Assessment of Chlorination Efficiency and Quality of Municipal Drinking Water in Gwalior City, Madhya Pradesh, India

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Abstract: ***The quality of drinking water at the point of delivery to the consumer is crucial in safeguarding people's health. This study was carried out to study effectiveness of chlorination throughout drinking water distribution system and quality of water supplied to households in Gwalior city. Water samples were collected from 10 sampling points within the city. The collected water samples were subjected to physicochemical and microbiological analysis by using standard methods and values recorded were compared with World Health Organization (WHO) guidelines for drinking water. The results of the study demonstrated that physicochemical and bacteriological quality of water just leaving water treatment plant was satisfactory. In the distribution system, physicochemical quality of water was satisfactory while most of the samples contained bacteriological contamination and residual chlorine concentration in distribution system was decreasing considerably with increase in distance from water treatment plant. Average concentration of residual chlorine from all sampling location was 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/100ml. Diarrhoea was most the prevalent health problem in the study area as reported by 33% of households followed by Typhoid (21.5%). Among the methods of treatment, 32% of households were using boiling, 18% aqua guard and 16.5% alum for treatment of tap water before drinking it. Possible causes of contamination were leaking of water mains and cross connections between water mains and sewers due to close proximity. It is recommended to carry out compulsory chlorination at water sources while maintaining reasonable chlorine residuals at the consumer end to eliminate the bacteriological contamination.***

Keywords: Drinking water, Residual chlorine, Water treatment plant, Quality analysis, Questionnaire survey

1. Introduction

Water is one of the most vital components of all natural resources known on earth. It is important to all living organisms, most ecological systems, human health, food production and economic development (Postel *et al.,* 1996*)*. World Health Organization (WHO) states that domestic water consumption of 30-35 liters per capita per day is the minimum requirement for maintaining good health (Cleave, 1998). The safety of drinking water is prime concern within the global village. Drinking water should have high quality so that it can be consumed without threat of immediate or long term adverse impacts to health. Such water is commonly called as "potable water". Water availability is equally important as water quality. Good and adequate water supply services are essential for public health and well being. Many water resources in developing countries are unhealthy because they contain harmful physical, chemical and biological agents (Cheesbrough, 2000). To maintain good health, however water should be safe to drink and meet the local standards.

The safe drinking water is defined by WHO as that water having acceptable quality in terms of its physical, chemical and bacteriological parameters. The safe water is that which is free from pathogenic microbes, hazardous chemicals/substance and aesthetically acceptable (i.e. pleasing to sight, odourless and good taste). It is important that this type of water should not only be available, but also be available in enough quantity all the time (Park, 2005). The decline in availability of water supplies is one of the most important environmental issues faced by various countries at the present time. It has been estimated that nearly two-third of nation's world-wide will experience water stress by year 2025 (UNEP, 2002).

In India, chlorination is practiced at most of the filtration plant as means of water disinfection, and it is supplied to the public via distribution network. Chlorine due to its low cost and effectiveness is a chemical of choice in many countries including India. It is added to drinking water to disinfect pathogenic microorganisms. 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 residual reduces the microorganism level and frequency of occurrence at the consumer's tap (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).

India in 1981 launched the decade programme to supply safe drinking water through 100% coverage of urban and rural areas by piped water supply. To achieve the goals, conservation of water and preservation of water quality in water supply systems assume prime significance. The elements of surveillance include water quality surveillance, study of institutional setup and examination of water for physicochemical and bacteriological parameters. This include assessment of availability of water resources, appropriate treatment, safe storage and equitable safe distribution of water, the examination of water quality at the beneficiary points periodically and study of institutional and financial set-up. Systematic periodic monitoring of microbiological quality of drinking water supplies helps to

identify failures and initiate actions. Keeping in view of health, physicochemical and microbial analysis of packaged water brand of Gwalior city has carried out (Rather and Sharma et al, 2013). Some of these parameters constitute a risk to human health, others affect the aesthetic quality of the water supplied and others relate to treatment issues (Ratnayaka *et al.*, 2009).
Considering the deteriorating quality of drinking water in Gwalior city, present study was carried out. In the present investigation, water quality of treatment plants and consumer ends was monitored to assess the drinking water quality status. This study was an attempt to judge the water quality changes from the source to consumer, which may be useful in deciding appropriate remedial measures for preventing drinking water from contamination and help in safe drinking water supply to consumers.

2. Materials and Methods

2.1. Study Area

Gwalior is situated in the north of the state of Madhya Pradesh, in the Indo- Gangetic plains. The city has municipal area of approx. 173.65 Sq. km. and is administered by dividing the city into 60 municipal wards. It is also known as one of the eminent tourist destination in India. The city of Gwalior is located at 26° 12′ 12.50" N 78° 18′ 58.76" E and has an average elevation of 212 meters. The city consists of three distinct urban areas; Old Gwalior in the north, Lashkar about 3 km to the southwest, and Morar towards the east.

