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Quality of Water in Carboys in Greater Mexico City

Ma. de Guadalupe Sáinz[1], Blanca Martínez[1], Esperanza Robles[1], Reynaldo Ayala[1], Elizabeth Ramírez[1], Enrique D. Guevara[1], Ma. Elena González[1].
[1]Research Group on Conservation and Improvement of the environment. FES Iztacala, National Autonomous University of Mexico
E-mail address: erobles(at)unam.mx

***Abstract*— *In recent years reports have shown an increase in the consumption of bottled water, particularly in developing countries, due to the scarcity of drinking water and its quality. Gastrointestinal diseases are among the main public health problems in Mexico and are transmitted through the consumption of contaminated water and food. The aim of this study was to verify the quality of water in carboys when first opened and while in use and to determine whether the water is fit for human consumption. A bacteriological and physicochemical analysis was performed on the contents of 47 carboys of purified water; 15 (32%) had no contamination and 32 (68%) presented total coliforms and/or fecal coliforms putting them outside of the Mexican standards. Contamination by total coliforms was found in 68% of the samples and fecal coliforms in 43%. Physicochemical results: 44 carboys did not meet Standard 127 for manganese. Other physicochemical parameters which did not comply with Standard 127 and/or 201 were pH, fluorides, free chlorine, nitrites and nitrates. The consumption of bottled water from carboys is not synonymous with safety since both large and small companies had bacteriological and physicochemical contamination in some carboys.*

***Keywords*— *Fecal coliforms, physicochemical parameters, water quality from carboys.*

I. INTRODUCTION

One of the most serious problems worldwide, and which has been the primary cause of morbidity and mortality, is water pollution. Across the globe, around 3 out of 10 people are without drinking water in the home, and 6 out of 10 lack safe sanitation, according to a report by the World Health Organisation (WHO) [1] and UNICEF [2].

Gastrointestinal diseases are among the main public health problems in Mexico and are transmitted through the consumption of contaminated water and food. Such diseases mainly affect the child population, their incidence and prevalence being largely dependent on socioeconomic level. The search for and identification of the classic causative pathogens focuses mainly on bacteria such as *Salmonella spp., Shigella spp., Escherichia spp, Vibrio spp., Campylobacter spp.* and *Yersinia spp.* Other genera are also involved in these diseases, including *Aeromonas spp,* which in other countries has been documented as an etiological agent of gastrointestinal diseases and a marker of fecal pollution in water. Other pathogenic agents are viruses and parasites [3].

As a result, in recent years reports have shown an increase in the consumption of bottled water, particularly in developing countries, due to the scarcity of drinking water and its quality [4]. The safety of water for human consumption, specifically bottled waters, are of vital importance to guarantee and safeguard public health.

Bottled water is any type of processed drinking water packaged in plastic, glass or other material, in different forms and volumes, and which is destined for human consumption as a drink or food [5]. The framework within which water is considered fit or safe is a water quality standard.

An adequate standard is the reference that will guarantee that the water is not harmful to human health [6]. In Mexico, the Official Mexican Standard NOM-201-SSA1-2002 establishes the sanitary specifications for bottled water [7]. The surveillance and monitoring of water quality requires diagnostic tools to identify the organisms present. Among these diagnostic tools are bioindicator organisms, which behave similarly to pathogenic microorganisms. The microorganisms are easily identified and quantified and provide information in the monitoring of water quality [8].

Some of the microorganisms present in water that can indicate a potential health risk are bacteria such as *Salmonella spp., Sighella spp., Pseudomonas spp.* [9]; *Vibrio cholerae,* [10]; *Clostridium spp.*, [11] and *Legionella spp*, [12].

