International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Bacteriological and Physico-chemical Study of Household Water in Mexico City

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Abstract— *Water in Mexico City is supplied mainly by wells, followed by the Cutzamala System, the Magdalena River and natural springs. Mexico's geological framework consists of various types of rock which confer different qualities to the water circulating around them. The quality of water for human consumption must be assessed regularly since it is constantly changing as a result of both natural and anthropogenic pollutants. The aim of this study therefore was to determine the water quality of Mexico City households. Eleven delegations were sampled, choosing three households in each. Different sites were sampled in each house, including the main stop valve, water tanks and/or cisterns, kitchen and bathroom faucets and 20-liter carboys. The bacteriological parameters determined were total coliforms, fecal coliforms and 18 physico-chemical parameters. Of the 33 houses sampled, 16 presented no contamination of total or fecal coliforms in the main stop valve or interior. Fifteen had bacterial contamination in the interior and 10 were only contaminated in the main stop valve, which was related to little or no chlorination. Of the 19 carboys analyzed, 11 had bacterial contamination. Physico-chemically, only some houses were outside the norm in one or more of the following parameters: ammoniacal nitrogen, nitrates, dissolved solid turbidity and residual free chlorine. All, however, exceeded the limit for manganese. Delegation 4 presented the greatest differences in relation to salt content, while delegation 2 had the most similitude. In conclusion, the delegations whose three houses had no bacteriological contamination in neither the main stop valve nor the interior and which also gave the best physico-chemical results were 8 and 11; the worst delegations with all three houses contaminated in main stop valve and/or interior were 2 and 4. Regular cleaning and care of interior water deposits is highly important to avoid internal contamination.*

Keywords— *Drinking water, physicochemical parameters, total and fecal coliforms.*

I. Introduction

Potable water is a highly important but scarce resource for health [1], and its deterioration is an increasingly serious problem and considered a major environmental issue [2]. All over the world, around 3 of every 10 people lack access to household drinking water, and 6 out of 10 lack safe sanitation, according to a report from the World Health Organization (WHO) and UNICEF [3].

Human health depends on good quality water. According to WHO, almost one quarter of available hospital beds worldwide are occupied by patients whose illness is due primarily to unhealthy water [2].

Water-borne pathogens constitute a global problem that demands urgent control. Bacteria, viruses and parasites cause diseases of varying severity, [4]; their presence in water is associated with fecal contamination and an indication of inadequate treatments or subsequent contamination [5].

Several studies have reported contamination by coliforms in supplied drinking water. Among these, Taylor and Cordón, concluded that the well water of a community in Nicaragua is not suitable for human consumption [6]. Bracho-Fernández and Fernández-Rodríguez, reported that, from a bacteriological viewpoint, the main stop valve sources of a Venezuelan community are contaminated in excess of established safe values. In all cases, bacteriological examination indicated the presence of aerobic heterotrophs and total coliforms [7]. Rubio *et al*., detected the presence of total and fecal coliforms in all samples taken in a community in Chihuahua, Mexico [8]. Beltrán *et al*., found that 50% of the population of Columbia do not have access to drinking water, 10 million Colombians have no aquaduct and close to 800 municipal seats are about to disappear [9]. Bueno–Zabala *et al.*, showed the presence of some heavy metals and substances of sanitary interest that may represent health risks if the drinking water supply systems (SAAP), which supply water from the section evaluated, do not have adequate treatment barriers [10]. Monteverde *et al*., in their study on the Matanza-Riachuelo basin of Greater Buenos Aires found that, based on their origin, 9% of water samples from the public network, 45% from bottled water and 80% from drillings or individual wells were undrinkable due to excess coliforms, *Escherichia coli* or nitrates [11]. Bolaños, found that in a Greek province, the main problems are: the vulnerability of springs to contamination; defective chlorination processes, and contamination with total coliforms of several sites studied [12]. Briñez *et al*., found that 63.83% of municipalities in Tolima, Colombia, had undrinkable water [13]. In Tamaulipas, Mexico, bacteriological contamination is a prominent factor in the water supply sources of rural communities [14].

In Mexico City, water is mainly supplied from wells, followed by the Cutzamala System, Magdalena River and springs [15]. An average of 32 m^3/s is supplied to address the water demands of Mexico City inhabitants. Of this, 67% is obtained from ground water; 3% from springs and 30% from the Cutzamala System [15, 16].