The water supply system in Gwalior is mainly dependent on the Tighra-Kaketo system and ground water augments this supply. The supplies from Tighra dam located on the Sank River are supplemented by supply from another reservoir of the Kaketo dam on Narver River. In all, 190 MLD of water is reserved for drinking water supplies to Gwalior. Water is supplied from the dam to the two WTPs (old and new) at Motijheel, through two pipelines (17 Km long and diameter 1200 mm).

2.2. Sampling

In present study, the methods of sampling used were combination of random and purposive sampling. Water samples were collected from the households located at different distance from water treatment plant after the sterilization of house taps. Water samples were also collected from Motijheel WTP (before and after treatment). These samples were collected in sterilized glass bottles (500 ml), labeled properly with date and name of the location. All these bottles were closed carefully and transported to the laboratory in an ice box kept at 4^{o}C, and processed within 6 hours for and microbiological and physicochemical analysis.

2.3. Physico-chemical analysis

Physical parameters analyzed were temperature, turbidity, pH, TDS etc. and chemical parameters comprised of electrical conductivity, total hardness, total alkalinity, chloride, fluoride and residual chlorine. Residual chlorine was determined by DPD ferrous titrimetric method. Methods employed for analysis of physico-chemical parameters were in accordance with APHA (1992) and Gupta (2001).

2.4. Microbiological analysis

Microbiological parameters analyzed were total coliform and faecal coliform. The total coliform and faecal coliform counts were determined by multiple tube fermentation technique. For enumeration of total coliforms lauryle tryptose broth (LTB) was used for the presumptive test and brilliant green lactose broth for confirmation and for enumeration of faecal coliforms EC medium was used. Results were expressed in terms of most probable number (MPN). Standard methods were followed in collecting, handling, preserving, and analyzing samples for the above mentioned parameters (APHA, 1992).

2.5. Questionnaire survey for evaluation of drinking water quality and associated health problems

The field survey approach was also used to carry out present study. The selection of households in the study area was based on random sampling. At least 20 households were interviewed from each sampling locations (Total 200 households from 10 sampling locations). The respondents were interviewed during early morning and evening hours and observations were recorded on the spot. The respondents were given a brief orientation on the nature and purpose of the study. Questionnaire survey was carried out to analyze the present situations of school drinking water quality, equipment, and health problems related with it.

3. Results and Discussion

The measured value of different physical and chemical water quality parameters of the collected water samples is summarized in Table 1. Findings of the study have been assessed according to WHO drinking water quality guidelines and BIS as well.

Table 1: Physico-chemical and microbiological parameters of water samples collected from different sites.

Name of the Site	Temperature (°C)	pH	Turbidity (NTU)	TDS (mg/l)	Total hardness (mg/l)	BOD (mg/l)	Nitrate (mg/l)	Fluoride (mg/l)	Residual chlorine (mg/l)	Total coliforms (MPN/100ml)	Faecal coliforms (MPN/100 ml)
Motijheel WTP (After treatment)	26.50±0.58	7.25±0.30	2.16±0.87	330.50±24.69	85.61±3.57	2.09±1.18	2.85±0.88	0.28±0.07	1.30±0.25	0.0	0.0

