ASSESSING MICROBIOLOGICAL SAFETY OF DRINKING WATER: A CASE STUDY OF ISLAMABAD, PAKISTAN

By

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Abstract:
The distribution of drinking water in networks is a technological challenge both in quantitative and qualitative terms. It is essential that each point of the network be supplied without interruption with an invariable flow of water complying with all the qualitative parameters of the drinking water standards in force. This is essential in order to ensure the security of public health and general cleanliness of community. Numerous biological and physicochemical reactions take place in drinking water distribution systems, and give rise to phenomena whereby the organoleptic or bacteriological characteristics of the distributed water are modified. Keeping in view, the study was undertaken to assess the distribution network water supply to the residents of sector I-9 Islamabad as per Standard Methods. For microbiological analysis, total and faecal coliforms and standard counts were examined, whereas physicochemical analysis samples were analyzed for pH, temperature, turbidity, TDS, conductivity, free chlorine and chloramines. Water distribution network was monitored over a period of month; samples were collected from eight different sampling points. Data revealed that value of residual chlorine varied from 0.03 to 0.08 mg / L. This low value of residual chlorine resulted in high level of microbial contamination at consumer end ranging up to maximum value of 23 MPN / 100ml. Bacterial re-growth, measured by SPC varied from 33 to 77 CFU / ml. Turbidity was within permissible limit ranging from 0.45 to 1.05 NTU, pH ranged from 7.31 to 7.56, TDS value ranged between 335 to 364 mg / L, whereas highest value of conductivity obtained was 801 µS/cm. Quality of water supplied to community was not satisfactory as most of the samples collected were faecally contaminated. Poor budget allocation, sloppy governance and ageing infrastructure are some reasons. Implementation of national drinking water policy should be ensured for providing safe drinking water to consumers. The aim of this study was to evaluate the sanctity of potable water in circulation within I-9 / 4 sector of Islamabad and suggest safety measures to reduce the incidence of water-borne diseases.

Key Words: Microbiological quality; drinking water resources; SPC, coliforms, chlorine

1. Introduction

Water is one of the most important of all natural resources known on earth. It is important to all living organisms, most ecological systems, human health, food production and economic development [10]. The declining 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 nations world-wide will experience water stress by year 2025 [15]. The safety of drinking water is an on-going

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concern within the global village. Traditionally, the safety of potable water supplies has been controlled by disinfection, usually by chlorination and coliform population estimates. However, it has been reported that coliform-free potable water may not necessarily be free of pathogens [14]. According to figures published by the United Nations, subsidiary organisations and other international organisations, 1.1bn people are without a sufficient access to water, and 2.4bn people have to live without adequate sanitation. Under current trends, the prognosis is that about 3bn people of a population of 8.5bn will suffer from water shortage by 2025. 83% of them will live in developing countries, mostly in rural areas where even today sometimes only 20% of the population have access to a sufficient water supply [3]. Access to an improved drinking water supply is not only a basic need and precondition for a healthy life; it is also a human right. If a state has not deployed a maximum of available resources to guarantee a basic supply of drinking water, to ensure that access to safe and clean water supply, the human right to water has been violated.

One of the key issues to Pakistan is the growing population pressure, which is responsible for driving its water resource development. It has the world's fastest growing population that has surpassed the 170 million mark by now and is still increasing at an alarming rate of around 2.8%, which needs to be checked. Present century is a century for better utilization of water. We have to change our cultivation mode and living styles [8]. Simultaneously the quality of groundwater and surface-water is low and further deteriorating because of unchecked disposal of untreated municipal and industrial wastes [9]. Regular monitoring programs to assess the water quality at the treatment plants or in the distribution system is not practiced in Pakistan, except at few major water treatment plants which may be associated with health risks for susceptible individuals due to deterioration of microbiological water quality in distribution systems [11-13]. Current monitoring systems are only for random testing and cannot record pollution level. Most of the reported studies in Pakistan only indicate contamination by faecal source through detecting the presence of faecal coli-form in drinking water without any information on the level of chlorine present in the water distribution network [6]. Waterborne pathogens, including a variety of viral, bacterial and protozoan agents, account for much of the estimated 4 billion cases and 2.5 million deaths from endemic diarrhoeal disease each year [7, 17]. The Pakistan Council of Research and Water Resources assesses that 40 percent of all reported illnesses are water-related [1]. It is estimated that water related diseases cause annual national income losses of USD 380–883 million—or approximately 0.6–1.44 percent of GDP [17]. Disinfection of potable water is most crucial for ensuring public health.

