Evaluation of Drinking Water Quality in Urban Areas of Pakistan: A Case Study of Southern Lahore

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Abstract

A study was carried out to evaluate the quality of water supplied by Water and Sanitation Agency (WASA), Lahore. A portion of southern Lahore was selected for this purpose. Water samples from four different sources (tubewells) and eight house connections (two from each tubewell) were collected making a total of twelve sampling points. Two set of samples, one before monsoon and one after the monsoon were taken from each sampling point. Four physicochemical parameters (pH, turbidity, hardness and total dissolved solids) and two bacteriological parameters (total coliform and faecal coliform) were tested for each sample and values compared with World Health Organization (WHO) guidelines for drinking water. The results of the study demonstrated that physicochemical and bacteriological quality of water at sources was satisfactory. In the distribution system, physicochemical quality of water was satisfactory while 50 to 62.5% of the samples contained bacteriological contamination before monsoon. This percentage rose to 75% after the monsoon. Possible causes of contamination were leaking 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 residuals at the consumers' end to eliminate the bacteriological contamination.

Key Words: Water quality; Lahore, WASA, physicochemical characteristics; bacteriological characteristics.

1. Introduction

Drinking water must be free from components which may adversely affect the human health. Such components include minerals, organic substances and disease causing microorganisms. A large portion of the population in developing countries suffers from health problems associated with either lack of drinking water or due to the presence of microbiological contamination in water [1]. Poor water quality is responsible for the death of an estimated 5 million children in the developing countries [2]. The problem is further aggravated by rapidly increasing population which results in poor water-quality management [3].

In Pakistan, water supply coverage through piped network and hand pumps is around 66% [4]. It is estimated that, in Pakistan, 30% of all diseases and 40% of all deaths are due to poor water quality [5]. Diarrhoea, a water borne disease is reported as the leading cause of death in infants and children in the country while every fifth citizen suffers from illness and disease caused by the polluted water [6]. Unfortunately, little attention is being paid to drinking-water quality issues and quantity remains the priority focus of water supply agencies. There is a lack of drinking-water quality monitoring and surveillance programmes in the country. Weak institutional arrangements, lack of well equipped laboratories and the absence of a legal framework for drinking-water quality issues have aggravated the situation. Above all, the public awareness of the issue of water quality is dismally low [7].

Intermittent water supply is common in urban areas and outbreaks of gastroenteritis and other water born diseases have become a normal feature [8]. Estimates indicate that more than three million Pakistanis suffer from waterborne diseases each year of which 0.1 million die [9]. Thus there is a need to find out where the actual problem lies; whether the water sources are contaminated or lapses occur in the distribution system. Presently, Pakistan has no national drinking water quality standards and WHO guidelines are followed [10-11]. This research work was undertaken with the objective: (1) to evaluate the drinking water quality in southern Lahore both at the source and in the distribution system according to WHO guidelines and (2) to suggest preventive measures in case of any lapses found.

2. MATERIALS AND METHODS

2.1 Parameters Tested

Six water quality parameters; two physical, two chemical and two bacteriological were tested for the samples collected for this research work. Physical parameters testes were pH and turbidity. These two parameters play an important role in the disinfection of water. Turbidity should be less than 0.5 Nephelometric Turbidity Units (NTU) and pH should be less than 8 for effective disinfection [10]. Chemical parameters chosen were hardness and total dissolved solids (TDS). Water with high hardness results in excessive use of soap for washing purposes in household use while water with high TDS may impart taste. High values of both these parameters also

result in scale deposition in pipes and utensils. Bacteriological parameters tested were total coliform (T.C) and faecal coliform (F.C) [10-11]. These parameters indicate the possibility of the presence of pathogenic bacteria in the supplied water. All the tests were conducted according to the procedures laid down in the Standard Methods [11].