Anand Nagar	28.00±0.82	7.42±0.30	2.28±0.66	472.50±17.18	53.73±6.72	2.50±0.55	3.45±0.69	0.31±0.08	0.98±0.13	0.82±0.54	0.0
Kishan Bagh	27.25±2.06	7.28±0.15	2.39±0.69	482.00±68.23	74.25±1.76	2.87±0.80	3.68±0.85	0.42±0.06	0.72±0.10	1.1±0.0	0.0
Vinay Nagar	27.50±1.29	7.05±0.24	2.78±0.45	459.75±17.17	66.33±1.43	2.41±0.53	4.97±0.80	0.39±0.10	0.65±0.13	2.22±0.75	0.0
Lashkar	27.75±0.50	7.00±0.18	2.96±0.35	561.50±22.66	129.00±2.57	2.61±0.54	5.55±0.66	0.50±0.08	0.47±0.10	4.10±1.00	1.20±1.07
Kampoo	31.00±1.41	8.20±0.14	3.68±0.69	479.00±38.04	134.08±4.55	2.64±0.38	3.49±0.73	0.47±0.04	0.36±0.10	3.60±1.15	1.48±0.75
Bada	27.50±0.58	7.55±0.52	3.22±0.33	462.26±33.64	143.16±4.41	2.70±0.40	3.87±1.06	0.35±0.11	0.27±0.09	4.6±0.0	2.22±0.75
Sikandar Kampoo	30.50±2.38	7.95±0.44	3.78±0.64	466.50±36.00	118.70±2.48	2.82±0.51	3.43±0.71	0.37±0.06	0.21±0.10	4.6±0.0	2.72±1.44
Govindpuri	29.00±0.82	7.30±0.64	4.14±0.83	421.75±9.43	107.74±2.11	4.00±1.22	3.14±0.38	0.36±0.06	0.15±0.06	5.45±1.70	3.10±1.00
Thatipur	28.25±2.63	7.32±0.7	4.20±0.80	391.50±54.36	94.30±2.08	3.06±0.91	4.57±1.30	0.30±0.08	0.12±0.05	7.15±1.70	3.60±1.15
Morar	29.00±2.83	7.33±0.17	4.38±0.65	482.25±38.91	88.52±2.22	4.11±1.46	4.00±0.92	0.44±0.07	0.08±0.01	7.15±1.70	4.10±1.00
Motijheel WTP (Before treatment)	32.50±0.58	6.60±0.14	8.21±1.82	946.95±106.63	166.79±3.77	7.18±0.59	9.09±1.53	0.72±0.12	0.0	8.0±0.0	7.15±1.70
WHO permissible limits	--	6.5-8.5	5.0	500.0	500.0	6.0	50.0	1.5	0.6-1.0	0.0	0.0

3.1. Water quality characteristics

Temperature

Temperature of water samples from all sampling locations ranged from 27.25±2.06 to 31.00±1.41°C. Highest value of temperature was observed in water samples of Kampoo (31.00°C) and lowest value was observed in water samples of Kishan Bagh (27.25°C). The value of temperature recorded in the water samples before treatment at Motijheel WTP was 32.50±0.58°C and after treatment the value of the temperature recorded was 26.50±0.58°C. Whereas WHO has not recommended any definite temperature value for drinking water. A temperature of about 40°C is permissible limit for drinking water (BIS, 1991). Knowledge of water temperature is important because temperature is a critical factor in determining the growth of the microorganisms (Ramteke et al., 1992). Temperature also affects the solubility of oxygen in water.

pH

The average pH values of water samples taken from different sampling locations ranged from 7.00±0.18 to 8.20±0.14. A maximum pH of 8.20 was observed at Kampoo and a minimum pH of 7.00 was recorded at Lashkar. Value of pH was 6.60±0.14 at Motijheel WTP before treatment and 7.25±0.30 after treatment. pH of water samples from all sampling locations ranges from neutral to slightly alkaline and was found well within WHO limits of 6.5 to 8.5. Similar results were obtained by Roohul-Amin *et al.*, (2012) in urban parts Peshawar Pakistan. However higher values of pH hasten the scale formation in water heater and reduce the germicidal potential of Chlorine (Gard *et al.*, 2007). pH of the water samples analyzed before treatment process at Motijheel treatment plant was found slightly acidic. The pH of treated water is an important factor for chlorination efficiency (Boyacioglu, 2007). It is one of the important parameter in determining the corrosivity of water because generally the lower pH results in higher level of corrosion (WHO, 1996).

Turbidity

Turbidity of most of the water samples was below 5 NTU. But few samples possess higher values. Levels of Turbidity in all water samples collected from different locations ranged from 2.28±0.66 to 4.38±0.65 NTU. Similar results were also reported earlier in a study conducted by the National Water Quality Program, PCRWR, (2005) which revealed that the turbidity ranges from 1.10 to 4.40 NTU. Turbidity was recorded maximum at Morar with a value of 8.21 NTU and minimum value of 2.16 NTU at Anand Nagar. Turbidity was recorded 8.21±1.82 mg/l at Motijheel WTP before treatment and 2.16±0.87 mg/l after treatment. Turbidity of water samples collected from various sampling locations was well within WHO limit of 5 NTU. It is suggested that turbidity more than 1 NTU will influence the disinfection efficiency; turbidity more than 5 NTU can be identified by the naked eye and is often complained by the users. Maximum levels of Turbidity can provide shelter for opportunistic microorganisms and pathogens (Aulicino and Pastoni, 2004). Turbidity shows increase from Motijheel WTP towards end users with respect to distance from treatment plant. This can be attributed to accumulation of more suspended particles in water towards end users through faulty joints in pipelines.

TDS

Evaluation of TDS of water samples collected from different locations ranged from 391.50±54.36 to 482.25±38.91 mg/l. Maximum value of 482.25 mg/l was found at Thatipur and minimum value of 391.50 mg/l was recorded at Morar.