The knowledge on environmental policies regarding water issues such as the National Water Policy (Draft), National Environment Policy etc. and regulatory framework like the Pakistan Environmental Protection Act 1997 do exist in Pakistan, but there is no clear strategy devised so far to implement them. Government of Pakistan in early nineties introduced National Environmental Quality Standards (NEQS) through statutory notifications as per recommendations of various advisory committees. The implementation of these NEQS is, however, proceeding at a very slow pace.

2. Material and methods:

To assess the current state of surface water quality in Islamabad, water samples were collected from different sites of I-9 sector. It is the weakest point regarding water disinfection practices and overall drinking water quality in distribution network. Samples were collected from sites including underground water tank and consumer end receiving water supply. The collected samples were analyzed for chlorine residual, (MPN: total coliform and faecal coliform), spread plate count as per Standard Methods [2].

2.1. Sampling

Samples were collected thrice from sampling area over a two week period (total 24 samples) to determine any variation in the results of water quality as per Standard Methods. Water samples were collected in sterile glass bottles containing 3 to 4 drops of 3% sodium thiosulphate in order to neutralize any residual chlorine. Water samples were stored in ice boxes and transported to the laboratory for microbiological and physicochemical analysis within 2 hours.

2.2. Physio-Chemical Analysis

Chemical analysis of water supplies was necessary to guarantee the quality, compliance with established quality criteria and efficiency of operation of water treatment plants and distribution systems.

On site, samples were analyzed for temperature and pH (Hach pH meter sension 1), turbidity (Hach 2100) and TDS and electrical conductivity by Hach meter (sension 5) while chemical analysis for chlorine residual, free chlorine, monochloramine and dichloramines was carried out using DPD Ferrous Titrimetric method [19]. For the detection of free chlorine, 5 ml of phosphate buffer and DPD were placed in a flask with 100 ml sample; development of red color was titrated against standard ferrous ammonium sulfate (FAS). Observation was recorded as soon as the color discharges giving value of free chlorine. For determination of monochloramine 0.5 g KI was added to the above sample and was titrated against FAS. The volume of FAS used gives monochloramine in mg / l. For dichloramines 1 g KI was added in the above sample and similar procedure was repeated after 2 minutes standing. Similarly for total chlorine 5 ml of phosphate buffer and DPD was placed in a flask with 100 ml sample along with 1.5 mg KI and observation was noted after two minutes standing in dark.

2.3. Microbiological Analysis

The total coliform and faecal coliform counts were determined by the multiple tube dilution procedure given in Standard Methods for the Examination of Water and Wastewater. Standard plate counts (SPC) were also determined as per Standard Methods [2].