The different types of rock that make up the Mexican Republic's geographical framework confer different qualities to the surrounding water; for example, acidic igneous rocks, such as those found on the eastern Sierra Madre, generally speaking add chemical elements (iron, manganese, fluoride, arsenic and others), which enter drinking water supply systems. The presence of these elements has been increasing over time. It is evident, therefore, that so-called freshwater does not generally adhere to a universal quality in terms of the chemical elements and compounds dissolved therein [17].

Due to the importance of this vital liquid and the above, the quality of water for human consumption must be regularly evaluated since it is constantly changing as a result of both natural pollutants and those of anthropogenic origin. The aim of this study, therefore, was to determine household water quality in Mexico City.

II. METHODOLOGY

Eleven delegations were sampled: Gustavo Madero (1), Tlalpan (2), Miguel Hidalgo (3), Iztapalapa (4), Tlahuac (5), Azcapotzalco (6), Benito Juárez (7), Cuauhtémoc (8), Xochimilco (9), Milpa Alta (10) and Iztacalco (11) (Figure 1). Three houses were chosen from each delegation, and samples were taken from different sites, such as the main stop valve, water tanks and/or cisterns, kitchen or bathroom faucets and 20-L carboys.

The bacteriological parameters were determined as total coliforms, fecal coliforms and 18 physico-chemical parameters. The analyses were carried out based on the standardized methods of water analysis [18].

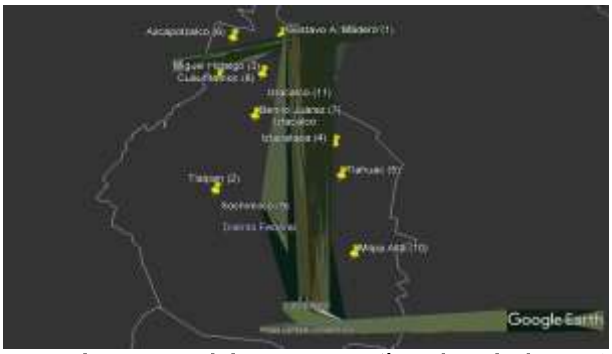

Fig. 1. Delegations sampled in Mexico City (formerly, Federal District).

III. RESULTS AND DISCUSSION

Sixteen houses showed no contamination with total or fecal coliforms in the main stop valve or the interior; these houses belong to delegations 1, 3, 5, 6, 7, 8, 9, 10 and 11. Delegations 8 and 11 had the best results as none of their three houses presented bacterial contamination (Table I, Fig. 2).

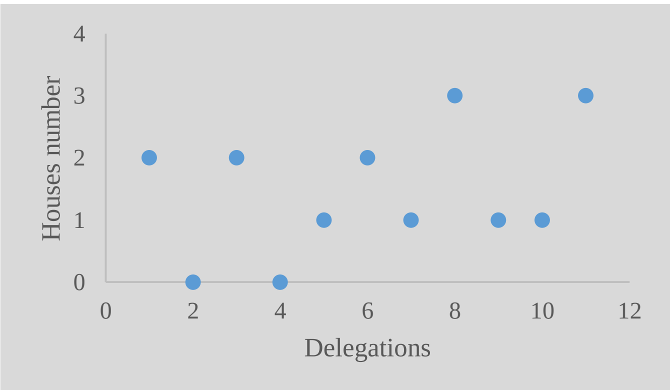

Fig. 2. Frequency of houses without coliform contamination in main supply or interior, by delegation.

TABLE I. Number of houses with and without bacterial contamination.

Delegation	One or more points contaminated	Without Contamination.	Contamination in supply	Indoor Contamination
1	1	2	0	1
2	3	0	1	2
3	1	2	1	1
4	3	0	3	2
5	2	1	1	2
6	1	2	0	1
7	2	1	1	2
8	0	3	0	0
9	2	1	1	2
10	2	1	2	2
11	0	3	0	0
Houses total	17	16	10	15

The main stop valve in twenty-three houses was free from coliforms (Fig. 3); 15 houses had interior bacterial contamination and 10 had contamination only in the main stop valve (Table I). This latter contamination was related to low or zero levels of chlorination (Figs. 4 and 5).

Fig. 3. Frequency of houses without coliform contamination in main supply by delegation.

The results were also compared to the maximum permissible limits established in Mexican Standard: Amendment to NOM 127-SSA1-1994 published in the Official Gazette in 2002 [19]. The main stop valve of 23 houses meets the standard (Fig. 3).

The presence of micro-organisms in 10 supplies (Table I) was due mainly to very little or no chlorination (Fig. 5).