2.2 Sampling Area

Southern Lahore was selected for the purpose of this study as a test case. It mainly consisted of well planned government and private housing societies. Localities selected were Green Town, M. A. Jauhar Twon, Model Town Extention and Faisal Town as shown in Fig. 1. WASA supplies water to all these localities.
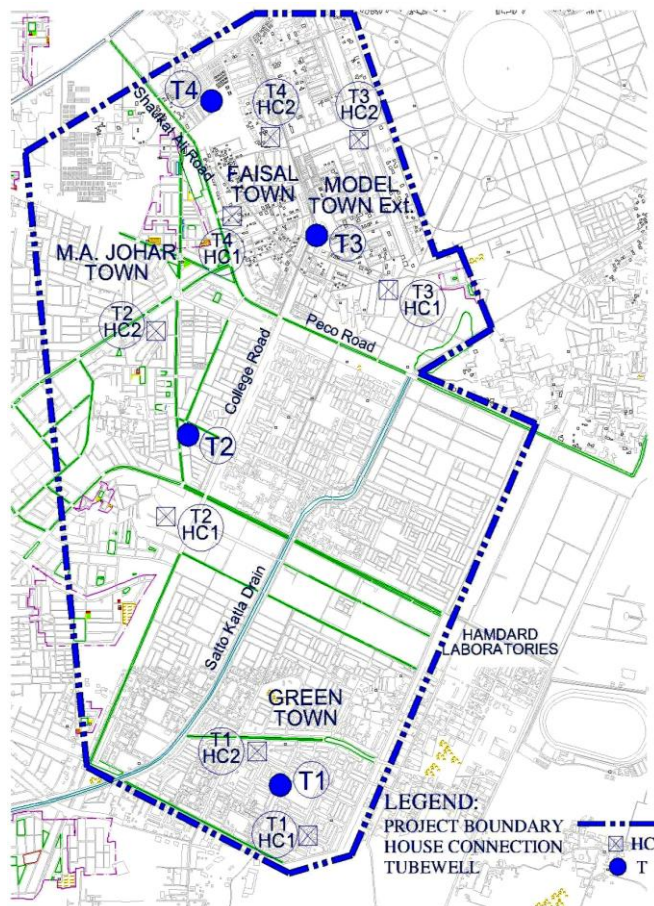

Fig.1   Location plan of localities in southern Lahore.

One tubewell (T/W) in each locality and two house connections in the service area of that T/W were selected for the purpose of sampling. According to WHO guidelines, one sample per 5000 heads of population should be collected from the distribution system. Since all these localities had a population ranging from 8000 to 12000, therefore, two samples from the distribution system located in the service area of each T/W were collected. It was ensured to take water from the farthest point of the service area of a T/W to realistically evaluate the effect of distribution network on the quality of water. A complete detail and nomenclature used for the sampling locations used is given in Table 1.

Table 1 Details of 12 sampling location and nomenclature used

S.No.	Location	Detail
1	T1	Tubewell in Green Town
2	T1HC1	House Connection (HC) no. 1 of T1
3	T1HC2	House Connection (HC) no. 2 of T1
4	T2	Tubewell in M.A Johar Town
5	T2HC1	House Connection (HC) no. 1 of T2
6	T2HC2	House Connection (HC) no. 2 of T2
7	T3	Tubewell in Model Town Extension
8	T3HC1	House Connection (HC) no. 1 of T3
9	T3HC2	House Connection (HC) no. 2 of T3
10	T4	Tubewell in Faisal Town
11	T4HC1	House Connection (HC) no. 1 of T4
12	T4HC2	House Connection (HC) no. 2 of T4

2.2 Sampling Methodology

From each sampling location, samples were collected before and after the monsoon as recommended in WHO guidelines. For statistical significance of the test results, each sampling location was sampled three times before and three times after the monsoon on the dates as shown in Table 2. On a specific date, samples from all the twelve sampling locations were collected. In this way a total of 72 samples were collected and tested during this study. Mean values of the quality parameters for the three samples at each sampling point before and after the monsoon are reported in this paper.

Table 2 Sampling Schedule

	Before monsoon			After monsoon		
Sample No.	1	2	3	1	2	3
Sampling date	5-4-08	19-4-08	3-5-08	19-7-08	2-8-08	16-8-08

For physicochemical analysis, water samples were collected in a one liter polyethylene (PET) bottle while a 0.5 liter sterilized PET bottle was used to collect sample for bacteriological analysis. In case of water samples from the distribution system, un-rusted taps supplying water from a service pipe, directly connected to the main and not served from the household storage tank, were selected. Samples were not taken from those taps which were leaking between the spindle and gland to avoid outside contamination. Taps were opened fully and let run for 2 to 3 minutes before sampling to get a truely representative sample both from the source and the distribution system.

