

*Full Length Research Paper*

# Assessment of microbiological quality of drinking water treated with chlorine in the Gwalior city of Madhya Pradesh, India

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The quality of drinking water at the point of delivery to the consumer is crucial in safeguarding consumer's health. The current study was undertaken to assess the changes in residual chlorine content with distance in water distribution system in Gwalior city of Madhya Pradesh and assess its relation with the occurrence of total and faecal coliforms. Water samples were collected from the exit point of the treatment plant and taps at consumer households at an interval of 1 to 2 km. A total of 56 water samples were tested to determine residual chlorine content and presence of total and fecal coliforms using standard methods. Average concentrations of residual chlorine from all sampling location were between 0.08 to 0.98 mg/L. Total coliform was found at most of the sampling locations in the range of 0.82 to 7.15 MPN/100 ml. The fecal coliform at all sampling locations was found in the range of 0 to 4.10 MPN/100 ml. With time, the residual chlorine in the transported water dechlorinates. After covering some distance, the residual chlorine of the water was completely diminished thereby supporting massive microbial growth. The study proposed the likely causes of the transit dechlorination of water and recommended carrying out compulsory chlorination at water sources while maintaining reasonable residuals at the consumers' end to eliminate the bacteriological contamination.

**Key words:** Residual chlorine, total and fecal coliforms, drinking water chlorination, water contamination.

## INTRODUCTION

Water is an indispensable component of the environment. The quality of drinking water has a direct link with the human health and providing clean water to the consumers is one of the most important public health priorities (UNCED, 1992). Drinking water should have high quality

so that it can be consumed without threat of immediate or long term adverse impacts to human health. Good and adequate water supply services are the most critical prerequisite for public health and well-being (Eassa and Mahmood, 2012). Many water resources in developing

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countries are unhealthy because they contain harmful physical, chemical and biological agents (WHO, 2011). To maintain good health, water should be safe to drink and meet the local standards for taste, odor and appearance (Cheesbrough, 2000).

Microbial water quality is one of the most important aspects of drinking water in relation to the diseases caused by the water. Detection of indicator bacteria in drinking water means the presence of pathogenic organisms that are the source of waterborne diseases (Macler and Merkel, 2000). Such diseases can have large scale ramifications for the human health (Egoz et al., 1991; Macler et al., 2000). Microbiological water quality is deteriorating day by day due to unplanned industrialization, urban sprawl, reckless development and faulty water distribution systems (Varale and Varale, 2012). Microbiological contamination of such kinds has been reported worldwide (Dowidar et al., 1990; Mroz et al., 1994; Appleyard, 1996; Zacheus et al., 2001).

Over large parts of the world, humans drink untreated water that contains pathogens or unacceptable levels of dissolved and suspended pollutants (Hashmi et al., 2009). Such polluted water is not suitable for drinking because it may cause widespread acute and chronic diseases resulting in large number of deaths in many developing countries like India. Over 100 million people do not have access to an adequate supply of safe water for household consumption while 300 millions lack proper sanitary means for excreta disposal (Bern et al., 1992). In 2004, 1.1 billion people were lacking access to improved water sources, which is nearly 17% of the world's population (UNCED, 2012). According to WHO, every year 1.8 million people die from diarrheal diseases including cholera. 88% of the diarrheal disease is attributed to the contaminated water supply and inadequate sanitation (WHO, 2011). Over 1.3 million people die of malaria every year and there are 1.5 million cases of hepatitis-A each year (WHO, 2004).

Microbiological examination of the drinking water mainly covers detection of coliforms and total bacterial count. Coliforms are common bacteria that exist in the intestines of human beings and mammals, and excreted out in the dejection. If large quantities of coliforms are present in the water, it is a prominent indicator of possible contamination caused by dejection of human beings or mammals (Haydar et al., 2009). In developed countries, it is often regulated that coliforms must be undetectable in drinking water (Uriu-Hare et al., 1995). Coliforms detection helps to determine whether the water is well disinfected or polluted by foreign substances, in order to ensure the safety of drinking water for people (Payment, 1999). The presence of coliform organisms indicates the biological contamination of drinking water (Khan et al., 2012). Too high total bacterial count means that the water is not perfectly disinfected and the water has already been polluted by microbes (Batterman et al.,

2000).