Concentration of TDS was 946.95±106.63 mg/l at Motijheel WTP before treatment and 330.50±24.69 mg/l after treatment. This showed that coagulation method employed at Motijheel WTP was effective in coagulating the dissolved materials in water. Water which has TDS level less than 500 mg/l is regarded as good, while water having TDS more than 1000 mg/l is unacceptable for human consumption (WHO, 2006). High TDS may result in offensive odors, tastes, colors, and health problems depending on the specific contaminant(s) present (Jenson et al., 2007). TDS of all water samples from all locations were within WHO and BIS standards. US-EPA (1978) recommends treatment when TDS concentrations exceed 500 mg/l or 500 ppm.

Total hardness

The range of total hardness of water samples collected from different sampling locations was 53.73±6.72 to 143.16±4.41 mg/l. Maximum value of total hardness level was found at Badha (143.16 mg/l) and minimum level was recorded at Anand Nagar (53.73 mg/l). Level of total hardness before and after treatment at Motijheel WTP was 166.79±3.77 mg/l and 85.61±3.57 mg/l respectively. Total hardness of drinking water at all sampling locations was within WHO guideline value of 500 mg/l. As a matter of fact, this guideline value is not proposed on the basis of health. Consumers can tolerate water hardness in excess of 500 mg/l. Hardness above 500 mg/l needs excess use of soap to achieve cleaning and results in scaling of pipelines and water boilers. A thorough look at the results revealed that water was soft to moderately hard at all sampling location. The total hardness of water is mainly caused by dissolved calcium and magnesium salts from the surrounding ores (Lin *et al.,* 1996). The hardness will influence the taste of water, but the taste threshold differs from person to person. If the total hardness is too low, the water may accelerate the pipe erosion; when the total hardness is too high (higher than 200 mg/l), boiler scale and water scale are formed in the heating process (Yisa and Jimoh, 2010).

Biological oxygen demand (BOD)

BOD values examined in water samples collected from different sampling locations ranged from 2.41±0.53 to 4.11±1.46 mg/l. Maximum concentration of BOD was recorded from Morar (4.11 mg/l) and minimum concentration was found at Vinay Nagar (2.41 mg/l). Levels of BOD before and after treatment at Motijheel WTP were 7.18±0.59 mg/l and 2.09±1.18 mg/l respectively. BOD at all sampling locations was well within permissible limit of 6 mg/l of WHO. The findings are similar with those of Kataria *et al.,* (2008). Water samples collected just from the outlet of Motijheel WTP possess less BOD. Therefore, high BOD concentration in the distribution system towards end users might be due to cross-contamination through leaking pipes, unauthorized connection and improper domestic storage facilities.

Nitrate

Nitrate values observed in water samples collected from various sampling locations ranged from 3.14±0.38 to 5.55±0.66 mg/l. Maximum level of nitrate was recorded from Lashkar (5.55 mg/l) and minimum concentration was found at Govindpuri (3.14mg/l). Levels of nitrate before and after treatment at Motijheel WTP were found to be 9.09±1.53 mg/l and 2.85±0.88 mg/l respectively. Nitrate levels of samples collected from different sites were well with WHO permissible limit of 50mg/l. Nitrate concentrations may be encountered in water impacted by intensive fertilizer application, or septic effluents. This can lead to serious water contamination. Nitrate has been implicated in methaemoglobinaemia and also a number of currently inconclusive health outcomes. These include proposed effects such as cancer (via the bacterial production of *N*-nitroso compounds), hypertension, increased infant mortality, birth defects, diabetes, spontaneous abortions, respiratory tract infections and alterations to the immune system (Gupta *et al*., 2000).

Fluoride

Evaluation of fluoride of water samples from different sampling locations ranged 0.30±0.08 to 0.47±0.04 mg/l. Maximum value of 0.47 mg/l was found at Kampoo and minimum value of 0.30 mg/l was recorded at Thatipur. Concentration of fluoride was 0.72±0.12 mg/l at Motijheel WTP before treatment and 0.28±0.07 after treatment. fluoride concentrations at all sampling location were well below WHO standard (1.5 mg/l). F^- has a significant mitigating effect against dental cares if the concentration is approximately 1 mg/l (Soticha *et al.,* 2014). However, continuing consumption of higher concentrations of 4mg/l or more can cause dental fluorosis and in extreme cases even skeletal fluorosis (Dissanayake, 1991).

