

# Microbiological quality of drinking water of urban and rural communities, Brazil

## Qualidade microbiológica de água potável de comunidades urbanas e rurais, Paraná

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### Keywords

Water analysis. Water pollution. Water quality control. Water microbiological characteristics. Enterobacteriaceae. Rural zones. Urban zones.

### Abstract

#### Objective

To evaluate the microbiological quality of treated and untreated water samples came from urban and rural communities and to examine the relationship between coliforms occurrence and average water temperature, and a comparison of the rainfall levels.

#### Methods

A sample of 3,073 untreated and treated (chlorinated) water from taps (1,594), reservoir used to store treated water (1,033), spring water (96) and private well (350) collected for routine testing between 1996 and 1999 was analyzed by the multiple dilution tube methods used to detect the most probable number of total and fecal coliforms. These samples were obtained in the region of Maringá, state of Paraná, Brazil.

#### Results

The highest numbers water samples contaminated by TC (83%) and FC (48%) were found in the untreated water. TC and FC in samples taken from reservoirs used to store treated water was higher than that from taps midway along distribution lines. Among the treated water samples examined, coliform bacteria were found in 171 of the 1,033 sampling reservoirs.

#### Conclusions

Insufficient treatment or regrowth is suggested by the observation that more than 17% of these treated potable water contained coliform. TC and FC positive samples appear to be similar and seasonally influenced in treated water. Two different periods must be considered for the occurrence of both TC and FC positive samples: (i) a warm-weather period (September-March) with high percentage of contaminated samples; and (ii) cold-weather period (April-August) were they are lower. Both TC and TF positive samples declined with the decreased of water temperature.

### Resumo

#### Objetivo

Avaliar a qualidade microbiológica de amostras de água tratada e não-tratada proveniente de comunidades urbanas e rurais e examinar a relação entre ocorrência de coliformes e a média de temperatura da água, e uma comparação dos níveis de precipitação de chuva.

#### Métodos

No período de 1996 a 1999, foram analisadas 3.073 amostras de água tratada

### Descritores

Análise da água. Poluição da água. Controle da qualidade da água. Características microbiológicas da água. Enterobacteriaceae. Zonas rurais. Zonas urbanas.

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(clorada) e não-tratada pelo método dos tubos múltiplos para determinar o número mais provável de coliformes totais e fecais. Destas, 1.594 provenientes de água de torneiras, 1.033 de reservatório para estocar água tratada, 96 de água de minas e 350 de poços particulares. Tais amostras foram obtidas na região de Maringá, Paraná, Brasil.

#### **Resultados**

O maior número de amostras contaminadas por TC (coliformes totais) (83%) e FC (coliformes fecais) (48%) foi observado em água não tratada. O índice de TC e FC foi maior nas amostras de reservatórios do que nas torneiras ao longo de sistema de distribuição. Entre as amostras de água tratada, foram encontradas bactérias do grupo coliforme em 171 dos 1.033 reservatórios amostrados.

#### **Conclusões**

A observação de que mais de 17% da água potável tratada contém coliformes sugere tratamento insuficiente ou recrescimento. Em água tratada, amostras positivas para TC e FC parecem ser similares e sazonalmente influenciadas. Dois diferentes períodos podem ser considerados para a ocorrência de amostras positivas para TC e FC: (i) período quente e úmido (Setembro-Março) com alta percentagem de amostras contaminadas; e (ii) período frio e úmido (Abril-Agosto) onde a positividade é baixa. Amostras positivas para TC e FC diminuem com o decréscimo da temperatura da água.

## **INTRODUCTION**

The contamination of natural water with fecal material, domestic and industrial sewage and agricultural and pasture runoff may result in an increased risk of disease transmission to humans who use those waters.<sup>7,12</sup> Diarrheal disease from contaminated water continues to be a serious problem in developing countries and a lesser, but chronic, problem in developed countries.<sup>8</sup>