Chlorination is practiced at the most of filtration plants as a mean of water disinfection, and it is supplied to the public via distribution network (WHO, 2003). As a result of low cost and effectiveness of chlorine against pathogenic microorganisms, it is a chemical of choice in many countries including India (Lienyao et al. 2004). It is added to drinking water to disinfect pathogenic micro-organisms. Chlorine residuals of drinking water have long been recognized as an excellent indicator for studying water quality in the distribution network (Lienyao et al., 2004). The presence of any disinfectant residue reduces the microorganism level and frequency of occurrence at the consumer's taps (Olivieri et al., 1986). Addition of chlorine in different water treatment plant is a common practice, but it is not sufficient to ensure the safety of water. The maintenance of chlorine residue is needed at all points in the distribution system supplied with chlorine as disinfectant (Kitazawa, 2006).

The current study was carried out to determine the levels of residual chlorine in treated drinking water, as it is transported to different locations through pipelines from water treatment plant and its relation to the occurrence of total and faecal coliforms at Gwalior city of Madhya Pradesh.

## MATERIALS AND METHODS

### Study area

The present study was carried out in the Gwalior city, which is a historical city of the state of Madhya Pradesh, India. The present population of the city is about nine lacs and it is expected to increase to 14.40 lacs by the year 2024. Gwalior city has two Water Treatment Plants (Old and New) located at Motijheel built in 1930 and 1986, respectively. These plants have undergone expansions from time to time in conjunction with the development of the city to meet the growing water demand. These plants provide potable drinking water to the major portion of the city through an extensive network of underground pipes. In these circumstances there is always a possibility of the microbiological contamination of the drinking water due to the seepage and intrusion from the adjacent underground sewers.

### Sample collection and analysis

Water samples were collected from treatment plants and consumer ends at a regular interval of 1 to 2 km (APHA, 2005; Collins and Lyne, 1985). Standard analytical methods for the enumeration of microbiological parameters of water were used as prescribed by the American Public Health Association series of Standard Methods of Examination of Water and Effluent (APHA, 2005). The total coliform and faecal coliform counts were determined by multiple tube fermentation technique. For the enumeration of total coliforms, lauryl tryptose broth (LTB) was used for the presumptive test and brilliant green lactose broth (BGLB) for confirmation and for the enumeration of faecal coliforms, EC medium was used. Results were expressed in terms of most probable number (MPN). Residual chlorine was determined by DPD (N, N-diethyl-p-phenylene

**Table 1.** Average values of Residual chlorine, total coliform and faecal coliform of water samples collected from different sites.

Name of the Site	Distance from filtration plant (km)	Residual chlorine (mg/L)	Total coliforms (MPN/100 ml)	Faecal coliforms (MPN/100 ml)
Filtration plant (after treatment)	0	1.30±0.25	0	0
Anand Nagar	2	0.98±0.13	0.82±0.54	0
Kishan Bagh	4	0.72±0.10	1.1±0.0	0
Vinay Nagar	5.5	0.65±0.13	2.22±0.75	0
Lashkar	7	0.47±0.10	4.10±1.00	1.20±1.07
Kampoo	9	0.36±0.10	3.60±1.15	1.48±0.75
Badha	11	0.27±0.09	4.6±0.0	2.22±0.75
Sikandar Kampoo	12.5	0.21±0.10	4.6±0.0	2.72±1.44
Govindpuri	15	0.15±0.06	5.45±1.70	3.10±1.00
Thatipur	17	0.12±0.05	7.15±1.70	3.60±1.15
Morar	19	0.08±0.01	7.15±1.70	4.10±1.00

diamine) ferrous titrimetric method (APHA, 2005).

#### Statistical analysis

The samples were analyzed and results were subjected to data analysis using the *MSTATC*<sup>®</sup> application after suitable transformation. The results were expressed as mean ± SD.

## RESULTS AND DISCUSSION

The summary of the values of residual chlorine, total coliform and faecal coliform of water samples collected from different locations are presented at Table 1.

