# The Problem of the Social Adoption of Appropriate Technologies in Villa Nicolás Zapata

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**Fig. 1 Satellite picture of Villa Nicolas Zapata**

## Abstract

This articulated paper seeks to demonstrates through such a particular Mexican case study, the economic benefit and the advantages of having water by means of WRH and its disinfection by means of the employment the tUVo. In this paper we also identified situations that restrict and determine the disuse of a successful technology even in conditions of economic advantages and capacities of improvement in comparison with other system involved in solving the issue of water access.

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**Water available pro capita in Mexico**

A vital problem affecting underdeveloped or developing countries is potable water's supply and sanitation. According to the Health World Organization in 2004 1,100 million people in the world lacked access to water drink services, this represents 17% of the world population's. In Mexico the CONAGUA (National Water Commision) estimates that towards the end of 2008, the 90.3% of population's had potable water. Out of this figure, the 94.3% corresponds to urban areas and 76.8% to rural ones. There has been an important improvement in covering these services, but this has shown that it is not enough.

In 2008, ANEAS (National Water Enterprise and Sanitation Association) in his annual convention, (Memorias Aneas, 2008) estimated that in Mexico, more than 11 million people had no access to drinkable water; around 24 millions had no access to drainage services; the sanitation water coverage was at 36%. Rural and peripheral urban population is the most affected by the lack of services for the most part. In the 1950s, the annual water available pro capita was about 17 thousand 742 m3 and there has been dramatic decrease in 2007 down to 4 312 m3 (Cepal report, in Fernandez Vega:2010) that is low but in certain regions, during draught seasons, it could be under 1 700 m3. (Semarnat 2005). In these circumstances, Mexico can be considered as a country that has entered the phase of hydric stress in coincidence to certain areas of the Mexican territory. The main reasons of this tremendous decrease have been the over-exploited hydric resources, contamination of water, waste of water, persistence in continuing with mega-hydraulic model buildings to satisfy the demand, failed processes in the technology transfer, insufficient social administration of hydric resources and, of course, the effects due to climate change.

**General overview of potable water and sanitation in Mexico**

In Mexico, volumes of water concession are for different uses but the 77% of those volumes is used for agriculture which represent the main activity using such a resource. A significant part of this productive activity depends on, by great measures, underground

water which is the most exploited due to the demand pressure. Since the seventies, the number of overexploited aquifers had increased. In 2008, 101 people out of a total of 603 found in these conditions.

Until the year 2007, they registered 101 aquifers and 58% of those was underground water extracted for all kind of uses (CONAGUA, 2008. Technical General Subdirection). In the case of the state of Morelos, there is the presence of overexploited aquifers, the total of water extracted for agricultural purposes reaches 82%. (CEAMA,2010) .

The National Council of Mexico Population (El Consejo Nacional de Población, CONAPO) estimates that, between 2007 and 2030, the population in the country will increase up to 14. 9 million people whose total population, about the 82% will settle in urban towns. This will require to provide new services of potable water and sanitation.

Now, all the water that is distributed is not sufficient to supply the whole population, especially small communities with less than 2000 inhabitants. Due to conditions of marginalization and settlements' dispersion, they have serious problems in water supply and water access: water usually contains polluted agents and pathogens. Generally, these towns don't have hydraulic supply infrastructure either drainage allowing them to face the scarcity problem or to have an effective and sustainable use of their hydric resources. As a consequence, they face critical situations to satisfy their minimum necessities what is translated in a deterioration of their hygienic and sanitation conditions and in a reduction of life quality.

It is necessary to highlight that monthly distribution of rain precipitation accentuates, in particular, problems related to availability of resource, since the 68% of the monthly normal precipitation occurs between the months of June and September every year.