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3. Results and Discussion

3.1 pH

The mean values of pH at twelve sampling points before and after the monsoon are shown in Fig.2. As a matter of fact, no health base guidelines are proposed by WHO for the pH of drinking water. However, it is one of the most important operational water quality parameters. pH values higher than 8 are not suitable for effective disinfection while values less than 6.5 enhance corrosion in water mains and household plumbing system. Therefore, WHO proposes a desirable range of 6.5 to 8.0 for pH of drinking water. As can be seen in Fig.3, the pH values at all the sources and house connections are well within the WHO desirable limit both before and after the monsoon season.

3.2 Turbidity

Mean values of turbidity at all the sampling locations before and after the monsoon have been shown in Fig. 3. No health based guidelines are proposed for turbidity by WHO.
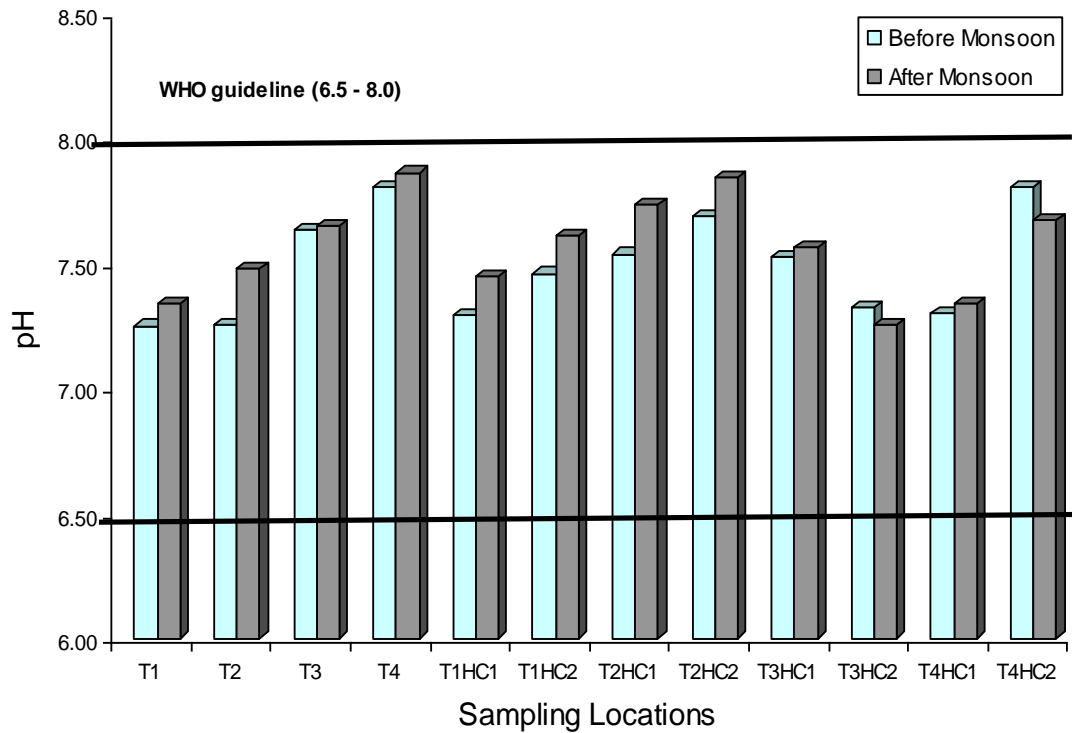