Residual chlorine concentration of the water samples at most of the sampling locations ranged from 0.08±0.01 to 0.98±0.13 mg/L. The maximum residual chlorine concentration was recorded at Anand Nagar with a value of 0.98 mg/L and minimum value of 0.08 mg/L was observed at Morar. The level of residual chlorine in drinking water just leaving the filtration plant was 1.30±0.25 mg/L. Residual chlorine showed sharp decline with increase in distance of sampling locations from filtration plant (Figure 1).

Total coliform was found positive at most of the sampling locations. Total coliform count at most sampling locations were ranged from 0.82±0.54 to 7.15±1.70 MPN/100 ml. Highest count of total coliform was recorded at Morar with 7.15 MPN/100 ml and lowest count was found at Anand Nagar with a value of 0.82 MPN/100 ml. Total coliform count showed an increasing trend from filtration plant towards end users. Faecal coliform was found absent at locations just close to filtration plant. Faecal coliform count of water samples collected from different sampling locations situated at varying distances from filtration plant were ranged from 0 to 4.10±1.00 MPN/100 ml. The highest count of 4.10 MPN/100 ml was recorded at Morar situated at a distance of 19 km from

filtration plant. These results are not in agreement with the WHO bacteriological water quality standards for treated water entering the distribution system, which recommends a standard of 0 MPN/100 ml for total and faecal coliform bacteria (WHO, 2003). In drinking water just leaving filtration plant, faecal coliform count was 0 MPN/100 ml. It was found that sampling locations situated close to filtration plant were having less coliform count. This might be attributed to presence of sufficient residual chlorine at location which results in effective disinfection of microbes present there (Lahlou, 2002). Both total coliform as well as faecal coliform counts showed an increasing trend with decrease in residual chlorine in the water samples at sampling locations (Figure 2).

Application of chlorine is essential to ensure the safety property of drinking water. When the concentration of chlorine in water is about 2 to 3 mg/L, people can smell an irritant odor. In consideration of the feeling of most people and the disinfection efficiency of residual dosage, WHO (2006) recommend the residual chlorine level of 0.6 to 1.0 mg/L as standard. When compared with WHO standards residual chlorine concentration of most of the sampling locations was found below 0.6 mg/L. Concentration below 0.6 mg/L is inadequate for disinfection and this might result in pathogenic bacterial growth in the distribution system (Olivieri et al., 1986). The current study showed that there is a gradual decrease in the residual chlorine as the water moves in the distribution system. The probable reason is that the chlorine in the distribution system is subjected to degradation due to its unstable and photosensitive nature paving the way for the microbiological growth and subsequent reduction of the quality of the drinking water (WHO, 2011).

Total coliform and faecal coliform count in drinking water was found varying considerably with residual chlorine concentration present in water. Due to low

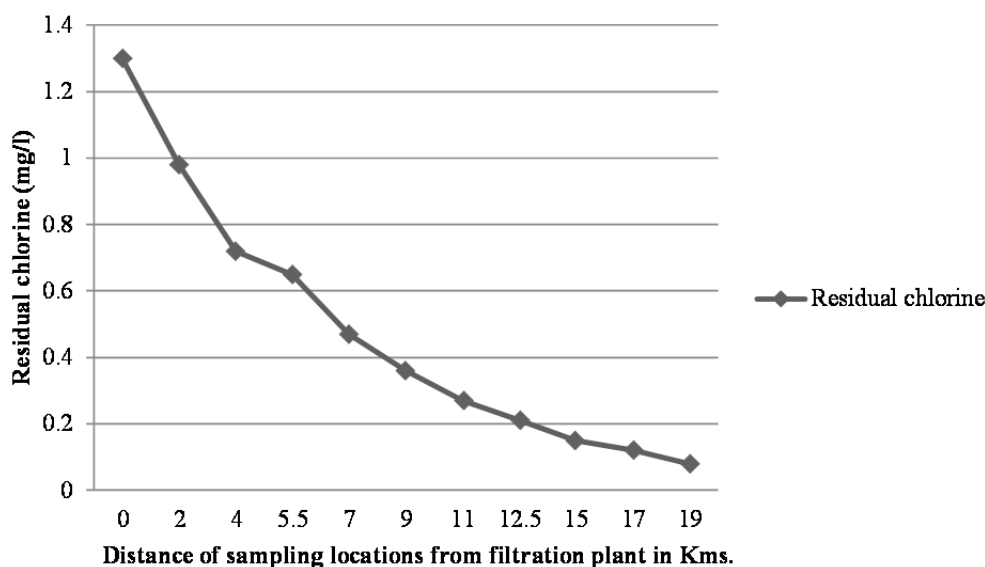


Figure 1. Decrease of residual chlorine with distance.