Mexico – CONAGUA data sources- receives about 1,488 thousands of millions of cubic meters of water in the form of rain. Of this water, the 72.5% is subjected to vapor-transpiration since it goes back to atmosphere, the 2.1% is slippery for rivers or streams

and the remaining 5.4 % infiltrates to the underground until recharging the aquifers, in such a way that annually the country counts 458 thousand million cubic meters of a renewable fresh water to what is denominated readiness of natural stocking.
But in these populations of less than 2500 inhabitants, his availability in real terms is even lower. Mexico counts at the moment 137,515 towns with less than 100 inhabitants and 47,233 towns of 100 to 2,499 inhabitants (CONAGUA, 2008). In these usually isolated communities where Government participation doesn't have the necessary budget to support residents in the supply of potable water, an alternative method in the supply of this vital liquid is that one promoting the RWH system for domestic supply. This option depends on pluvial precipitations as well as on the area subject to water reception. In those towns showing good precipitation conditions, families of that community have used an interesting water collection system by exploiting house roofs that would conduct water through canaletas (gutters). This system has been a profitable and successful one. This device has the advantage of being cheap in terms of construction and operation when compared to conventional systems and that the rain water is also of a good quality. Therefore, if population had practiced measures of hygiene and sanitation, then, better conditions of life quality would generate from them. Practice as well as knowledge on pluvial collection are both part of culture of these towns of Mexico and part of their secular customs in some regions they are kept as cultural habits as it happens in some towns of Campeche, Chiapas and Yucatan and others. If we also say that these families might have alternative technologies to purify water, as for example, sun boxes or the employment of UV rays domestic devices, they would be able to decrease health risks and diminish hydric illnesses. In addition, it contributes at reducing the costs that families pay to have access to the clean water and to mitigate the over exploitation aquifers.

**Villa Nicolás Zapata**

The village of Villa Nicolás Zapata is located in a valley of 2450 msm in the Municipality of Totolapan at the north of Morelos

State. With a humid subtropical climate, the annual average temperature is of 17.4°C. In this municipality elevations of hills vary between 1950 and 2500 meters on the sea level. The pluvial precipitation averages yearly is of 914 mm. It has a population of 338 inhabitants (Garrido et al., 2008:5).
The main economic activity is agriculture but services are beginning to be important and advantageous in the tertiary sector. In case of unstable sources of water supply, the population faces problems concerning lack of portable water service and drainage infrastructure. In the following chart, obtained from the censuses applied by the National Institute of Statistic and Geography in Mexico, some of the basic indicators of the population of Villa Nicolás Zapata are introduced to identify the level of marginalization.

| **%** Housings without drainage neither toilet | **%** Housings without electric power | **%** Housings without water tubed in the environment of the house | **Margination index** |
|---|---|---|---|
| **8.97** | **1.28** | **100** | **- 0.17151** |

| **Grade of marginalisation** | % Housings with earth floor | % Houses without refrigerator |
|---|---|---|
| **High** | **34.62** | **73.08** |

**Fig. 2 Source: INEGI, 2005**

It is evident that according to indicators referring to water and sanitation the impact they have in the majority of families from Villa Nicolás Zapata is that population lives under conditions of high marginalization. This is why if they had water available and easy access to it this would have made the difference at the marginalization level. The average of current water is between 30 and 40 liters pro capita.

In this area there are no permanent superficial bodies and for that reason an alternative way was to collect water, during the rain season, running copiously along the ravine, going down through pipes as far as reaching pots with a storage capacity of 3,500 $m^3$ per each. Unfortunately, filters installed for water purification haven't worked correctly since one of the pots went out of order and the other one showed serious damages. The community has a tank of a regulation of 38 $m^3$, at the bottom of pots, that should collect rain water without working since its location was not the most suitable one (Bailzabal, 2006-56).

Once, it was used to store water that municipality supplied at weekly basis by means of truck-cisterns and the volume capacity was of 14 m3; but, due to problems of filtrations in its walls, it is currently not working and its use has decreased.

The main use of this water was to provide drinking water to animals and to domestic uses. It has to be mentioned that in a study of water quality, carried out by the IMTA, results of pots' stored water were defined as "high value of turbid: 180-56 true UTN; color 125-12 UPt-Co, and fecal coliforms 13-1 NMP/100m" (Garrido et al., 2008:75).

The presence of these pathogens is due to the lack of drainage infrastructure that houses discharge directly into ravines. In order to use this water for human consumption usage it is necessary to have a system of appropriate treatment. Starting from 2008 the population has considered a treatment plant for filtration in multiple stages, designed and built by the IMTA in coordination with the municipality, central government of Morelos and the National Council of Science and Technology (CONACYT). This plant has as objective to treat the pots' water for human consumption.