Human pathogenic microorganisms that are transmitted by water include bacteria, viruses, and protozoa. Most of the microorganisms transmitted by water usually grow in the human intestinal tract and reach the outside through in the feces. Traditionally, the presence of coliform bacteria in drinking water has been seen as an indicator of fecal contamination through cross connection, inadequate treatment, or an inability to maintain a disinfectant residual in the water distribution system.<sup>9</sup> Coliform bacteria are regarded as belonging to the genera *Escherichia*, *Citrobacter*, *Enterobacter*, and *Klebsiella*. Although coliform organisms may not always be directly related to the presence of fecal contamination or pathogens in drinking water, the coliform test is still useful for monitoring microbial quality of treated piped water supplies.<sup>11</sup> Typically, the tests for coliforms come in two formats, a most-probable-number multiple-tube fermentation based on lactose fermentation with production of acid and gas within 48 hours and a membrane filtration method also based on lactose fermentation. If the water sample yields presumptively positive results, confirmation taking an extra 24 to 48 hours of incubation time is required. Fecal coliform

is detected with these same methods, but often by using elevated temperatures and different medium formulations.<sup>1</sup>

The purpose of this study was to evaluate the microbiological quality of treated and untreated water samples from sources and points of consumption of urban and rural communities of the northwest of the state of Paraná, Brazil, supplied by different municipal water systems. Also, to examine the relationship between coliform occurrence and average water temperature, and make a comparison of precipitation data of treated and untreated water. To analyze the seasonal variation in coliform occurrence, data from all three years were combined.

## **METHODS**

Between 1996 and 1999, 3,073 untreated and treated (chlorinated) water samples from 1,594 taps located midway along distribution lines 1,033 reservoirs used to store treated water, 96 spring water and 350 private wells, collected for routine testing, were comparatively studied. All samples were obtained from surrounding communities of the city of Maringá supplied by different municipal water systems. The samples were collected in sterile 250-ml-glass bottles containing 0.2 ml of a sterile sodium thiosulfate solution (10%). They were kept at 4°C and analyzed within 24 hours in the laboratory.

To assess water quality, samples were analyzed for total coliforms (TC) using a multiple-tube fermentation technique based on lactose fermentation with production of acid and gas within 48 hours in a lauryl

**Table 1** - Detection of coliform bacteria in water samples from sources and points of consumption among urban and rural communities.

Water type	Total of samples N	Total coliform N (%)	Contaminated water	
				Fecal coliform N (%)
All	3,073	513 (17)		209 (7)
Treated				
Reservoir	1,033	171 (17)		82 (8)
Taps	1,594	102 (6)		29 (2)
Untreated				
Spring water	96	80 (83)		46 (48)
Private well	350	160 (46)		52 (15)

tryptose broth. If the water sample yielded presumptively positive results, simultaneous inoculation into brilliant green lactose bile broth for total coliforms and EC broth for fecal coliforms (FC) was required. Positive result for EC broth, incubated at 44.5°C for 24 hours, was considered as positive completed test response. Parallel positive brilliant green lactose bile broth with negative EC broth cultures indicated the presence of nonfecal coliforms. The number of coliforms per 100 ml of water was then calculated from the distribution of positive and negative tubes in the test by referring to an appropriate table.<sup>1</sup> Presence of coliform bacteria is an indication that disease-causing bacteria also may be present and that water is unsafe for drinking.

## RESULTS AND DISCUSSION

Testing for evidence of water contamination has been traditionally accomplished by the detection or enumeration of total and fecal coliforms. Coliform bacteria should not be detectable in treated water supplies and, if so, suggest inadequate treatment, inability to maintain a disinfectant residual in the water distribution system, or excessive nutrients.<sup>9,11</sup>

The results of microbiological analyses performed on 3,073 water samples from a wide variety of sources are presented in Table 1. As expected, the highest number of water samples contaminated by TC (83%) and FC (48%) was found in untreated water. The enumeration of TC (17%) and FC (8%) in samples collected from reservoirs used to store treated water was higher than that from taps located midway along distribution lines (6% and 2%, respectively). It was also compared the respective proportions of treated water samples contaminated by TC and FC in residences (16 and 7%) and workplaces (18 and 6%) (Table 2).