Several authors have studied the quality of bottled water, among them, Arévalo *et al.*, (2014), who reported bacterial contamination in 69% of samples and failure to meet the Colombian standard on finding trihalomethanes and haloacetic acids in 30% of the samples [4]. Rojas *et al.*, (2014) analyzed 50 20-L carboys in Carabobo, Venezuela, finding fecal coliforms in 92% of the samples, thermo-tolerant microorganisms in 84%, and aerobic heterotrophs in 86%, of which *Acinetobacter baumannii* (29.3%) and *Pseudomonas aeruginosa* (17.4%) were the organisms most isolated. In Ecuador in 2015 [13], Macías studied 5 brands of bottled water, finding that all 5 brands met the standard for coliforms but exceeded the established limits for mesophilic aerobes [5].

Scientists from Mexico's National Polytechnic Institute (IPN) corroborated the presence of fecal coliforms in 20-L water carboys sold by 111 small purification plants and suggested they be audited since many of them operate irregularly within the 16 delegations of Mexico City [14]. Vidal *et al*., concluded that much of the water plastic bag packed manufactured in Sincelejo, have a risk to consumers health, due to the presence of pathogenic microorganisms [15].

In a study conducted in Mexico by Barrio, et al. (2016), it was concluded that the water was not fit for consumption since the values for aerobic microorganisms, total coliforms

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and fecal coliforms exceeded the Standard [16]. Marzano et al., evaluated the bacteriological quality of unprocessed bottled spring water, the results indicated a high contamination frequency with P. aeruginosa (57.5%) [17]. Daniel and Priyadarshana in Sri Lanka (2019) showed that after analyzing and comparing a total of 50 samples from different brands, 11 (22%) tested positive for Salmonella, 6 samples (12%) were not contaminated and 33 samples (66%) were positive for other types of bacteria, among them E. coli [18]. Evangelista et al., (2019) analyzed 40 samples from water filling purifiers in Mexico finding the presence of E. coli, total coliforms and Pseudomonas spp. Of the establishments visited, 35% did not meet the respective standard; while the standard does not require the determination of Pseudomonas, its detection implies a high health risk [19]. Molefe et al., 2020 conducted comparative microbiological analyses in bottled, tap and spring water in Lesotho, South Africa, finding that several bottled water samples and one tap water sample contain a high microbial load and were contaminated with Escherichia coli, and still others with Staphylococcus spp. [20]. In Nepal, Gautam (2021) found that 48% of 50 samples taken from 20-L carboys had microbial contamination [1]. Shahryari et al., (2021), analyzed 400 bottles of water from 10 brands in Iran finding high bacterial contamination and a positive association between water quality and length of storage [21]. Faviel et al., found that the bacteriological parameters of bottled water that was marketed in the communities during the study period indicate that it is not suitable for human consumption according to national regulations, while the physicochemical parameters of bottled water are still within the allowed range [22].

The aim of this study was to verify the quality of water in carboys when first opened and while in use and to determine whether the water is fit for human consumption.

II. METHODOLOGY

A questionnaire was prepared to gather information about the carboys (bought from a large or small business, handling in the home, etc.) during a period from 2018 to 2019. A bacterial analysis was performed on the contents of 47 carboys of purified water, the first sample being taken immediately on opening (start) and the second when the carboy was half-full or less (use). The samples for bacteriological analysis were taken in sterile 500 ml polypropylene flasks. Total and fecal coliforms were determined by the membrane filter technique

Samples were also taken in 1.5 L PET bottles when the carboys were first opened for the physicochemical parameters. In the laboratory, 12 parameters were determined in accordance with standard methods [23].

The results were compared with the maximum permissible limits established in the Official Mexican Standard NOM-201-SSA1-2002 for bottled water [7] and the amendment to NOM-127-SSA I-1994 for drinking water [24].

III. RESULTS

Of the 47 carboys analyzed, 15 (32%) were found to be without contamination. 32 (68%) were contaminated with total coliforms (Figure 1) and of the contaminated, 20 (43%) had fecal coliforms (Figure 2).