Other alternatives to which the population has appealed to are the purchase of private or municipal truck-cistern; the purchase of large bottles of 19 liters; the transporting of rain water from neighbors towns as Felipe Neri and the collection of rain water. The pluvial collection for the inhabitants of Villa Nicolás Zapata takes place throughout the months of May until October, being June, July and August the months of more precipitation and May

and October those of smaller precipitation. From October to May the population seeks other methods to collect water such as the commercial or municipal truck-cistern or by means of purchase of commercial bottle of 19 liters.

These options have been implemented due to topographical conditions and are present in the region because the soil could not retain the liquid and their extraction implied a considerable expenditure of money. According to the municipality, in order to have access to underground water it is necessary to perforate up to 500 meters deep. In fact, the water supplied by the Municipality is through truck-cisterns and comes from a well perforated to a smaller depth and located in the neighboring municipality of Cuautla. It is important to notice that in accordance with María Esther Baizal's assumption, the aquifer of the valley of Cuautla-Yautepec find in an underexploited condition with a deficit of recharge of 50,092 mm (Baizal,2006:53). The State Commission of Water and Environment (CEAMA) in 2010 water diagnosis report stated that the Northern area of the state where Totolapan is located was the region with more pluvial precipitations but, paradoxically, the deficit is bigger to 50 liters per second (CEAMA,2010:5).

Water infrastructure inside the community have been persistently complained by residents. We highlight the installation of two pots of rain collection (run off water and pluvial); the storage tank for community use by means of a collective hydrant; as well as the design and construction of cisterns at domiciliary level and of water treatment plant. Nevertheless, in spite the fact that social organization has not been really empowered and recognized by the community, efforts in implementing infrastructure and services, except from the system of pluvial collection, water technologies have not been used in an efficient way, due to a wrong use, error designs and due to a lack of an appropriate maintenance. This situation reflects the fact that technologies have not been socially adopted because of technical reasons or due to a lack of knowledge on the environmental, hygienic, social and economic benefits or simply for organizational lacks and ineffective community participation in the local administration of water (this

happens even if there are representatives of the municipality in the water committees). For example, reception pots storing rain water and running off the water itself, do not have a good technical performance since sand removers were placed in inappropriate places so that the sedimentation didn't work correctly and recently, since one of the pots had presented flaws in their membrane cover, it is in disuse.

Additionally, because in the pots two people of the community had drowned, users distrust the use of water coming from the reception pots, as they consider a bad luck to use this liquid where members of their community have die. Another example of a organizational nature is the system of filtration treatment for multiple stages that, nevertheless, even though they had an excellent technological performance, it is not yet working because the community could not find an agreement in the payment of quota for operation and maintenance.

Due to these factors the system of rain water collection has become a more effective method at a domiciliary level for the community, based on structures adapted preferably for glides like the roofs of the housings, grooved sheet and other surfaces.

To support people, the Totalapan municipality has a truck-cistern service, with a capacity of 10 m3 and at a cost of $400 (price for the year 2009). Also, there is a private truck-cistern service of water supply whose cost is of $700 for cubic meter. Starting from a statistical sample carried out by the IMTA in the year 2006 and applied to 25 families with 6 members' average for each an of a total of 64, gave the following result:

| Supply source | No. of Families | Sample% |
|---|---|---|
| Truck-cistern | 6 | 24 |
| Rain | 14 | 56 |
| Bottle | 5 | 20 |
| Total | 25 | 100 |

**Fig. 3 Source: Baizal 2006**

In 2009, within the framework of the project Antinomos[1], a research team from IMTA and CEMDS, carried out 4 field visits to revise the performance and the use of different technologies. Results were captured through the technique of reports' evaluation, which was supplemented with open interviews and application of questionnaires by more than 10 family's heads. From the analysis of reports and interviews, it has been possible to observe that this tendency stays but for what concern the purchase of bottle, there were modifications with the introduction of filters' domestic water purification aiming at disinfecting water by the employment of ultraviolet light, denominated tUVo. At this point, technology transferred in 2005 to 15 families by the Mexican Institute of Water Technology.