Fig. 2   Comparison of mean values of pH before and after the monsoon at various sampling locations
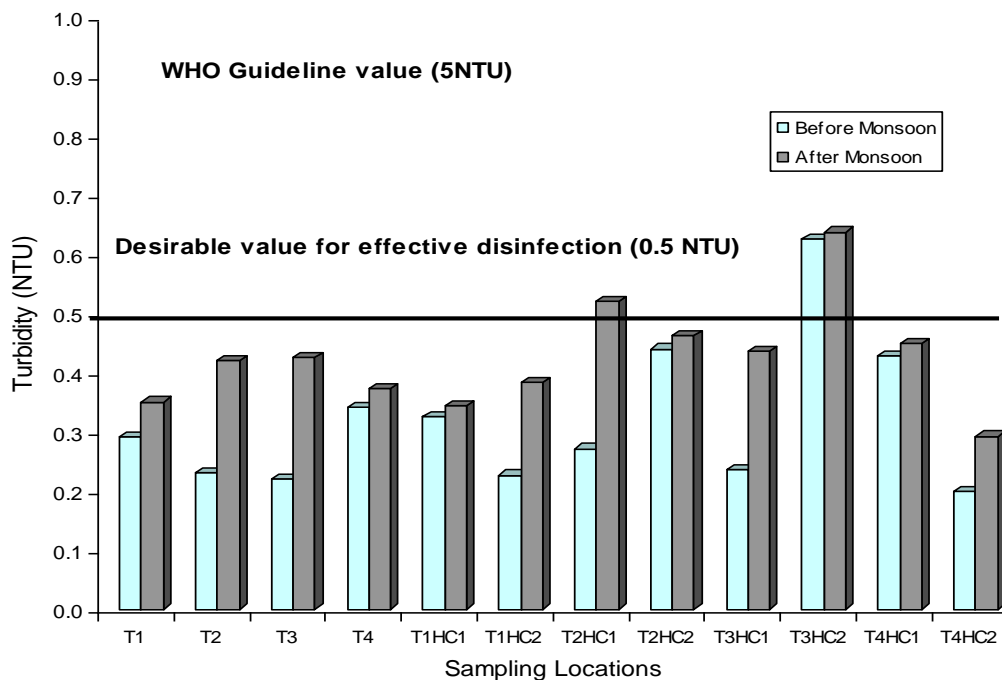

Fig. 3: Comparison of mean values of turbidity before and after the monsoon at various sampling locations

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Nevertheless, a value of 0.5 NTU is recommended for effective disinfection [10]. It is evident from Fig. 3 that at all the sources (T/W), the turbidity in water is less than the desirable limit of 0.5 NTU while it is more than 0.5 NTU before and after the monsoon at T3HC2. At T2HC1, it rose above 0.5 NTU after the monsoon. On the other hand a value upto 5 NTU is considered acceptable to the consumers [10]. It is evident from Fig. 3 that values of turbidity at all the sampling locations were well below 5 NTU. Values of turbidity rose in water samples obtained from all the locations after the monsoon. This difference was, however, very small. No apparent reason could be ascribed to this phenomenon on the basis of this study and further research is recommended to find out the facts. Values of turbidity and pH as measured for all the sources (Fig.2 and 3) suggest that disinfection of water can be carried out effectively.

3.3 Hardness

The mean values of hardness in the water samples at all the locations have been shown in Fig. 4. It can be seen in the figure that hardness at all the sources (T/W) and house connections were less than the WHO guideline value of 500 mg/L as $CaCO_3$ [10]. 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. Water

hardness above 500 mg/L needs excess use of soap to achieve cleaning. Hardness for sources (T/W) varied from 117 to 230 mg/L as $CaCO_3$, before and after the monsoon. For house connections the variation was 130 to 333 mg/L as $CaCO_3$ before and after the monsoon. Another important observation from Fig. 4 is that hardness decreased after the monsoon at almost all the sampling locations. This may be due to the dilution effect on the aquifer after the monsoon season.

If the hardness values at sources and respective house connections are compared then it is revealed that the hardness at house connections sometimes increased or decreased as compared to the hardness at the source. No reason could be ascribed for this effect on the basis of present research work. Further probe and investigations is needed on this issue.