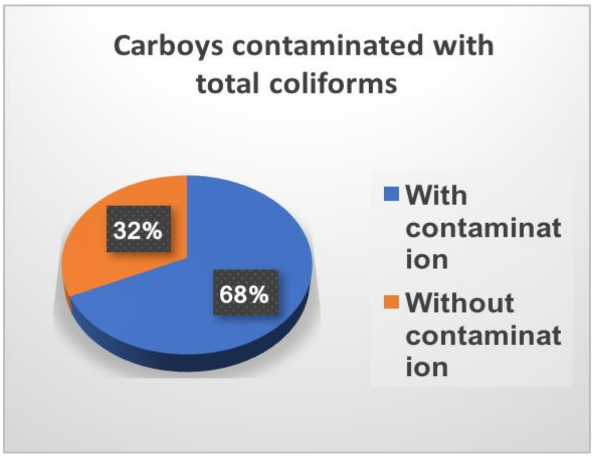

Fig. 1. Percentage of total carboys contaminated with total coliforms.

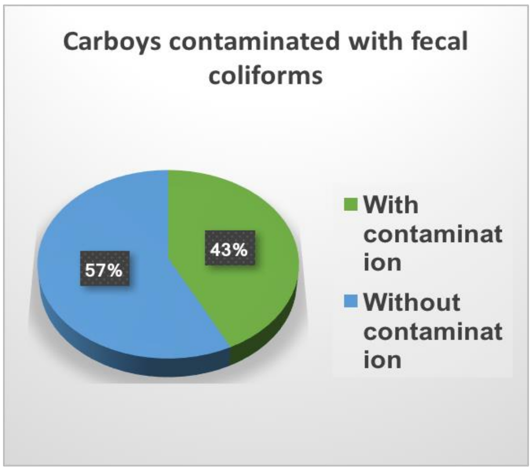

Fig. 2. Percentage of total carboys contaminated with fecal coliforms

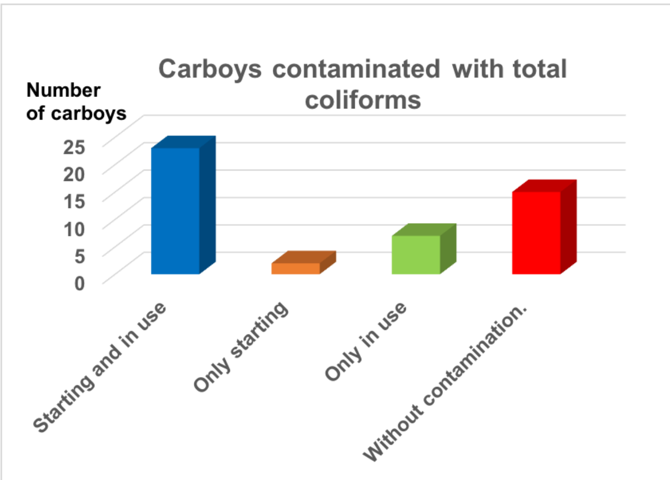

Fig. 3. Carboys contaminated with total coliforms at the start and in use

The carboys contaminated with total coliforms from the start and in use amounted to 23 (47%), 2 (4%) only from the start and 7 (11%) only while in use (Figure 3). The carboys contaminated with fecal coliforms from the start and in use

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totaled 13 (28%), 2 (4%) just at the start and 5 (15%) only while in use (Figure 4).

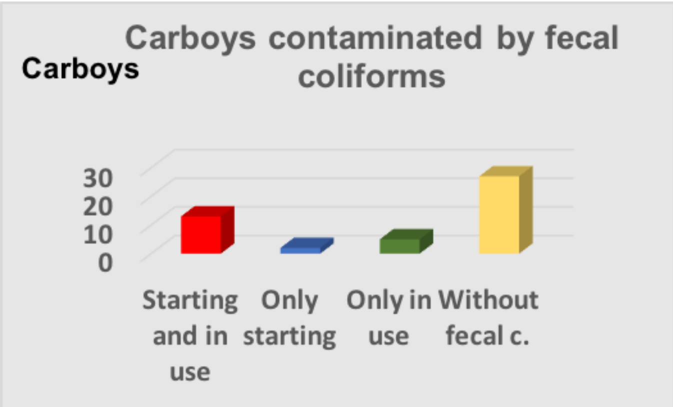

Fig. 4. Carboys contaminated with fecal coliforms at the start and in use.