Of treated water samples examined, coliform bacteria were found in 171 of 1,033 sampling reservoirs. The occurrence of insufficient treatment or regrowth is suggested by the observation that more than 17% of treated drinking water contained coliform. Water reservoirs of workplaces and residences can be sites

**Table 2** - Proportions of contaminated water in residences and workplaces.

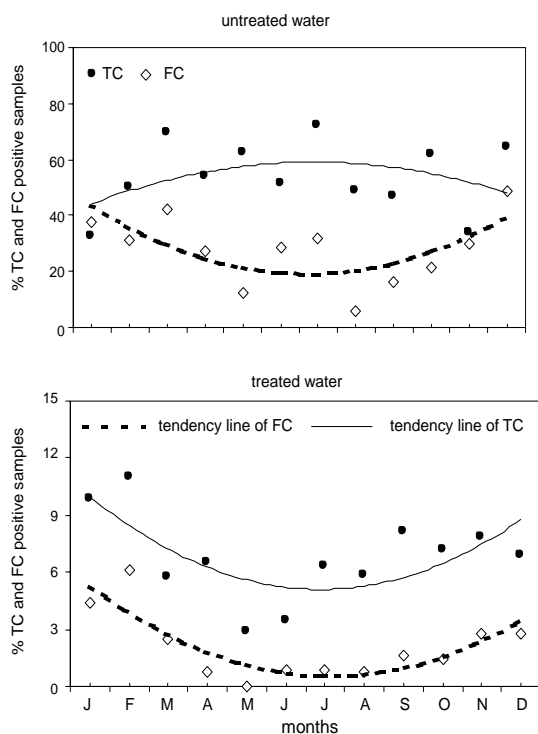
Indicator bacterium	Contaminated water	
	Residences %	Workplaces %
Total coliform	16	18
Fecal coliform	7	6

where water stagnates, disinfectant residuals dissipate, and microbial water quality deteriorates.

The weather in the city of Maringá is classified as CW 'h type (Köppen classification) and is called tropical with two wet seasons (fall, late spring and early summer) and two dry seasons (winter and early spring). The annual rainfall is about 1,582.2 mm. The annual mean temperature is approximately 22°C.<sup>4</sup>

Figure 1 illustrates the average monthly coliform occurrence in untreated and treated water. To analyze the seasonal variation in coliform occurrence, data from all three years were combined. The mean values for both TC and FC positive samples were not associated with any particular month in untreated water, but there was a great variety of distribution patterns. Conversely, TC and FC positive samples appear to be similar and seasonally influenced in treated water, with the highest counts seen during the months of September to March and falling from April through August. Data fell into two clearly defined periods, spring and summer (September through March) when counts increased, and fall and winter period (April through August) when counts decreased.

Figure 2 shows the relationship between coliform-positive samples and average water temperatures and a comparison of the precipitation data of treated and untreated water obtained for routine testing and combined as described above. These results indicate a mixed effect for water temperature and rainfall on coliform occurrences. In treated water, at least two different periods must be considered for the occurrence of both TC and FC positive samples: (i) a warm-weather period (September-March) with high percentage of contaminated samples; and (ii) a cold-weather period (April-August) when they are lower. The number of both TC and FC



**Figure 1** - Seasonal occurrence of total and fecal coliforms positive samples in untreated and treated water. Solid and dashed lines represent tendency lines of total and fecal coliforms, respectively.

positive samples decreased with the decline of water temperature. However, in untreated water, a similar pattern of behavior within the climatic periods was only observed in FC positive samples. The highest number of TC positive samples was found during the months of May to September with a decrease in coliform occurrence when water temperature went from 20 to 25°C. Similar correlation was found between accumulated monthly rainfall and bacteriological parameters.

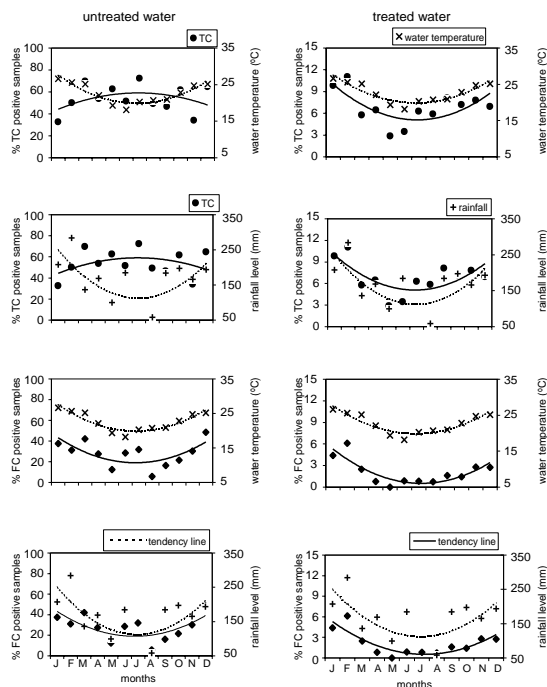
Foregoing studies have reported that water temperature influenced microbial growth rate, lag phase, and cell yield.<sup>5</sup> They have shown that the growth of *Escherichia coli* and *Enterobacter aerogenes* was very slow below 20°C. They have also showed that the lag in the growth phase of *Pseudomonas putida* was within 3 days at 7.5°C but only 10 hours at 17.5°C.

