Installation of a Water Disinfection System in a Mexico City Hospital[1]

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With a view to evaluating a small-scale water disinfection system based on production and application of oxidizing gases, the level of equivalent residual chlorine and the degree of contamination by fecal and total coliform bacteria was assessed at various points in the drinking water system of a Mexico City hospital before and after installation of the disinfection equipment. Tests done in May and June 1989, prior to installation of the equipment, showed that residual chlorine concentrations were lower than the national standard in most of the samples and that a sizable portion of these samples were also contaminated with fecal and total coliform concentrations exceeding national standards. After installation of the disinfection system at the main inflow to the hospital's drinking water supply in August 1989, the equivalent residual chlorine concentrations were found adequate and no coliform bacteria were detected. These results indicate that the oxidant mixture generated by the newly installed system was effectively disinfecting the water.

The Mexican Ministry of Health has promoted development and use of appropriate technology to assess water's bacteriologic quality and, as necessary, to disinfect water consumed in suburban and rural communities as part of the strategy for attaining the goal of health for all by the year 2000.

Development of technologies for bacteriologic evaluation and disinfection of water is justified by the morbidity and mortality due to gastrointestinal and liver diseases, not only in Mexico but also in other countries (*1–3*). Most of these diseases are associated with ingestion of water contaminated with microorganisms, although they can also be associated with other public health, economic, and cultural conditions (*4, 5*). According to the Health Ministry's weekly *Boletín Epidemiológico Semanario,* during the fifty-second week of 1989 there were 117,243 cases of assorted types of diarrhea in Mexico's Federal District (*6*).

Conventional chlorine-based methods of disinfecting water are often rendered ineffective by pressure changes, sequestering of the chlorine, pipeline losses, and other circumstances that contribute to water supply contamination (*7, 8*).

Ongoing surveillance to ensure that drinking water quality is within the limits established by national standards (*9*) is a legal function of the Ministry of Health, which has evaluated various technologies for both water purification and control of bacteriologic quality (*10*).

[1]Edited translation of the article "Aplicación de un sistema de desinfección del agua en un hospital de la ciudad de México" published in the *Boletín de la Oficina Sanitaria Panamericana,* 112(5):395–405, 1992.

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The lack of available technology suited to meeting existing needs prompted the Ministry of Health's Center for Development and Technological Applications (CEDAT), with the financial and technical support of PAHO, to design and build equipment for water disinfection and bacteriologic control. The equipment was designed to inject the water supply with a mixture of oxidizing gases (oxygen, ozone, and chlorine) generated *in situ* by electrolysis of a saturated aqueous sodium chloride solution (*11*).

The equipment was designed to disinfect water supplies for communities of 200 to 10,000 inhabitants. It can also be used by facilities such as schools, day care centers, and hospitals to complement the urban water treatment system or to serve as a sole treatment system.

The aim of the study reported here was to evaluate the effectiveness of the installed equipment as a possible complement to central water treatment systems. The study was carried out at the "Manuel Gea González" General Hospital in Mexico City.

MATERIALS AND METHODS

Equipment brought together for the task, collectively designated "equipment for comprehensive treatment of water for human use and consumption" (*12*), included a membrane filter, a two-chamber incubator, an ultraviolet light sterilizer, a two-chamber electrolytic cell for generating the oxidant mixture, and a Venturi tube. The mixture of oxidants was produced in the electrolytic cell by passing direct current through it, the direct current coming from a power supply that used a 60 hertz alternating current of 110 volts. The electrolysis was started by placing an aqueous solution of sodium chloride (table salt) in one compartment and a 10% aqueous solution of sodium hydroxide (caustic soda) in the other. Once underway, the electrolysis produced more caustic soda, and this had to be diluted periodically by adding water to the appropriate compartment.