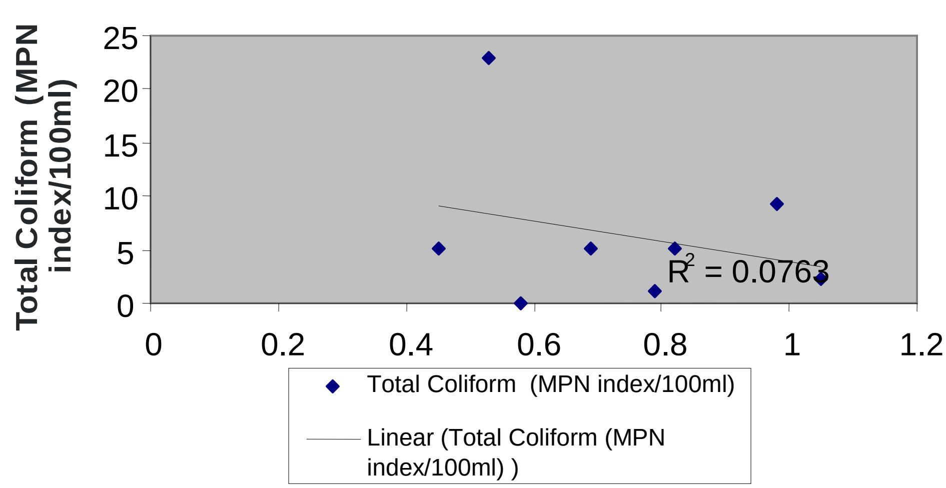
3. Results and discussion

The analysis results of drinking water samples collected from the distribution lines in I-9 / 4 sector are presented in Table-1. Results reveal that the pH and temperature of the water in circulation falls within WHO limits. pH ranges from 7.31-7.56 which are well within WHO permissible limit of 6.5-8.5. TDS describes the load of inorganic matter and directly relates to conductivity of the water. TDS of all samples were found to be within limits.

Table 1 :Mean value of Microbial and Chemical Analysis of Water Samples Collected from Residential area of I-9/4 during July & August 0

Water Parameters	Station Numbers							
	1	2	3	4	5	6	7	8
Station Name	UGT	H1	H2	H3	H4	H5	H6	H7
Temp in °C	25-27.4 26.3	25-26.7 25.9	24.5-27 26	24.8-27.2 26	24.7-27.1 26	24.5-26.8 25.8	24.1-27 26	24.2-27. 26
pH	7.23-7.65 7.49	7.21-7.37 7.31	7.51-7.59 7.56	7.35-7.53 7.50	7.43-7.71 7.54	7.31-7.62 7.42	7.29-7.70 7.43	7.18-7.6 7.35
TDS (mg/l)	288-376 335	398-403 401	387-390 389	390-311 364	300-399 363	313-380 351	381-389 386	372-391 382
Conductivity(µS/cm)	576-753 671	796-804 801	703-779 752	621-781 727	599-798 725	626-760 703	761-778 772	745-792 767
Turbidity (NTU)	0.32-0.81 0.53	0.68-0.98 0.82	0.30-0.70 0.45	0.59-1.48 1.05	0.30-0.95 0.58	0.31-1.25 0.69	0.48-1.40 0.79	0.34-1.3 0.98
Total Chlorine (ppm)	0.07-0.20 0.14	0.08-0.17 0.12	0.05-0.21 0.12	0.06-0.16 0.11	0.06-0.20 0.13	0-0.20 0.11	0-0.16 0.08	0-0.27 0.12
Free chlorine	0.02-0.17 0.08	0.04-0.05 0.04	0.03-0.13 0.07	0.02-0.10 0.056	0.02-0.17 0.08	0-0.11 0.05	0.01-0.06 0.04	0.01-0.0 0.03
Monochloramine	0.03-0.09 0.06	0.02-0.08 0.05	0.01-0.09 0.05	0.03-0.08 0.05	0.01-0.17 0.07	0-0.1 0.05	0-0.09 0.05	0-0.05 0.03
Dichloramines	0.05-0.06 0.05	0.05-0.09 0.06	0.05-0.1 0.08	0.03-0.17 0.08	0.03-0.10 0.07	0-0.08 0.05	0-0.1 0.04	0-0.25 0.16
Total Coliform (MPN index/100ml)	5.1	23	>23.0	5.1	1.1	5.1	9.2	2.
Faecal Coliform (MPN index 100ml)	2.2	23	23	3.6	1.1	5.1	9.2	2.
Range 95% Probability	TC 1.3-13.4 FC 0.26-8.1	8.1-59.5	TC13.5-Infinite FC 8.1-59.5	TC 1.3-13.4 FC 0.69-10.6	0-3.0	1.3-13.4	3.1-21.1	0.26-8.1
CFU /ml	0-94 33	29-161 77	45-60 54	0-13 8	3-10 8	5-67 26	0-23 12	0-7 4