Residual chlorine

Concentration of residual chlorine of most of the water samples from all sampling locations was below 0.6 mg/l. But few samples possess higher values. Levels of residual chlorine in all water samples collected from different locations ranged from 0.08±0.01 to 0.98±0.13 mg/l. findings have also been reported by Olivieri *et al.,* (1986) & Hashmi *et al.,* 2009) who found residual chlorine in the range of 0.1 to 1.0 mg/l in drinking water distribution system. The maximum residual chlorine 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. Level of residual chlorine was absent at Motijheel WTP before treatment and 1.30±0.25 mg/l after treatment. Residual chlorine shows sharp decrease with the increase in distance of sampling locations from Motijheel WTP (Fig 1). WHO (2006) had recommend that the residual chlorine of 0.6–1.0 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). Total coliform count in drinking water was found varying considerably with residual chlorine concentration present in water (Fig. 2). Due to low concentration of residual chlorine in many sampling locations, coliform bacteria counts were recorded to be very high. And at these sampling locations health problems were prevalent as indicated by questionnaire survey. These findings are in line with 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 gastrointestinal illness. In another study, Cardenas *et al.*, (1993) reported that people in Colombia drinking un-chlorinated water were at increased risk of contracting cholera and diarrhoea.

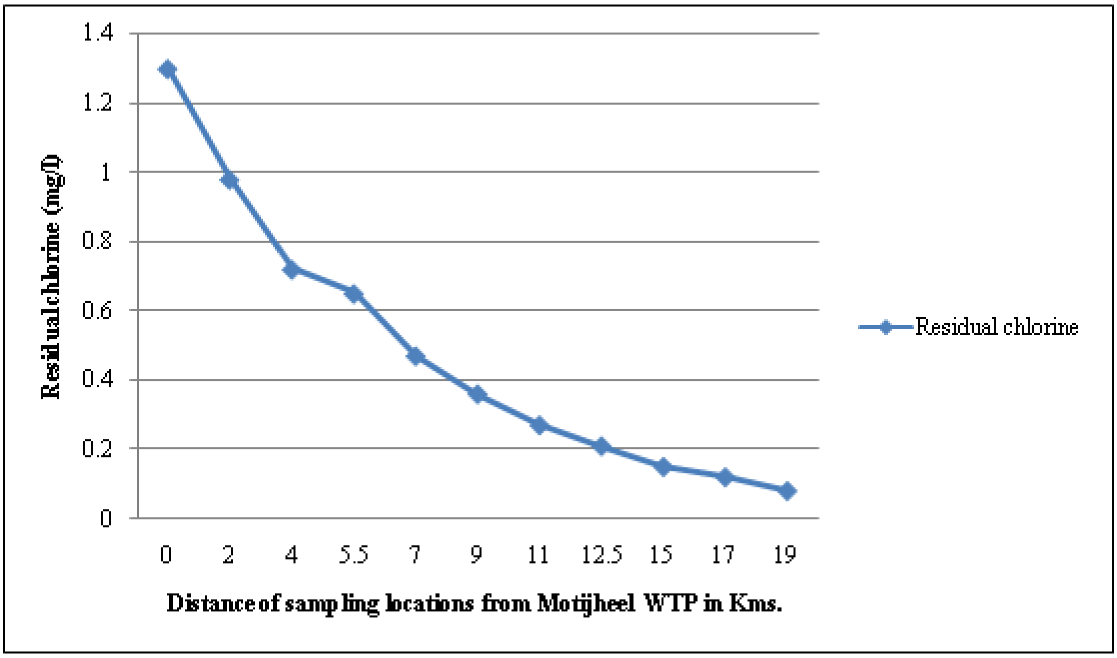

Figure 1: Decrease of residual chlorine with distance.