3.4 Total Dissolved Solids (TDS)

The mean values of TDS in samples taken at all the locations before and after the monsoon are presented in Fig. 5. No health based guideline is proposed by WHO for TDS. Since TDS higher than 1000 mg/L impart taste to the water, therefore, a desirable value of 1000 mg/L is proposed by WHO. Furthermore, a value higher than 1000 mg/L results in excessive scales in water pipes, heaters, boilers and household appliances [10].
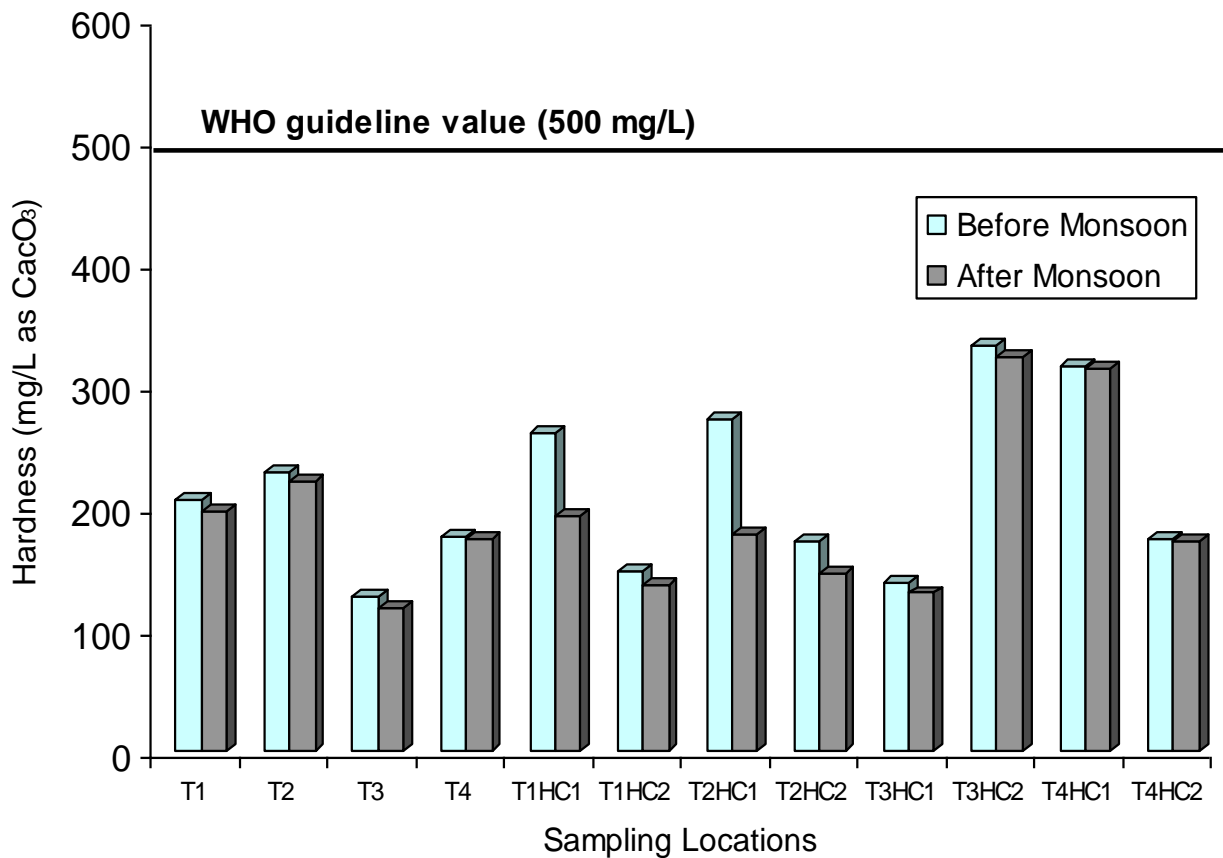

