ON- LINE INSTRUMENTATION SYSTEM AND MONITORING OF MICROBIOLOGICAL QUALITY OF DRINKING WATER FOR URBAN AND RURAL COMMUNITIES

M. Murugan
District Environmental Engineer
TamilNadu Pollution Control Board, Namakkal
Email: mmnkms1959@gmail.com

Abstract

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. 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. 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. 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.

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

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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 (Geldreich, 1991) and (Wiggins, 1996). Diarrhea disease from contaminated water continues to be a serious problem in developing countries and a lesser, but chronic, problem in developed countries (Grant, 1997).

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 (Lechavallier et al., 1996). 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 (World Health Organization, 1993). 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 (APHA, 1995). 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 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 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 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 table1. 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 (Lechavallier et al., 1996) and (World Health Organization, 1993). 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.

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

Water type	Total samples	Contaminated water	
	N	Total coliform N (%)	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)

Table 2. Proportions of contaminated water in residences and workplaces

Indicator Bacterium	Contaminated water	
	Residences (%)	Work places (%)
Total coliform	16	18
Fecal coliform	7	6

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 where water stagnates, disinfectant residuals dissipate, and microbial water quality deteriorates. The weather in the city 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 (Deffune et al., 1994). 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.

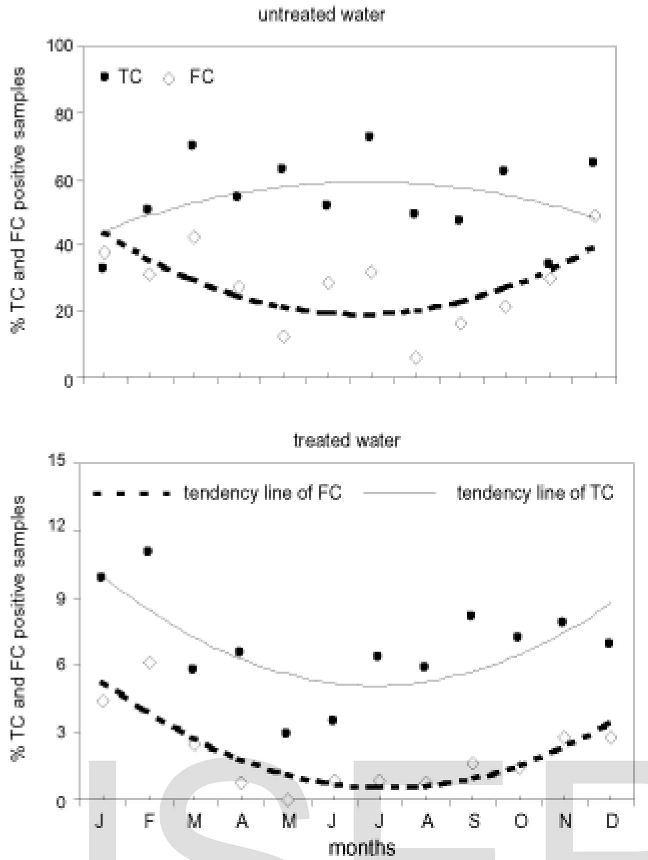

Figure 1 - Seasonal occurrence of total and fecal coliforms positive samples in untreated and treated water. Solid and dashed lines represent tendency lines of total and fecal coliforms, respectively.

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 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 ^{o}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 (Fransolet et al., 1985). They have shown that the growth of *Escherichia coli* and *Enterobacter aerogenes* was very slow below 20 ºC. They have also showed that the lag in the growth phase of *Pseudomonas putida* was within 3 days at 7.5 ^{o}C but only 10 hours at 17.5 ^{o}C (Lechavallier et al., 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.

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 (World Health Organization, 1993) waterborne transmissions 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.

Conclusion

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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