LeChevallier et al<sup>9</sup> (1996) emphasized that the generalization between water temperature and microbial activity can vary somewhat between systems. According to these authors, utilities in cold climates may experience increased microbial activity even at cold water temperature because the microbial populations present in the supply have adapted to growth at low temperature.

Foregoing studies have associated the occurrence

of coliform bacteria in drinking water system with rainfall events.<sup>9,10</sup> According to these authors, rainfall is a complex variable and may have many different impacts on drinking water quality: (i) rainfall can be a mechanism that introduces coliform bacteria into the system through leaks and cross-connections and (ii) rainfall can wash dissolved nutrients into the watershed and increase organic carbon levels.

The present study investigated water quality at sources and points of consumption of urban and rural communities. Most people of such areas use water directly from available sources, without any treatment and therefore are exposed to a variety of water-related diseases. Both spring water and private wells samples obtained for routine testing had high coliform-positive samples. Previous studies have shown that a significant percentage of bacteria of fecal origin found in rural wells originated from animal manure.<sup>3</sup> Furthermore, Gallegos et al<sup>6</sup> (1999) studied the environmental effects of wastewater irrigation of the subsurface at two locations in Mexico. According to these authors, the data obtained showed that: (a) an elevated concentration of fecal and total coliform recorded at both sites indicates that fecal bacteria had been transported through the subsurface, and (b) the level of subsurface contamination was affected



**Figure 2** - Relationship between coliform positive samples and average water temperature and a comparison of the precipitation data of treated and untreated water. Solid and dashed lines represent tendency lines of total or fecal coliforms and water temperature or rainfall level, respectively.

by both spatial and temporal factors with higher coliform concentrations occurring at shallower depths (<10 m below surface) and at the top of the water table, and during the wet season. They have also discussed the potential effects of groundwater degradation on public health and the need for guidelines to protect groundwater quality.

Arnade<sup>2</sup> (1999) tested sixty residential wells in Palm Bay, Florida, for fecal coliform, nitrates, and phosphates, to determine whether season has a significant effect on the correlation between these parameters and the proximity of wells to septic tanks. According to this author, ground water samples collected at all distances from septic tanks during the wet season contained twice as many fecal coliforms and higher concentrations of nitrates and phosphates compared with samples collected during the dry season.

Infectious diseases caused by pathogenic bacteria, viruses, protozoa and other parasites are the most common and widespread health risk associated with drinking water. Those that pose a serious disease risk whenever present in drinking water include *Salmonella* spp., *Shigella* spp., pathogenic *Escherichia coli*, *Vibrio cholerae*, *Yersinia enterocolitica*, *Campylobacter jejuni*, and *Campylobacter coli*, the viruses Adenoviruses, enteroviruses, hepatitis A virus, Norwalk virus, Rotavirus, Small round viruses, and the parasites *Giardia* spp., *Cryptosporidium* spp., *Entamoeba*

*histolytica*, and *Dracunculus medinensis*. According to WHO<sup>11</sup> (1993) waterborne transmission of these pathogens have been confirmed by epidemiological studies and case histories. Part of the demonstration of pathogenicity involves reproducing the disease in suitable hosts. Experimental studies of infectivity provide relative information, but it is doubtful whether the infective doses obtained are relevant to natural infections. In Brazil, little or no information on this subject is available.

The present study investigated water quality at sources and points of consumption of urban and rural communities. Most people of such areas use water directly from available sources, without any treatment and therefore are exposed to a variety of water-related diseases.

A more extensive study would be a prerequisite to determine chemical, physical, and operational factors that influence the occurrence of coliform bacteria either in finished drinking water systems or at sources and points of consumption of rural and peri-urban communities.

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