Fig. 4 Comparison of mean values of hardness before and after the monsoon at various sampling locations
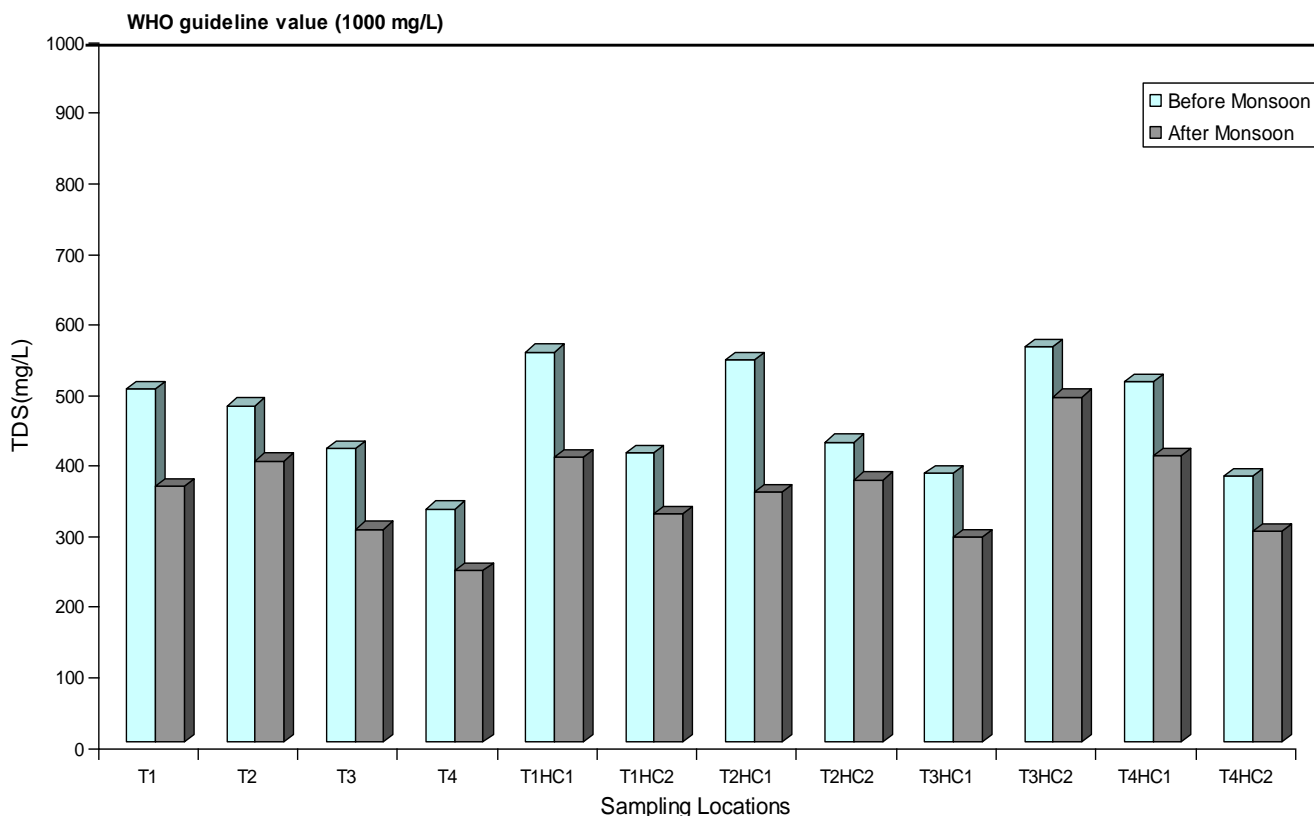
Fig. 5 Comparison of mean values of TDS before and after the monsoon at various sampling locations

It can be see in Fig. 5 that TDS values, both at the source (T/W) and house connections were well below the upper desirable value of 1000 mg/L. It can further be pointed out that TDS in the collected samples consistently decreased at all the sampling points after monsoon. This may be due to the dilution of underground aquifer after the monsoon season. TDS at some house connections increased as compared to the source (see T4 and T4HC1 and T4HC2). This may be due to the mixing of wastewater into the water mains due to faulty joints. However, further investigation on this aspect is needed.

3.5 Total Coliform (T.C.)

The mean values of T.C [11] at all the sampling locations before and after the monsoon have been presented in Fig.6. T.C group includes both faecal and environmental species. Their presence shows that water has come in contact with any of the materials like human faeces, soil, plants etc. It can be seen in Fig.6 that the water at all the sources is free from T.C contamination before and after the monsoon. Similarly two house connections T2HC1 and T3HC2 were free from T.C which clearly shows that water distribution system in that area is in good condition. T.C was not found at T1HC1 before monsoon; however, it appeared after the monsoon. Rest of the house connections, in addition to that mentioned above, had T.C contamination, both before and after the monsoon. Putting in other words 62.5% of house connections were contaminated with T.C,

before monsoon and the percentage rose to 75% after the monsoon.

Various reasons of bacteriological contamination may be: (1) intermittent water supply which allows entry of any wastewater in distribution system through poor joints during no flow conditions; (2) layout of water pipes in close proximity to the sewer lines and (3) overloading of sewage channels and sewers which in most cases remain blocked. Fig. 7 shows stagnant wastewater in front of house connection T1HC2 due to blockage of sewer line. Water sample from this house connection had both T.C and F.C before and after the monsoon.