**Basic description of tUVo**

According to the technical report of the IMTA (González et al., 2008), the initial prototype installed in the houses of 15 families in Villa Nicolás Zapata consisted of the following basic components:

- a feeding bucket.
- a transparent plastic hose of ½" of diameter that connected the bucket with the entrance of the tUVo.
- The tUVo placed in the interior of a PVC tube, which is mounted in the wall with bands, with exit elbow o of 90° and an inch of diameter.
- The tUVo produces ultraviolet rays of germicidal type that disinfect water and it inhibits the virus activation, bacteria and cysts protozoa.
- A recipient, generally a bottle of 19 liters, to collect and to store the disinfected water.
- The system works with electric power.

[1] A Knowledge network for solving real-life water problems in developing countries: Bridging contrasts(ANTINOMOS)

**Fig. 4. tUVo operating user house inVNZ. Photography José Luis Martínez**

**Fig 5 tUVo installed by the user. Photography : José Luis Martínez**

## Diagrams

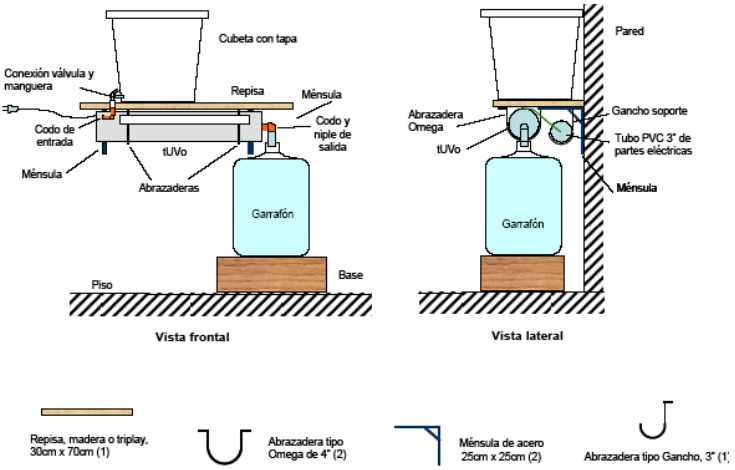


**Fig. 6 Source: IMTA-2008**

Installation of the one had on shelf, buck with valve and direct discharge to the bottle enter.

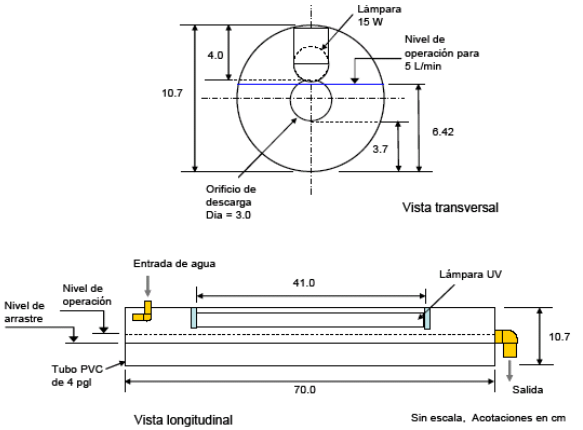


**Fig. 7 Outline of the disinfection system called tUVo**
Source: IMTA, 2008.

**Supply technologies**

It is evident that the problems concerning water supply and installed technologies, have direct reverberations on health, economy and quality of social life. They are two principal outline points of this work: the first one is to demonstrate that costs relative to pipes and bottles' purchase and the implementation of new domestic technologies arise as the most effective economic option for water supply and disinfection for inhabitants of Villa Nicolás Zapata. The second outline is that it is urgent to go deeper in the social, cultural, technical causes; as well, the technologies' transfer and social adoption process which are capable to elucidate the reasons for an incorrect operation and the consideration of an ad hoc promotion in marginalized community living in special conditions of social integrated management of hydric resources, hydraulic and social capital , is a key factor.