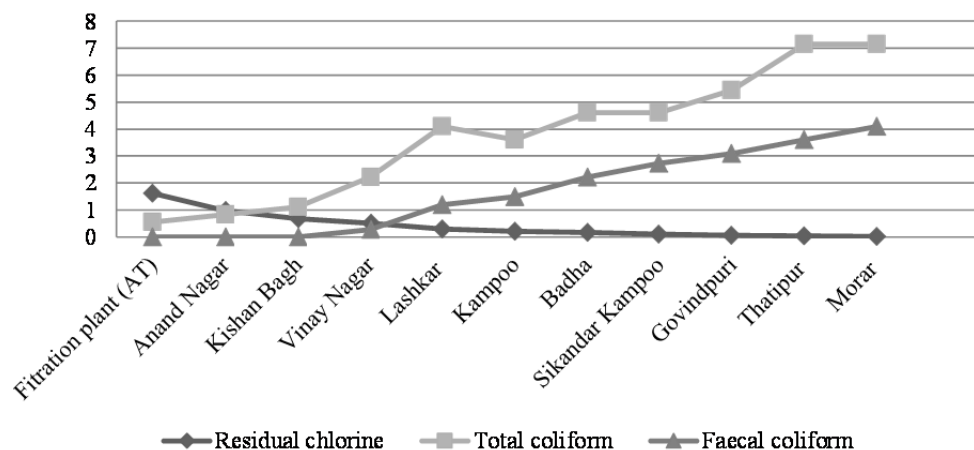


Figure 2. Relation of total coliform, faecal coliform count with residual chlorine recorded at different sampling locations.

concentration of residual chlorine at many sampling locations, coliform bacteria counts were recorded to be very high. These findings draw its support from the study conducted by Egorov et al. (2002) in Cherepovets, Russia, who found that a decline in residual chlorine concentration in the distribution system resulted in microbiological contamination that can culminate into gastrointestinal illness. Similar results were also reported by Cardenas et al. (1993) who enunciated that the people in Colombia drinking un-chlorinated water were at increased risk of contracting cholera and diarrhoea. The other probable reason may be the intrusion of the contaminated water from the surroundings into the water

distribution system through the fissures and the cracks. Owing to the underground nature of the distribution pipes, there is little or zero maintenance, a fact that presents a potential health hazard to the water consumers (Mendels, 1998). The rise in the microbiological population of water between the treatment points to the consumer point signifies that there is a drastic contamination between the treatment point and consumer point that can culminate in the outbreak of various water borne diseases.

In present study, water distribution systems were not capable of maintaining adequate residual chlorine in water distribution network to ensure safe drinking water towards end users. Water quality decay in the distribution

network can be caused by properties of pipeline materials, hydraulic conditions, biofilm thickness, excessive network leakages, corrosion of parts, and intermittent service (Lee and Schwab, 2005). The need of the hour is to carry out the regular surveillance and maintenance of water distribution systems in order to reduce breakage of pipelines and intrusion of the contaminated water into the distribution system. Interruption in the water supply should be minimized. Prescribed residual chlorine level should be maintained in the distribution system to check the growth of the microorganism to alleviate their potential health hazard.

### Conclusion

The present study enunciated that monitoring of water quality is essential to ensure adequate free residual chlorine at the consumer end. Residual chlorine level of the water supply for public use decreases with distance owing to the unstable and photo-sensitive nature of the chlorine. It can be concluded that treatment applied to water at the filtration plant in the locality is not enough to absolutely eradicate microorganisms. Moreover, the microbial population rises with relative increase in distance from filtration plant reducing the quality of the drinking water for human consumption. The result of this study will help government and allied agencies to take appropriate action with regard to chlorination practices and the maintenance of the distribution systems to alleviate the negative consequences of using the water having ample microorganism growth.

### Conflict of Interest

The author(s) did not declare any conflict of interest.

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