3.6 Faecal Coliform (F.C.)

Mean values of F.C [10] at various sampling locations before and after the monsoon have been shown in Fig. 8. Faecal contamination shows that water has come in contact with human faeces. It is evident from Fig. 8 that all the sources (T/W) are free from F.C, both before and after the monsoon while only one house connection T2HC1 was free from F.C before and after the monsoon. At T1HC1 and T3HC1, F.C were not present before the monsoon and only appeared after it. Rest of the house connections in addition to those mentioned above were faecally contaminated before and after the monsoon. Putting in other words, 50% of the house connections were faecally contaminated before the monsoon and this percentage rose to 75% after the monsoon.
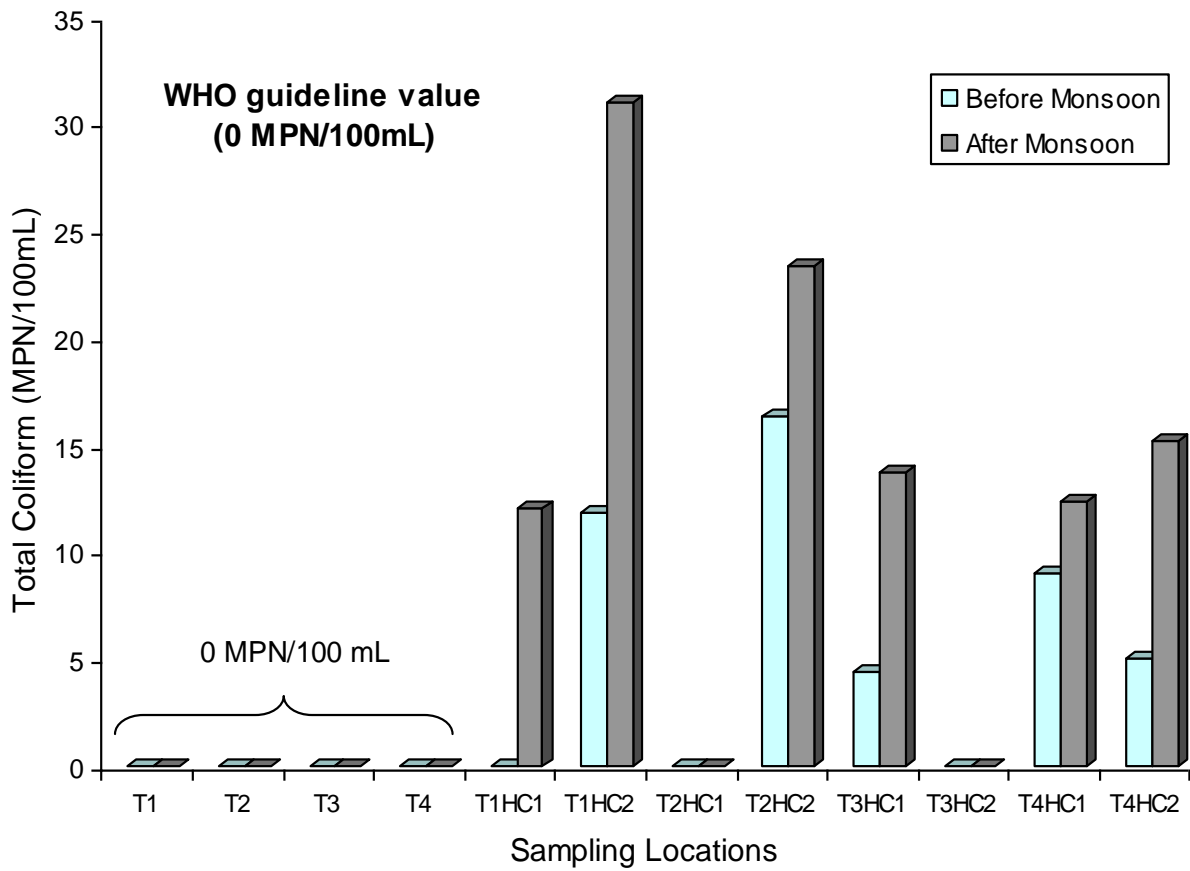
Fig. 6 Comparison of mean values of total coliform before and after the monsoon at various sampling locations