The results of the physicochemical analyses were used to calculate the average, maximum and minimum values (Table I).

The results were compared with the maximum permissible limits of NOM 127 and NOM 201 (Table II) and the parameters which exceeded the standards are shown in Figure 5.

TABLE I. Average, maximum and minimum values for each physicochemical parameter

Parameter	Average	Maximum value	Minimum value
pH	**6.62**	**7.95**	**4.86**
Free chlorine	**0.12**	**1.71**	**0**
Nitrates	**5.76**	**25.5**	**0.017**
Nitrites	**0.03**	**0.28**	**0.004**
Ammoniacal nitrogen	**0.021**	**0.3**	**0**
Total Alkalinity	**94.85**	**354**	**6**
Total Hardness	**78.11**	**356**	**4.12**
Fluorides	**0.248**	**1.63**	**0**
Dissolved solids	**181.3**	**615**	**10**
Color	**0.425**	**10**	**0**
Turbidity	**0.330**	**0.69**	**0.163**
Manganese	**2.27**	**6.6**	**0**

TABLE II. Maximum permissible limits of the Amendment to NOM 127-SSAI-1994 and NOM 201-SSAI-2002

Parameter	NOM 127	NOM 201
pH	**6.5-8-5**	**n.a.**
Nitrates (mg/L de N-NO_3)	**10**	**10**
Fluoride (mg/L de F)	**1.5**	**1.5**
Manganese (mg/L de Mn)	**0.15**	**n. a.**
Nitrites (mg/L de N-NO_2)	**1**	**0.05**
Free chlorine (mg/L Fc)	**n.a.**	**0.1**

n.a.= not applicable

Manganese exceeded the limits of NOM 127 in 44 carboys, followed by pH in 16 carboys which presented values lower than 6.5 (NOM 127); free chlorine in 11 carboys exceeded the limits of NOM 201; nitrates surpassed the limits of both standards in 7 carboys; nitrites surpassed the limits of NOM 201 in 3 carboys and lastly fluorides exceeded the limits of NOM 127 and 201 in only one carboy (Figure 5)

Based on the classification of Romero [25]. — in which water hardness is expressed as mg/L of $CaCO_3$, where soft water is between 0 and 75, moderately hard between 75 and 150, hard from 150 to 300 and very hard over 300 — of the carboys in this study 23 contained soft water, 19 moderately hard, 4 hard and 1 very hard (Figure 6).