By the research carried out in this community by the Mexican Institute of Water Technology (IMTA), concerning water's family expenditure over the year after using different forms of supply, we can mention the following elements: the purchase of bottles as well as private and municipal truck-cistern. IMTA took some parameters to measure the average cost per family which needed water provision for two seasons, and obtain the following data:

- families of 5 or 6 members on the average.
- purchase bottle of 19 liters.
- cost per municipal truck-cistern ($10m^3$).
- cost per private truck-cistern ($10m^3$).

In 2009, the cost of the private truck-cistern was of \$700 for 10 $m^3$ and considering that a family requires for its consumption an equivalent from one to 8 pipes per year, it will have an annual expenditure of \$5600. We should remember, in this case, that the purchase of private water's truck-cistern represents only the 10% of the overall population. The municipal truck-cistern has a cost of \$400 for 10 $m^3$ and it costs \$3,200 during the same months, and option that represents the 90% of the population. The purchase of water bottle is \$1,152.00 when each family use two bottles per week - The unitary cost is 12 pesos for 19 liters.

In the following graphs, the annual costs are shown per each resource of supply.

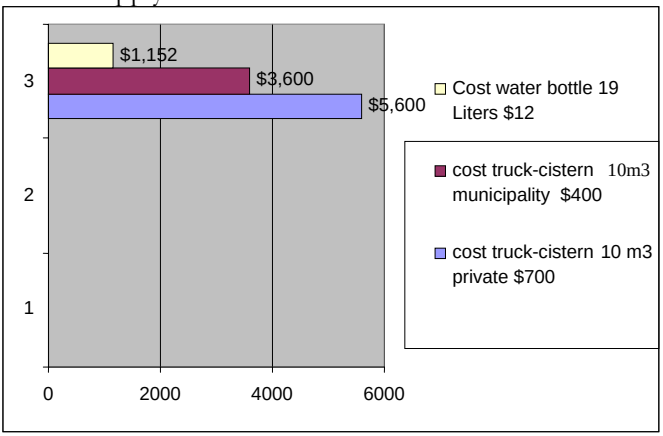


**Fig. 8 Graphic annual cost for source of supply**

Therefore, if we consider that supply by means of pluvial collection can store and have water during 6 months -that is the rain season -, it means to the residents of Villa Nicolas Zapata to save 4 truck-cistern, since a cistern with a capacity of 10 $m^3$ last about 45 days per each family group.

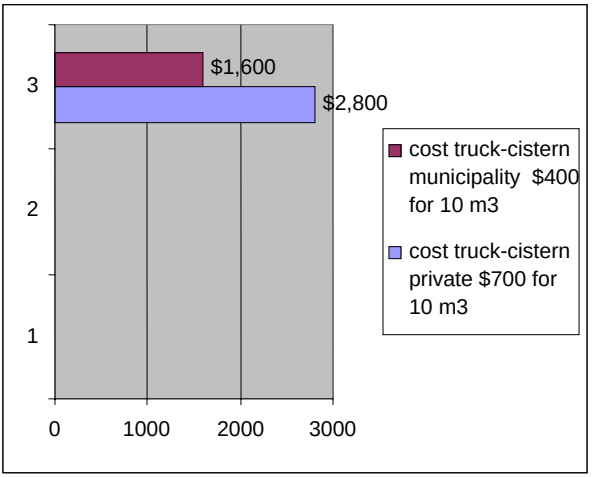


**Fig. 9 Graphic. Save of 4 truck-cistern thanks to the collection rain water**

**tUVo technology**

As we have mentioned before, the use of UV rays is an alternative way to obtain water for human consumption and in the case of families of Villa Nicolas Zapata, it represents a saving rather than paying for water purchase. The IMTA proposed to a group of families the construction of 15 units in a collective way in order to reduce costs. In this way, there was the necessity to look for the benefit of residents, substituting the consumption of water of bottle in favor of rain collection or water truck-cistern previously disinfected by tUVo. As mentioned before, this technology works with the electric power, so the consumption of the tUVo is smaller than the cost for the energy of a lamp of 25 watts. So its consumption is minimum and the saving is practically 100% compared to purchasing a bottle of water.

It is necessary to say that this technique competes with the use of chlorine pills and boiling the water using firewood or gas wise energy sources. In all those cases that have been mentioned, the cost of the electric power is less than other costs. In the case of pills chlorine, although delivery by municipalities is free but not a regular service, people have to purchase pills and another disadvantaged is the fact that most of the rural people don't like the taste of chlorine water and prefers to boil water, instead.