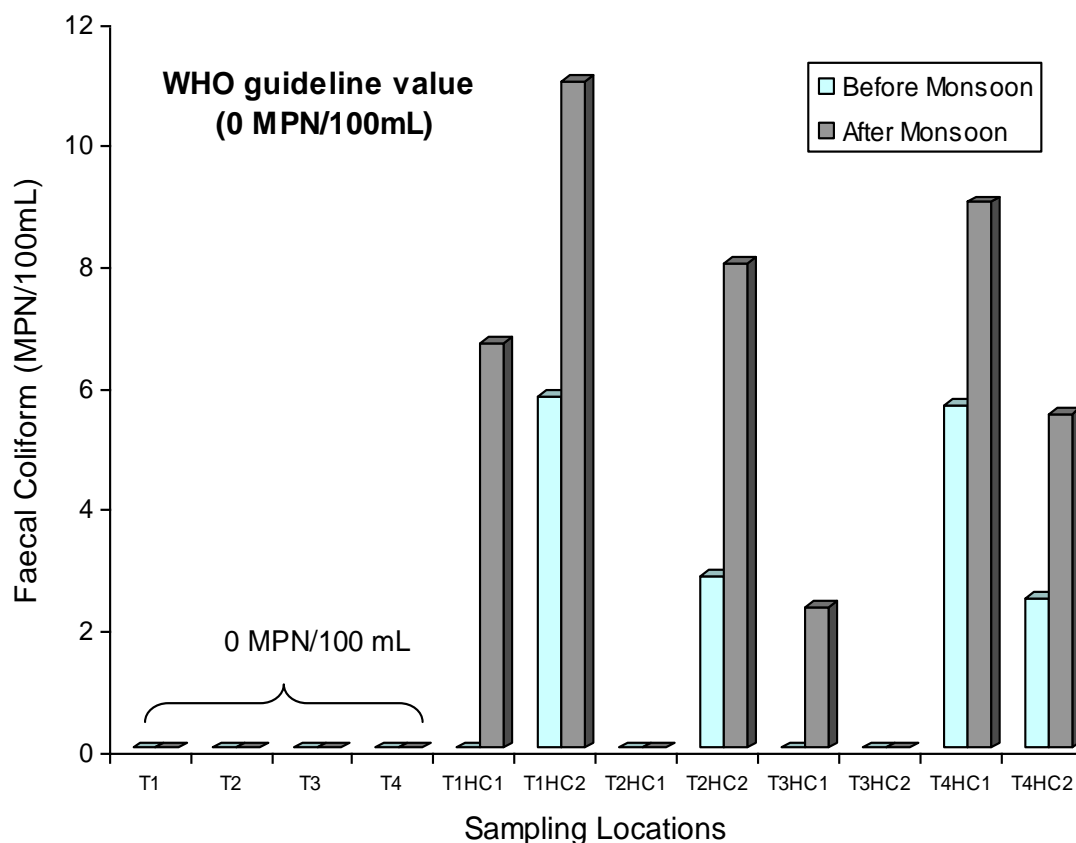**Fig. 7 Stagnation of sewage in front of house connection T1HC2**

Fig. 8 Comparison of mean values of faecal coliform before and after the monsoon at various sampling locations

In most of the cases where bacteriological contamination was found, it was observed that pounding of wastewater from blocked pipes or stagnation of rain water due to lack of proper drainage could be a cause. Pipe material used in the study area was galvanized iron and asbestos cement and was 30-35 years old. Water supply and sewer lines in some areas were laid side by side without any consideration of safe distance between the two. This situation is also one of the causes of bacteriological contamination in water distribution system. Intermittent nature of the water supply further aggravates the situation. A remedial measure may be the provision of over head reservoirs, which maintain a constant pressure in the lines despite disruption in pumping. Although all the sources were equipped with chlorination devices but none was functional or in regular use. WASA did not carry out any monitoring programme to evaluate the water quality on regular basis.

4.0 CONCLUSIONS & RECOMMENDATIONS

1. The physicochemical (pH, turbidity, hardness and TDS) and bacteriological (T.C and F.C) parameters at all the sources (T/W) in the study area were within the limits prescribed by WHO guidelines for drinking water quality. It can, therefore, be concluded that the groundwater in the study area is suitable for drinking and other household purposes.

2. Physicochemical quality of the sampled water at all the house connections was within the limits prescribed by WHO guidelines.

3. Bacteriological quality at 50-62.5% house connection was unsatisfactory before the monsoon and percentage rose to 75% after the monsoon. Various causes of bacteriological contamination included old and rusted water mains, laying of water supply pipes close to sewer lines, intermittent water supply system, clogging of sewer lines and inadequate storm drainage in the study area.

4. To improve the bacteriological quality of water, it is recommended to make the installed chlorination devices functional. Tubewell operators must be trained to use these devices properly and to administer proper dose of chlorine.

5. Pounding of wastewater in the streets be avoided through effective wastewater collection system.

6. Water supply and sewer lines be laid on the opposite sides of the street to maintain safe distance between them in future water supply and sanitation projects undertaken by WASA.

7. Very old/leaking pipes need to be replace/repaired to avoid bacteriological contamination.

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