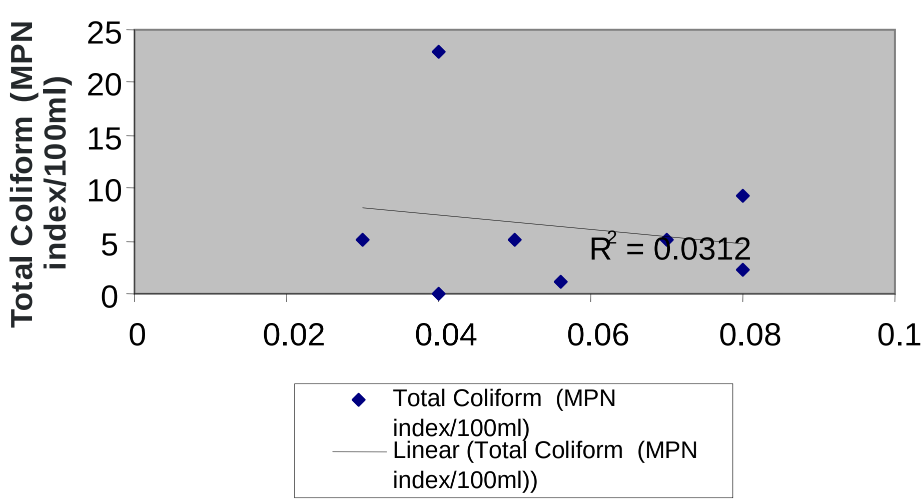
Figure-1 : Turbidity vs total Coliform



Turbidity is an important parameter to determine the water quality. It is defined as the interference of light passage through water by insoluble particles [4]. In I-9/4 sector, turbidity was in compliance with the standard set by WHO i.e. > 1 NTU, except *Station # 3* where value was 1.05 NTU. Increase in turbidity may contribute in high coliform count. It is a useful analytical tool in water treatment plant to ensure good quality, but it is not an effective indicator for the detection microbial population.

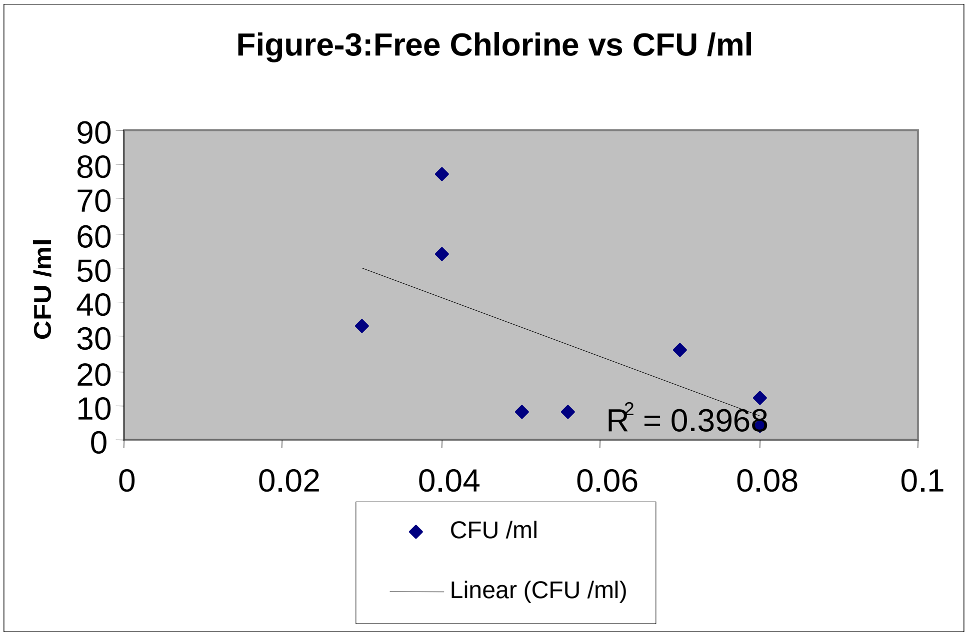
Detection of microbial contaminants of faecal origin is a major priority in assessing the quality of drinking water. Results from the analysis indicated the presence of coliform and faecal coliform bacteria in the water sample collected from all of the stations may be due to the contamination such as inclusion of the soil through leaks/ cracks or due to seepage of sewage water into the supply lines. The analysis results of bacteriological analysis of water samples from different sites are presented in (Table-1). The concentration of chloride ions detected in the water distributed was fluctuating within range of 0.03-0.08 ppm which is below WHO standard 0.2-0.5. Chloride content does not impose any significant health impact except taste. Chlorine is an effective antimicrobial agent with the capacity to react destructively with the protein components of all types of organisms and even protecting the water from contamination during distribution. It can be seen from (fig-2) the low concentration of residual chlorine contributes in high loads of faecal coliform bacteria.