Thus, if we compare the cost to purify the rain water against the purchase of bottle, there is an amortization of the investment of about $700 pesos out of the unitary cost of tUVo. We verified also that if they purified water exclusively with the UV device and they canceled the purchase of bottles, each family would have been saving $1,152 pesos per year.

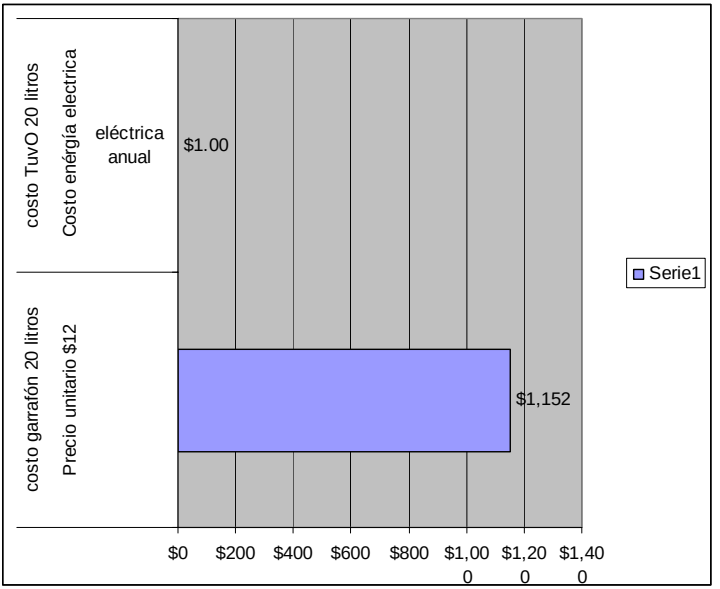


**Fig. 10 Graph: Savings in the cost of purchasing a bottle of water when using the tUVo.**

It is clear that the device had to fulfill its purpose of water disinfection that, in cost-benefit terms, is positive and its technically operation can be carried out by the own users. The combination of the rain water collection system and the use of the tUVo for water purification, represents a series of advantages and improvements in different items, amongst the main ones we will mention the following:

- to reduce the exploitation of the aquifer of the Cuautla-Yautepec Valley.
- It contributes to reduce the hydric illnesses.
- It leads to an economic improvement when the cost of 4 truck-cistern of about $1,500 (price municipality)or $2,800 (private truck-cistern) has been saved and $1,152 when not having to buy water bottle during one year.
- To have more time for other activities and to have shortcut to access to clean water.

- The installation cost, operation and technologies' maintenance are susceptible of being financed by the users or shared with government programs.
- It avoids that the hydric stress increases.
- It reduces the social marginalization.

**Limitations and problems concerning social adoption of the tUVo and users' correct use of the cistern and water management.**

**Quality of the water and hygienic practice**

**Fig11 RWH in VNZ Photography: José Luis Martínez**

Based on quality water, the studies made by IMTA and conducted by us in 2009 found the following results related to water management, risks for health and effectiveness of the tUVo in two family cases. In the first case, family drank water from a well, after UV disinfection. Two samples of treated water were analyzed: water coming out from the UV system and water once in the plastic jar.

These 2 samples were made in order to see if contamination between the disinfection system and the container used for drinking was present. We can see that the most important parameter, that is the quantity of faecal coliform, is not satisfactory with Mexican Quality Norm for Drinkable Water NOM 127 when

water samples was taken from the plastic jar but when samples was taken directly from the well, water had the correct parameter.
Going on with the parameters present in the norm, we see that the water doesn't present salmonella. In particular, we observe possible healthy individual risks caused by the absence of good hygienic practice and not from technology manipulation or malfunctioning.
In the second case, results show that rainwater storage, treated with tUVo, are acceptable according to the Mexican quality norm for drinkable water (NOM-127).
We remark in this second case, the efficiency of the UV treatment, because in our study we took a sample from the RWH storage in the cistern and according to our laboratory report, there were faecal and total coliform. However, after the UV treatment, pathogens were removed.
We also see that there is the need to be careful with the cleaning of containers used to stock water. Indeed, the quantities of total coliform and of mesophile (this ones aren't harmful for health) are higher in water taken from the plastic jar than that water taken directly. This is because the plastic jar has been contaminated..
Finally, we see that the turbidity of the rainwater is higher than 1 UNT, the limit of efficiency for the treatment by UV rays. However, this laboratory report demonstrates that the treatment with tUVo was efficient.