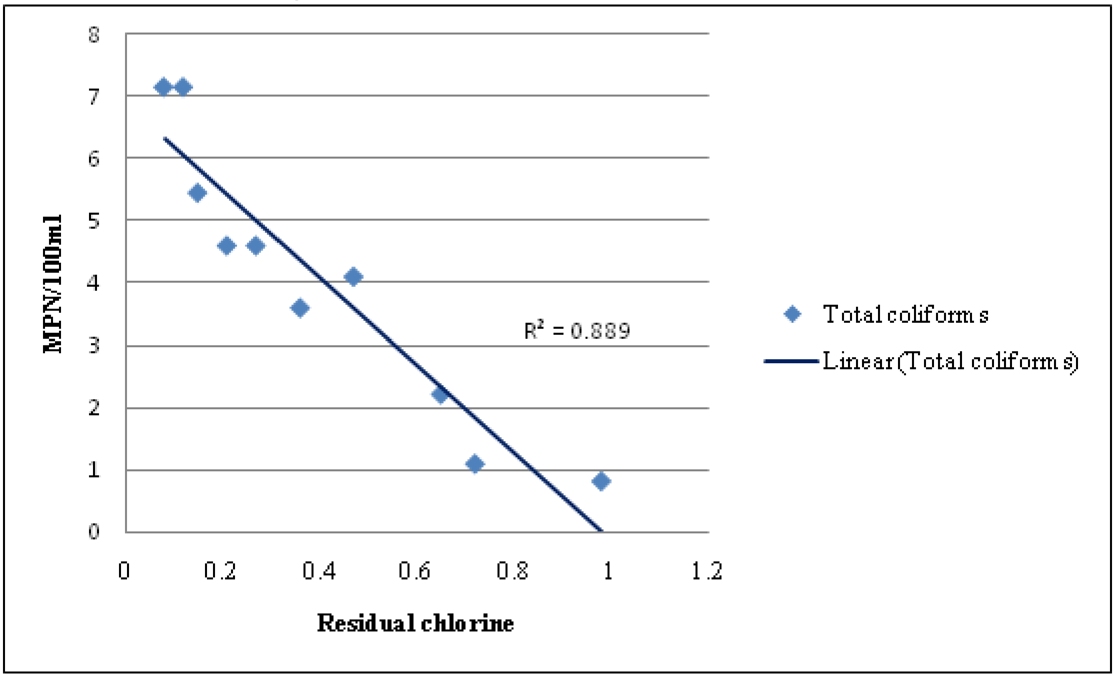

Figure 2: Relationship between total coliforms and residual chlorine.

Total and Faecal Coliform Analysis

Total coliform was found positive at most of the sampling locations. Total coliform count of all sampling locations ranged from 0.82±0.54 to 7.15±1.70 MPN/100ml. Highest count of total coliform was recorded at Morar with 7.15 MPN/100ml and lowest count was found at Anand Nagar with a value of 0.82 MPN/100ml. Total coliform count showed increased trend from Motijheel WTP towards end users. Evaluation of results showed a close positive correlation between total coliform count and turbidity value. Sampling locations with high turbidity were having high total coliform counts. Faecal coliform was found absent at locations just close to Motijheel WTP. Faecal coliform count of water samples collected from different sampling locations situated at different distances from Motijheel WTP ranges from 0 to 4.10±1.00 MPN/100ml. Highest count of 4.10 MPN/100ml was recorded at Morar situated at a distance of 15 km from Motijheel WTP. These results are not in confirmation to the WHO bacteriological water quality standards of treated water entering the distribution system, which recommends a standard of 0/100mL for total and faecal coliform bacteria (WHO 2003). At Motijheel treatment plant faecal coliform count was 7.15±1.70 MPN/100ml before treatment of raw water and after treatment the recorded value was 0 MPN/100ml. It was found that sampling locations situated close to Motijheel WTP 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. 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 3).

The presence of coliform organisms indicates the biological contamination of drinking water (LeChevallier *et al.*, 1991 & Khan *et al.*, 2012). Total and faecal coliform counts were very high at Govindpuri, Thatipur and Morar where residual chlorine was very low or almost absent. These findings are in compliance with the study conducted by Jiwa *et al.*, (1991) who assessed the bacteriological quality of potable water supply of the Morogoro municipality and determined fecal coliform by the MPN method. Hence, the water distribution systems were not capable of maintaining high water quality from the water treatment facilities to the end-user. Similarly studies were conducted by Hamida *et al.*, (2006) in Peshawar Pakistan. 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). Sampling locations with high turbidity were having high total coliform counts (Fig. 4). Correlation between various physico-chemical and microbial parameters analyzed during present study is shown in (Table 2).