Figure-2 : Free Chlorine vs Faecal Coliform



High microbial counts in water are undesirable because of the increased likelihood that pathogens may be present. It can be clearly seen from the results that all water samples were contaminated with organisms posing risk to human health. Meybeck (1985) reported that the faecal coliform up to 10^6 /100 are commonly found in India, Pakistan, and Indonesia [5]. These organisms are major source of water-borne infections in Pakistan. It is revealed from the study that value of MPN index / 100 ml for total coliform and faecal coliform was very high in station # 2 where MPN index was 23. However least MPN index was detected in station # 5 which is 1.1.

The viable count was measured by standard plate count (SPC) technique using nutrient agar as the growth medium and is reported as colony forming unit CFU/ml. Highest variable count was obtained at *Station # 2* around 77 CFU/ml and as low as 4 CFU/ ml. Low chlorine values contributed in higher CFU / ml (fig-3). Enumeration of (SPC) is a useful tool to indicate the presence of opportunistic pathogens, the potential for coliform suppression, and drinking water quality deterioration in a distribution system [18].



Pathogen intrusion may occur under these circumstances if poor sanitary conditions exist because of improper wastewater collection and leakage in the network. Consequently, these poor conditions may contribute in cross contamination of clean drinking water. It is important to note here that poor water quality is not because of single flaw, but combination of number of factors in the entire system.

4. Conclusion

Considering the deteriorating water quality status, the study aimed to assess the current water status of residential area of I-9 / 4 sector. It is expected that the monitoring results would lead to remedial measures for improving the existing drinking water quality situation. It can be concluded that:

The samples were collected from nine different sampling points from water distribution network of I-9/4 sector of Islamabad. Total residual chlorine varied largely among different sampling points, ranging from lowest value of 0.03 mg/l at *Station # 1* to the highest value of 0.08 mg/l at *Station # 7, 8*. At *Station # 5* total coliforms were less than 1.1 MPN/100 ml while at *Station # 2* highest count of 23 MPN/100 ml was observed. The samples were also tested for faecal coliforms and were found positive at all stations. *Station # 2 and 3* were found to be the most contaminated may be due to cross connection of drinking water with sewage. Physiochemical water quality parameters such as pH, temperature were also found to be within the permissible limits of WHO standards except total dissolved solids which were above the limits. As the chlorine concentration increased, microbial counts decreased while increase in turbidity also contributes in an increase in microbial contamination. Based upon the results of this study it is recommended that regular monitoring of residual chlorine concentration and total coliforms in the water distribution system should be carried out to ensure that the chlorine residual of 0.2–0.5 mg / l is available at the consumer end.

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