Bacteriologic assessment of the water was accomplished by membrane filtration, which is economical, highly precise, and amenable to being performed with little training. Indeed, this technique, which has been officially accepted, became a National Technical Standard that was published in the *Diario Oficial de la Federación* in January 1988 (*13*). Using this method, the water sample to be analyzed is passed through the membrane filter's sample collector tube. The tube fits tightly at the base, which has a stainless steel screen on which the sterile nitrocellulose membrane (with pores measuring 0.45 μm) is placed. The water passes through, as a result of both hydrostatic pressure and a vacuum created in the recipient container to which the base of the filter is affixed. The vacuum is created by suction with a manual pump. After passage of the water sample, the nitrocellulose membrane is extracted with sterile tweezers and placed on an appropriate culture medium in a Petri dish. The Petri dish is then placed in one of the incubator's two compartments, which are maintained at 37°C and 44°C. Appropriate media and temperature permit cultivation of the bacterial indicators of water pollution—total coliforms and fecal coliforms (*10*).

Analysis of another sample at this point requires that the sample collector tube and tweezers be sterilized. With the ultraviolet light sterilizer it is possible to perform the sterilization procedure at ambient temperatures and hence to immediately reutilize the same devices.

For 38 consecutive days (from 10 May to 20 June 1989) the concentration of equivalent residual chlorine was measured (using the orthotolidine technique—*14*) in the water entering the "Manuel Gea González" General Hospital's main water tank and at five points in the hospital's water distribution system. One sampling point was purposely located at the midpoint of the distribution system, while another was situated at the end.

For bacteriologic assessment of the water, random samples were taken on different days from the main inflow tank and at five additional points: (1) the sump pump, (2) the general services kitchen, (3) the day care center's kitchen, (4) the seventh floor (containing the infectious disease ward), and (5) the equipment and sterilization center. The sampling was done between 9:00 a.m. and 11:00 a.m.

The apparatus needed to analyze bacteriologic samples was installed on a small table in an annex to the clinical laboratory. The technique used, as described above, employed filtration with 0.45 μm pore nitrocellulose membranes, the filtrate being seeded onto media with agar in Petri dishes. One set of Petri dishes containing m-endo broth® (Becton Dickinson and Co., Cockeysville, Maryland, U.S.A.) was incubated at 37°C for total coliforms, while another set containing mfc-broth® (Difco Laboratories, Detroit, Michigan, U.S.A.) was incubated at 44°C for fecal coliforms.

The water disinfection equipment was installed on 15 August 1989. The Venturi tube, used for injecting oxidants into the water, was attached to the pipe leading to the main water tank. The electrolytic cell and the power supply were placed nearby on a cement slab under an overhanging roof.

Beginning at this time, the equipment was run with an electric current sufficient to generate oxidant concentrations equivalent to 1.0–2.0 mg of residual chlorine per liter in the main tank and equivalent to 0.2–1.0 mg of residual chlorine per liter at the five other sampling points mentioned. The cell ran continuously, 24 hours a day, except on weekends, when it operated intermittently in the mornings. The only problem occurred one weekend when the equipment was left running without replacing the corresponding solutions. This caused the screws holding the electrodes in place to overheat and to melt the polyvinyl chloride of which the cell was made.

Distilled water used for preparing the saline solution was consumed at a rate of 300–500 ml daily, at a cost coming to some 15,000 pesos (roughly US$5) per month. This daily quantity was mixed with 200 g sodium chloride costing 375 pesos per kg (less than US$1 per month). The electric current used was equivalent to one 100-watt light bulb burning continuously. The cost of the disinfection equipment was 3,555,125 pesos (about US$1,269). Installation by a plumber took two hours, and daily maintenance took 30 minutes to an hour of unspecialized personnel time.

RESULTS

The bacteriologic evaluation equipment worked as described in the technical operating manual. Seeding of the nitrocellulose membranes was accomplished easily and rapidly with the assistance of the vacuum generated by the manual suction pump. The dual chamber incubator was kept at the two specified temperatures within a range of ±0.5°C. The effectiveness of the ultraviolet sterilizer was tested by measuring the time needed to purify the contaminated water. In general, it was found that five minutes of exposure to the ultraviolet light served to sterilize water samples sufficiently contaminated to yield 500 to 2,000 colonies of total coliforms per liter.