Figure 5 shows the difference between the houses whose supplies had good chlorination and therefore had no bacteriological contamination. This result coincides with Pullés [4], who said that the origin of bacteriological contamination often originates from inadequate chlorination. Pullés [4] also mentioned other occasions including cracks and fissures in pipes and damages and repairs that occur in the distribution network, which happens to be outside the control of sanitation authorities at many of its critical points. Biofilms are also formed in distribution systems where high levels of aluminum and sporulated microorganisms hinder their control and represent a potential health problem for the population [20].

Fig. 4. Main supplies with residual free chlorine, without bacteriological contamination.

Pathogenic intrusion is a phenomenon present in potable water distribution systems, causing a decrease in water quality when (contaminated) fluids surrounding the conducts infiltrate through defects under low pressure conditions. Contamination under less favorable conditions may cause epidemic diseases due to the consumption of contaminated water [21].

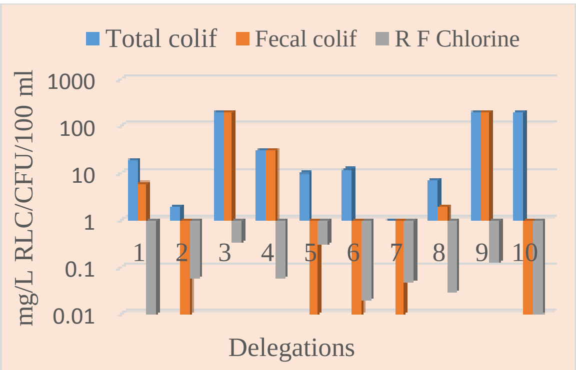

Fig. 5. Main supplies with bacteriological contamination and their residual free chlorine values.

The bacteriological contamination that presented in the interior of 15 houses mainly indicates the lack of cleanliness in water deposits, or the possible formation of films where potentially pathogenic bacteria grow [20].

Of the 19 carboys sampled from houses that consume bottled water, 11 presented bacteriological contamination (4 with total coliforms only and 7 with both total and fecal coliforms) (Fig. 6).

Regarding the physico-chemical parameters, in general, the majority of delegations met the standard in at least one of their three sampled houses, with the exception of dissolved solids in delegation 4; ammoniacal nitrogen in delegations 4 and 5; turbidity in delegations 3 and 9; nitrates in delegations 7, 8, 9, 10 and 11; residual free chlorine in all but delegations 1 and 8, and manganese in all delegations (Table II).

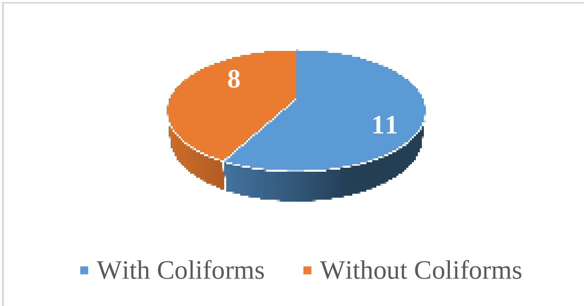

Fig. 6. Bacteriological analysis of water carboys.

The presence of some parameters, such as manganese, which were outside the standard's permissible limits, is due mainly to the type of soil in the country—as mentioned by the Federal District Legislative Assembly [12]—in which diverse rock types confer different qualities to the water that circulates around them.

The delegations with the best physico-chemical results were 8, where two houses were outside the standard for nitrates and one house for manganese; and delegation 11, with one house exceeding the limits for nitrates and 3 houses for manganese.

TABLE II. Physico-chemical parameters of sampled houses that deviate from the norm on one or more points.

Delegation	Nitrates	Ammonia nitrogen	Dissolved solids	Turbidity	Mangan Ese	Residual free chlorine
NOM 127	10 mg/L	0.5 mg/L	1000 mg/L	5 NTU	0.2 mg/L	0.2 a 1.5 mg/L
1					X	
2					X X X	X X X
3				X	X X	X
4		X	X		X X	X
5		X X X			X	X X X
6					X	X
7	X X				X X X	X X
8	X X				X	
9	X X			X	X	X X X
10	X X X				X X	X X
11	X				X X X	X X
Houses totals	10	4	1	2	20	18

The highest total alkalinity was presented by 2 houses in delegation 4. The lowest total alkalinity was found in delegation 2 (all three houses) and 1 house in delegation 10. These differences are mainly related to soil type [15] (Fig. 7).

The highest water hardness was found in delegations 1 and 4, one house in each, and the lowest in all three houses of delegations 10, and one house in delegation 6 (Fig. 8).