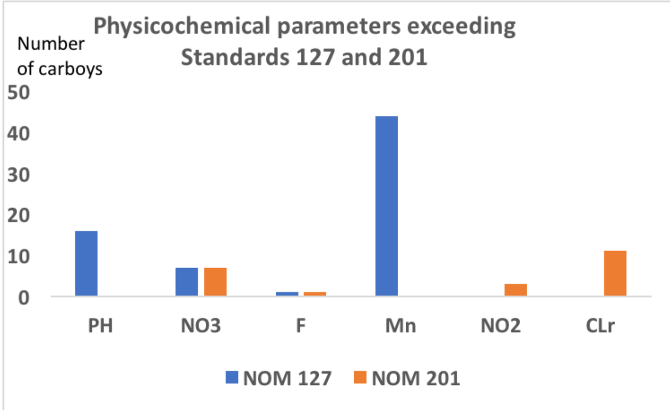

Fig. 5. Number of carboys exceeding the limits of NOM-127 and/or NOM-201

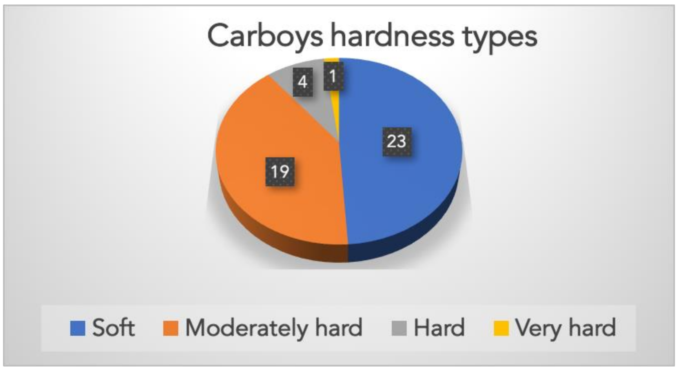

Fig. 6. Water hardness in the carboys

IV. Discussion of the Results

The information gathered from the questionnaires was compared with the bacteriological results; no differences were noted in terms of the contamination in carboys from large or small companies. Good bacteriological water quality was found in 9 carboys from large companies and 7 from small companies. Poor quality water was also found in both types of company with 16 carboys coming from large companies and 15 from small companies. The contamination issue in the purification plants is possibly due to lack of regular maintenance of the processes [26] and, in some cases, the poor washing of the carboys resulting in their contamination from the start. The presence of total and/or fecal coliform bacteria in some carboys coincides with the findings of Barrio *et al.* (2016) [16]., Molefe *et al.*, 2020 [20]., Arévalo *et al.* (2014) [4,]., IPN (2015) [14]., Rojas *et al.* (2014) [13]., Gautam (2021) [1]., Shahryari, *et al.* (2021) [21] and others.

In the carboys that were contaminated from the start, the contamination often increased while in use. The carboys which were only contaminated while in use were poorly handled, for example when water dispensers, syphons and

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sometimes pitchers were used to pour the water. In most of these cases, the water was contaminated while in use or increased when contaminated from the start, probably due to these devices not being washed regularly or carelessness on leaving the carboy open. This coincides with some authors who found that bacterial contamination could have been the result of lack of hygiene or cleanliness when handling the carboys while in use, or even prolonged storage [27].

For the physicochemical parameters, free chlorine was outside the limits of Standard 201 in 11 carboys, possibly due to poor washing which left behind chlorine residue.

The high values of manganese in 44 carboys could be due to the origin of the soil in Greater Mexico City which is rich in manganese because of the type of soil in the country, where there are many kinds of rocks that give it different qualities than groundwater [28].

In terms of pH, 16 carboys were below 6.5 giving the water more acidic characteristics, some with values of 4.8, 5.1 and 5.4, among others. A low pH can damage pipes and produce contamination in drinking water with adverse effects on appearance and taste, WHO (2006) [29].

Three carboys surpassed the limits of NOM 201 in nitrites and 7 carboys exceeded nitrates in both Standards 127 and 201; these values could be related to soil and subsoil contamination by seepage or runoff from agricultural areas and degradation of human and animal waste, which under anaerobic conditions can generate nitrites, WHO (2006) [29]. Montiel, *et al.*, found nitrates and nitrites in groundwater in the southern zone of the Mexican Basin, indicating contamination processes [30].

Only one carboy exceeded the limits for fluorides in Standards 127 and 201. The presence of fluorides and also manganese in the water could come from the type of soil in Greater Mexico City [28].

V. CONCLUSIONS

Of all the carboys that underwent bacteriological analysis, 15 (32%) had no contamination and 32 (68%) presented total coliforms and/or fecal coliforms putting them outside of the Mexican standards.

Contamination by total coliforms was found in 68% of the samples and fecal coliforms in 43%.

Based on the physicochemical results, 44 carboys did not meet Standard 127 for manganese.

Other physicochemical parameters which did not comply with Standard 127 and/or 201 were pH, fluorides, free chlorine, nitrites and nitrates. The remaining parameters analyzed complied with the standards.

Most of the carboys contained soft or moderately hard water and is therefore suitable for drinking.

The consumption of bottled water from carboys is not synonymous with safety since both large and small companies had bacteriological and physicochemical contamination in some carboys.

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