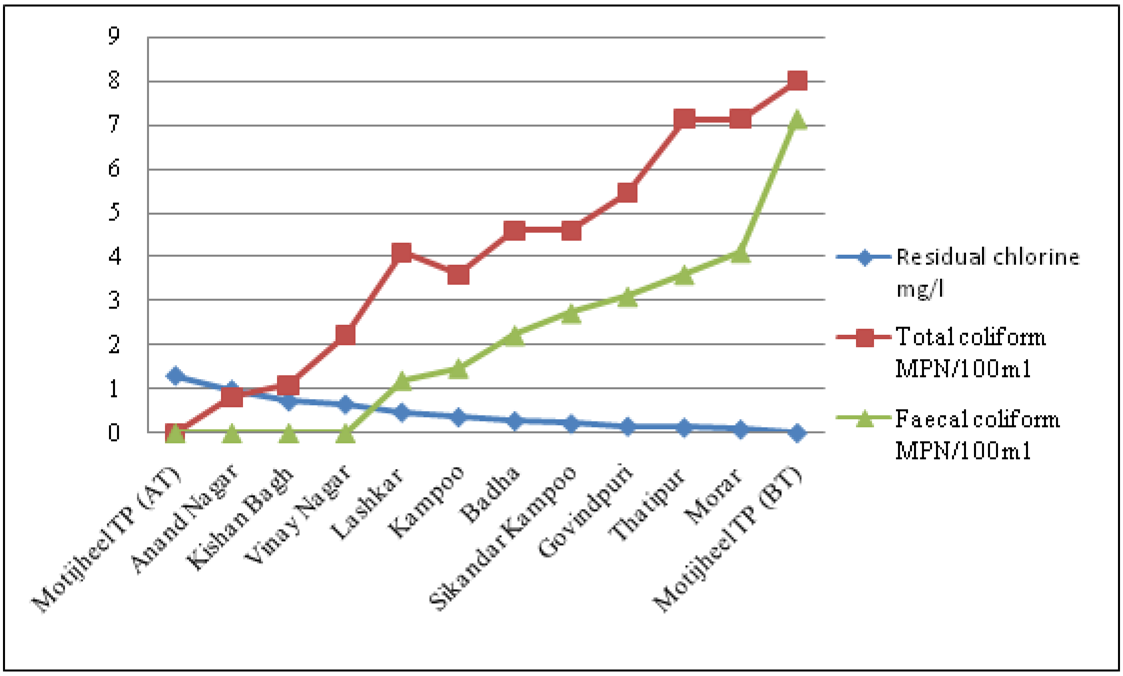

Figure 3: Relation of total coliform, faecal coliform count with residual chlorine recorded at different sampling locations.

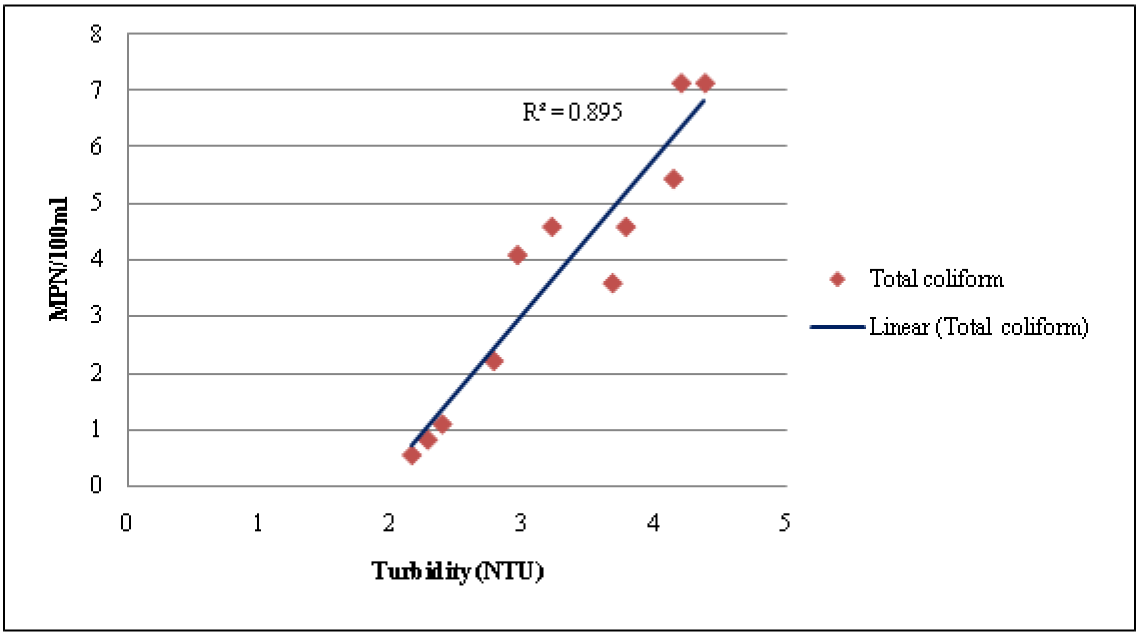

Figure 4: Relationship between total coliform and turbidity

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Subjective response of respondents to the questionnaire survey for water quality analysis

Questionnaire survey in the study area was carried out to know people's perception towards quality of water in distribution network. A total 200 households (20 households at each sampling location) were interviewed using questionnaires. 61.5% of households complained about the bad taste problem of tap water and for 38.5% households, the bad taste does not present any problem. 35.5% of households complained of bad odor issues and 27% households complained of water color issues from all study sites. 96% households reported that they were adversely affected by the use of tap water and 4% households reported that they were not affected by any health problem by using tap water. 78.5% households reported that they were treating the tap water before using it.