Measurement of equivalent residual chlorine levels during the 38 days of sampling preceding installation of the disinfection equipment (Table 1) showed concentrations equalling or exceeding 0.2

Table 1. Residual chlorine in urban network water received at the "Manuel Gea González" General Hospital in Mexico City from 10 May to 20 June 1989, as indicated by levels detected at six sampling points within the hospital.

Sampling site	No. of samples	Days when samples with chlorine were detected	Concentration (mg/l)	Proportion of samples acceptable[a]
Intake of main tank	38	5 June 7 June 8 June 20 June	0.2 0.2 0.2 0.3	4/38 = 11%
Sump pump	32	5 June 7 June 20 June	0.2 0.2 0.3	3/32 = 9%
Kitchen (general services)	38	5 June 7 June 8 June 20 June	0.2 0.2 0.2 0.3	4/38 = 11%
Kitchen (day care center)	32	5 June 7 June 20 June	0.2 0.2 0.3	3/32 = 9%
7th floor (infectious diseases)	36	5 June 7 June 8 June 20 June	0.2 0.2 0.2 0.3	4/36 = 11%
Equipment and sterilization center	30	5 June 7 June 8 June 20 June	0.2 0.2 0.2 0.3	4/30 = 13%
Total	206	22		22/206 = 11%

[a]National standard: 0.2 to 1.0 mg/l.

mg/l at the storage tank's main intake and at the other five sampling points on only three or four days (the national standard requires a concentration of 0.2–1.0 mg/l) (*9*). Lesser concentrations of 0.1 mg/l were registered on 10 days at the main tank, on seven days at the sump pump, and on five, four, or three days at the four other sampling points. No residual chlorine was detected in any of the samples taken during the remaining 24 days. (The threshold for the detection method used was 0.05 mg of residual chlorine per liter.)

On two occasions the water supply was supplemented with water from tank trucks. It appears that this tank truck water contained chlorine, since the analyses done the day after the water was discharged into the hospital system showed a greater concentration of residual chlorine than water tested on preceding days. Nonetheless, this did not stop the contamination, inasmuch as fecal coliforms developed in the cultures. Specifically, contaminated samples were collected from the sump pump, from the main tap in the general kitchen, and from the equipment and sterilization center. On 20 June, the day after the second supplement of tank truck water was delivered, the concentration of residual chlorine was 0.3

mg/l in the main tank and at all the sampling points.

Overall (see Table 1), approximately 89% of the water samples tested had unacceptably low levels of residual chlorine. The poor quality of the water supplied to the hospital by the general system was also demonstrated by the bacteriologic analysis, which showed over 35% of the 61 samples tested for total coliforms to have unacceptably high levels of total coliforms (Table 2) and 5 (15%) of the 34 samples tested for fecal coliforms to have unacceptably high levels of fecal coliforms (Table 3) in terms of national standards (see Table 2 and 3 footnotes).

After installation of the disinfection equipment, bacteriologic evaluation of samples taken on 28, 29, 30, and 31 August and on 1, 4, and 5 September of 1989 detected no coliforms in any of the water samples taken from the main tank, the sump pump, the day care center, the seventh (infectious disease) floor, or the equipment and sterilization center. Random bacteriologic control on different days and at different points in the distribution system did not reveal any coliform bacteria.

Unfortunately, the clinical laboratory staff's heavy workload and limited hospital funds did not permit more frequent

Table 2. Total coliforms in 61 water samples collected at six sampling points in the "Manuel Gea González" General Hospital from 10 May to 20 June 1989, as indicated by the number of colonies grown per liter of water sampled.