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The predominant hardness type was moderately hard (18 houses), followed by very hard (7), soft (5) and hard (3) (Table III).

TABLE III. Water hardness types.

Delegation	Hardness type
1 and 6	Hard and very hard
2, 9 and 10	Soft and moderately hard
3, 5 and 8	Moderadately hard and very hard
4	Soft, hard and very hard
7 and 11	Moderately hard

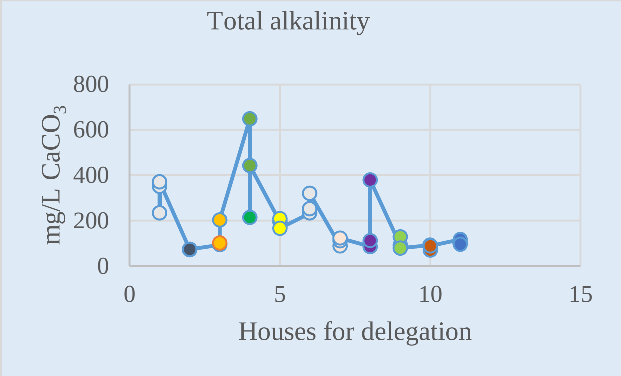

Fig. 7. Total Alkalinity dispersion graph of the houses of delegations Sampled.

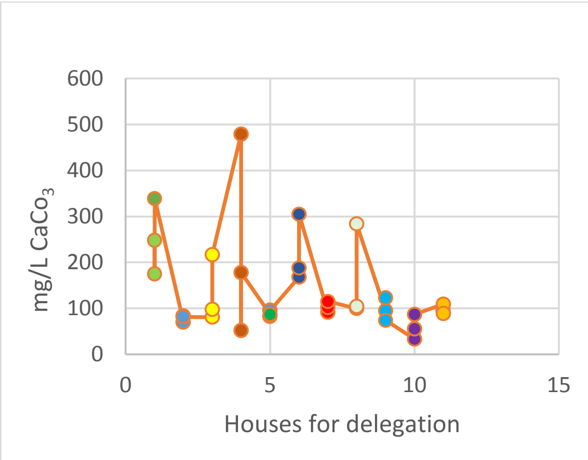

Fig. 8. Total hardness dispersion graph of the houses of delegations sample.

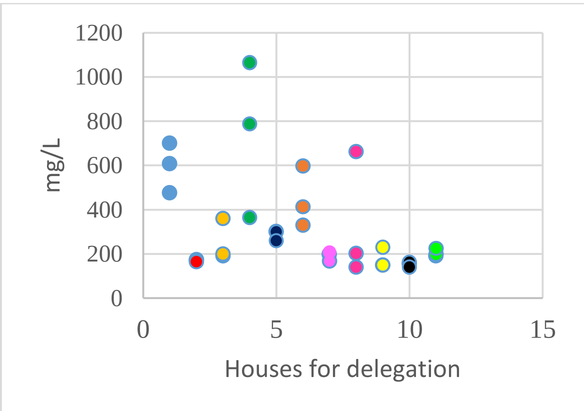

Fig. 9. Dissolved solids dispersion graph of the houses of delegations sampled.

As in the other graphs, delegation 4 shows more differences in dissolved solids, while the three houses of delegation 2 have more similarities in this parameter (Fig. 9).

IV. Conclusions

The delegations whose three houses were without bacteriological contamination both in the main stop valve and the interior were 8 and 11, the worst delegations being 2 and 4, where all three houses were contaminated in the main stop valve and/or interior.

In some delegations, chlorination in several main stop valves is very low or null, causing contamination by total and fecal coliforms.

Regular cleaning and care of the water deposits inside the houses is very important to avoid internal contamination.

Water purification plants for bottled water must be more careful when maintaining equipment, cleaning carboys and monitoring production quality control. The poor handling of carboys in the household may be another source of infection.

Physico-chemically, delegations 8 and 11 were the best, although in general, all the delegations had at least one of their houses with one or more parameters outside the standard limits.

Delegation 4 presented the most differences in total alkalinity, total hardness and dissolved solids, while delegation 2 showed the most similarities in those parameters (Figs. 7, 8 and 9).

The salt content was mainly influenced by the soil type through which groundwater passed, with notable differences in concentration in some houses.

V. Acknowledgement

Ignacio Cortes de Jesus, Pedro Hernández Colin, Javier Jurado Peña and Luis Alberto Ramírez Cortés for their collaboration in this work.

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