Diarrhoea was most the prevalent health problem in the study area as reported by 33% of households followed by Typhoid (21.5%), Jaundice (12.5%) and Dysentery (11%) (Fig.5). Among the methods of treatment, 32% of households were using boiling, 18% aqua guard and 16.5% alum as the methods of treatment for tap water before drinking it and 21.5% households were not treating water before using it for drinking or for cooking purposes (Fig. 6).

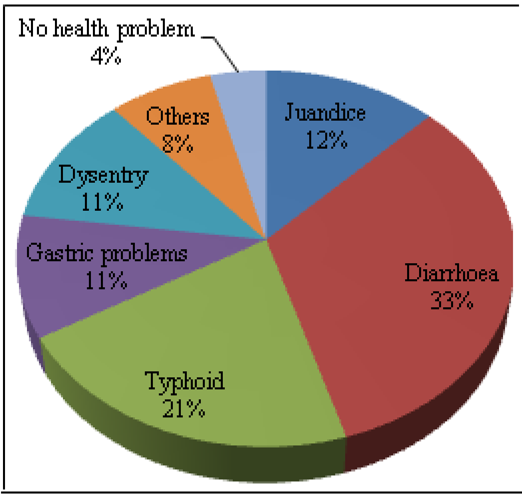

Figure 5: Occurrence of various water borne diseases in %age at in the study area

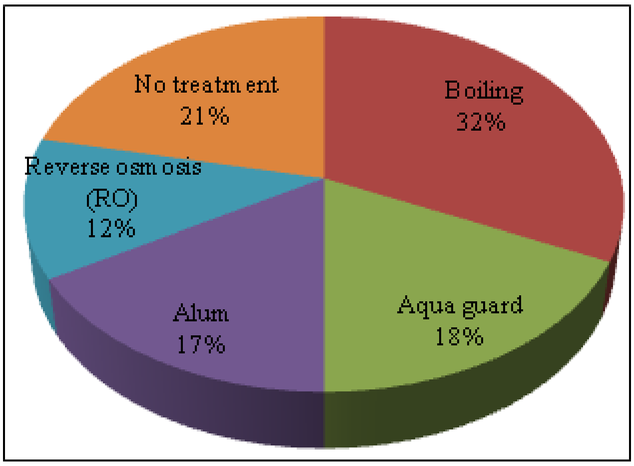

Figure 6: Various methods of water treatment used by the households (in %age) in the study area.

Table 2: Correlation matrix for different various physico-chemical and microbiological parameters analyzed during present study.

	Temp.	*pH*	*Turbidity*	*EC*	*TH*	*BOD*	*NO_3^-*	*Iron*	*F^-*	*RC*	*TC*	**TDS**
Temp.	1											
pH	0.8044	1										
Turbidity	0.6587	0.3103	1									
EC	0.3806	0.1837	0.1024	1								
TH	0.4316	0.4649	0.4283	0.3434	1							
BOD	0.3525	-0.0365	0.7753	-0.0086	0.0744	1						
NO_3^-	-0.1891	-0.4889	0.0657	0.5434	0.0776	-0.0824	1					
Iron	0.1112	-0.3285	0.4107	0.5986	0.1942	0.2980	0.7797	1				
F^-	0.3682	0.0908	0.1923	0.7201	0.3839	0.2000	0.4705	0.4641	1			
RC	-0.6010	-0.2715	-0.9216	-0.3541	-0.5328	-0.7140	-0.2569	-0.5049	-0.3491	1		
TC	0.4488	0.1089	0.9464	0.1437	0.4535	0.7285	0.2681	-0.5812	0.1764	0.9199	1	
TDS	0.2601	0.0213	0.0405	0.9300	0.2529	0.1014	0.5586	0.5752	0.8222	-0.4453	-0.3110	1

4. Conclusion

Results of water samples collected from the outlet of Motijheel WTP revealed that the water entering the distribution system was of desired physico-chemical quality and free from micro-organisms. However, good quality drinking water can suffer serious contamination in distribution system because of breaches in the integrity of the pipe work and storage reservoirs. All of the water samples collected from different sampling locations were found positive for total coliforms. Most of the water samples were positive for faecal coliforms except the water samples collected from Anand Nagar and Kishan Bagh. Residual chlorine was found very low at most of sampling locations as compared to WHO limits of (0.6-1.0 ml). The lowest value of 0.08 mg/l of residual chlorine was found at Morar.

This study revealed that monitoring of water quality is essential to ensure adequate free chlorine residual at the consumer end. Public response was quite interesting as revealed by questionnaire survey. People were very much concerned about the quality of drinking water they were consuming, as most of them gave suggestions with the stress on periodical monitoring by the government agencies. The result of this study may help government and allied agencies to take appropriate action with regard to appropriate chlorination practices in the area.

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