| | **Faecal Coliform** NMP1/ UFC2/100 mL | **Total Coliform** NMP1/ UFC2/100 mL | **Mesophile** UFC/mL | **Salmonella** P/A | **TSS** mg/L | **Turbidity** UNT |
|---|---|---|---|---|---|---|
| Water from well | 0 | 0 | 1 | Absence | <2.95 | 0,25 |
| Water from well, after 2 transit by tUVo, taken in the plastic jar | 0 | 12 | 9 | Absence | <2.95 | 0,3 |
| Water from well, after 2 transit by tUVo, taken directly | 0 | 0 | 2 | Absence | <2.95 | 0.3 |
| Rainwater (cistern) | 4 | 15 | 21700 | Absence | <2.95 | 0,55 |
| Rainwater (cistern) | 1,50E+02 | 4,60E+02 | 9,60E+03 | Absence | <2.95 | 1,2 |
| Rainwater, after 1 transit by tUVo, taken in plastic jar | 0 | 49 | 6,70E+02 | Absence | <2.95 | 1,6 |
| Rainwater, after 1 transit by tUVo, taken directly | 0 | 9 | 33 | Absence | * | * |

**Fig. 12 Lab. report source IMTA 2009**

Based on the analysis of results, we can say that it is very important to be careful about the cleaning of containers used to stock water, whether it's water to be treated or water to be drunk (on one side, the water may not be too much contaminated for the treatment to be effective and on the other side, it is a pity to contaminate water coming out from the UV system).

It is important to remind the family to filter the water to be treated, since it is fuelled with organic materials.

**Conclusions and learnt lessons**

Although our study demonstrates the economic benefits and the advantages of having water by means WRH together with water disinfection by means of the employment the tUVo, we also identified situations where a successful technology ended in disuse although the economic advantages and the improvements made towards how to solve the water access.

We have mentioned that the different options of water supply and sanitation residents of Villa Nicolas Zapata have, have been deteriorating until stopping the operation or preventing from working appropriately; such has been the case for pots, the regulation tank and the treatment plant. The infrastructure that has not known limitation in its usage and which is still continuing working is WRH and it is stored in cisterns.

In the case of the tUVo, after a certain time, the use was fully successful, and we identified that, unfortunately, this technology has been left unused for basic maintenance problems, faulty power supply and lack of interest by the users' side that do not adopt the technology for their advantage -12 from 15 of the initial users-.

In Villa Nicolás Zapata the lack of chances to have access to and for not having water for human consumption has reverberation in the quality of the family's life, especially the infantile population. It is clear that in Villa Nicolás Zapata there is the present of technological installations that sometimes end, for different reasons, as bad operations because of the wrong use. Often, due to a lack of information and practical hygiene, people are affected by an erroneous employment of the technology. The administration and various forms of organizations which use the hydric resources usually require a huge support at municipal local level.

The promotion and installation of appropriate technologies require also a bigger effort that involves, from the beginning of the project (diagnosis, technologies selection, planning and transfer process), the administration and the social participation's beneficiaries; the access to information, the understanding and the basic technical and technological knowledge and maintenance of systems, their economic, environmental, hygienic and health benefits should be assured by communication mechanisms and tools as well as

training the organization and the whole administration that allows not only water appropriation but social adoption.
Our main learnt lesson, in the case of Villa Nicolas Zapata, is that the problem is to have a sustainable technological alternative that provides the service of a qualitative and quantitative water supply. Then, if the technology was viable the main problem would be the social adoption. In second term, this situation is not exceptional, on the contrary, we consider that it prevails in numerous projects of technological transfer as much to local level as to international level. It is urgent to generate theoretical-practical positions that sustain and assure the social adoption of the transferred technologies.

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