place or the worked-on problem was a theoretical case study in a university project. In the case of the chlorinator installation however, the full responsibility of the safety of the design, the chlorination process and the potability of the water lied in our hands. Furthermore, this responsibility had an immediate and clearly visible impact: an unsafe design would immediately result in the students and teachers at the school in Santo Domingo in which we installed the chlorinator would drink toxic or contaminated water which would inevitably harm their health. Bearing this kind of responsibility was a new experience for us and strongly influenced our design and decision-making processes, aiming for the highest degree of safety possible.

Another important realization that we made throughout the project was that such a community intervention cannot be a short-term project and will always be a continuous process. In the case of a chlorinator installation, the intervention is not finished after the physical installation, but continues afterwards. Besides keeping up with the responsible people from the community that operate the chlorinator, the continuous training and education of the people using the chlorinator plays a key role. As we learned from the installation of the chlorinator in the school in Santo Domingo, the students were still hesitant to drink the water in the first days and weeks after the installation. Therefore, it was agreed with the teachers at the school, that they will provide further training regarding drinking water safety and the importance of hydration for the students. This shows the importance of maintaining the contact, collaboration and training with the communities that are worked with, even after the actual intervention. A community intervention and its effective and sustainable execution is a long-term process and not a one-time event.

Summary and Conclusions

This article documents a collaborative project between student teams from Universidad San Francisco de Quito and Delft University of Technology, aiming to provide safe drinking water for communities in Ecuador. The project involved the use of M-100 chlorinators donated by Water Ambassadors Canada to chlorinate water in schools and communities. The key success factors included proper water testing, meticulous system setup, and an understanding of local communities' needs. The report covers the selection process, challenges faced, installation procedures, and the unexpected cultural and technical lessons learned during the project.

The project demonstrated the significance of collaborative efforts in addressing water quality challenges. The adaptation of M-100 chlorinators in Ecuadorian schools, coupled with thorough community selection processes, reflected a commitment to sustainable solutions. The report emphasizes the importance of not just technical efficiency but also cultural understanding in humanitarian engineering projects. Challenges encountered, such as the need for adaptable solutions and the importance of ongoing community engagement, highlight the complexity of implementing initiatives in diverse socio-cultural contexts. This project serves as a valuable case study for future endeavors in providing safe drinking water and highlights the essential balance between technical expertise and community integration in such initiatives.

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