Sampling site	No. of samples	Days when coliforms were detected	Total coliforms (col/l)[a]	Proportion of samples acceptable[a]
Intake of main tank	12	29 May 14 June 15 June 20 June	Numerous[b] 20 240 130	8/12 = 67%
Sump pump	11	15 May 29 May 10 June 14 June 15 June 20 June	40 60 1,800 40 120 30	5/11 = 45%
Kitchen (general services)	11	15 May 31 May 10 June 14 June 15 June	20 1,370 40 70 120	6/11 = 55%
Kitchen (day care center)	10	30 May 31 May 15 June 20 June	140 100 50 30	6/10 = 60%
7th floor (infectious diseases)	8	31 May 10 June 15 June	1,030 40 150	5/8 = 63%
Equipment and sterilization center	9	15 June	190	8/9 = 89%
Total	61			38/61 = 62%

[a]National standard: less than 20 colonies per liter of water sampled using the membrane filtration method.
[b]Too numerous to count.

Table 3. Fecal coliforms in 34 water samples collected at four sampling points in the "Manuel Gea González" General Hospital in May and June 1989, as indicated by the number of colonies grown per liter of water sampled.

Sampling site	No. of samples	Days when coliforms were detected	Total coliforms (col/l)[a]	Proportion of samples acceptable[a]
Sump pump	8	15 June	20	7/8 = 88%
Kitchen (general services)	11	14 June 15 June	10 10	9/11 = 82%
7th floor (infectious diseases)	8	15 June	10	7/8 = 88%
Equipment and sterilization center	7	10 June	20	6/7 = 85%
Total	34			29/34 = 86%

[a]National standard: 0 colonies per liter of water sampled using the membrane filtration method.

bacteriologic analysis. Therefore, the results of much cheaper tests for appropriate levels of equivalent residual chlorine were accepted as indicative of water quality.

The levels of equivalent residual chlorine detected in the August and September samples cited above ranged from a minimum of 0.4 mg/l to a maximum of 1.0 mg/l. Similar levels were detected in the first two weeks of December 1989, while levels detected by tests in the first two weeks of January 1990 showed concentrations equivalent to 4 mg/l in the tank and 0.8 mg/l at the other sampling points.

DISCUSSION

In the 38 days of sampling prior to installation of the disinfection equipment, concentrations of equivalent residual chlorine that met the national standard were only found in the samples on four days. The situation grew worse when an urgent need for water caused the supply to be supplemented from backup tanks containing stored water. This stored water, while containing high concentrations of equivalent residual chlorine, also contained coliform bacteria—an indication that the chlorine was "sequestered," acting on organic material.

Generally speaking, the initial test results indicated that water disinfection in city treatment plants and the state of the urban water distribution network were not adequate to guarantee concentrations of free chlorine sufficient to keep the water safe for drinking by end users at the point where it entered the hospital. When this situation was aggravated by inadequate water storage and distribution within the hospital, it created conditions highly favorable for the spread of microbial contamination.

Overall, the data indicated that the hospital was in need of a local water disinfection system that would place sufficient concentrations of residual chlorine equivalents in all the storage tanks (4 mg/l) and distribution pipes (0.5–1.0 mg/l) to inhibit growth of contaminating bacteria from both external and internal sources. Establishment of this system was designed to complement disinfection measures taken in situations requiring provision of additional water from storage tanks that in all probability have not been carefully cleaned and disinfected. Such a local disinfection system can reduce the risk of secondary nosocomial infections, a noteworthy share of which are caused by enteric pathogens. In this vein, one study, by Ponce de León et al. (*15*), found nosocomial infections to involve diarrhea 14% of the time, *Escherichia coli* being the bacterium most frequently detected.

Since installation of the electrolytic cell disinfection system at the "Manuel Gea González" Hospital, levels of equivalent residual chlorine have been kept within the range called for by the national standards, reducing microbial contamination of the hospital water and creating conditions conducive to improved health care.

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