Water quality assessment of Raw and Chlorinated drinking water of a Residential University

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Abstract:

The safety of water is essential for life on earth. Drinking contaminated water can give rise to many health issues. To highlight the major causes of contamination in water, this study was carried out to determine the physicochemical and bacteriological quality of raw and chlorinated water. Raw and chlorinated water samples were obtained from three locations (zones) of a residential university (National University of Sciences and Technology, NUST). Ten physicochemical parameters were analyzed (pH, Electrical conductivity, Turbidity, Dissolved oxygen, Hardness, Alkalinity, Total suspended solids, Total dissolved solids, Total organic carbon, and Chlorine (free & total)). Bacteriological analysis was performed through the MPN technique. The results showed that all the physicochemical parameters were found within the permissible limits set by WHO and PSDWQ for raw and chlorinated water, except TSS and Chlorine (free & total). The TSS of raw and chlorinated water ranged from 3.3-14.3mg/L and 8.7-12.7mg/L, greater than the permissible limits. The free Chlorine for both raw and chlorinated water ranged from 0.04-0.09mg/L and 0.06-0.07mg/L and total Chlorine for both raw and chlorinated water in the range 0.10-0.09mg/L and 0.22-0.24mg/L, respectively, which were far below the recommended limit required for water disinfection. The MPN index for raw and chlorinated water ranged from 23 to >23MPN/100ml and 16 to >23MPN/100ml, exceeding the permissible limits. The results concluded that the water, whether raw or chlorinated, was not fit for drinking purposes. Proper dosages of Chlorine and filtration techniques are required to make the water fit for consumption.

Keywords: Drinking water, Raw water, Chlorinated water, Physicochemical quality, Bacteriological quality.

Introduction:

Water is one of the essential chemical compounds found on earth [1]. Access to clean and safe drinking water is a fundamental human right of every person nevertheless of his/her color, creed, religion, wealth, or nationality [2]. Clean and safe water is a natural resource necessary for a strong economy and sustainability of life [3]. Potable water does not contain any disease-causing microorganisms and hazardous chemicals that can deteriorate the health of living beings [4].

Humans acquire water for drinking from surface and groundwater sources. These water sources can become polluted with chemical and biological pollutants emerging from various point and non-point sources [5]. Mainly anthropogenic activities are responsible for the contamination of water bodies like disposal of plastic materials, household chemicals, personal care products, discharge of waste from sewage treatment plants, domestic waste, mining, construction activities, and multiple industrial and agricultural activities which degrade the surface and groundwater quality. All these factors can alter the physicochemical and biological parameters of water [6]. In underdeveloped countries, the pollution of potable water is one of the crucial problems. Thousands of people die due to the poor quality and unavailability of drinking water [7]. Many people in developing countries have no access to clean and safe drinking water. They are forced to consume unhealthy water to fulfill their drinking needs and domestic activities [8].

It is stated that worldwide a minimum of 2 million people uses drinking water from sources that are contaminated with feces [2]. Lack of clean and safe drinking water and improper sanitation systems give rise to numerous health issues which directly affect half of the population of developing countries. Waterborne diseases caused by the consumption of contaminated water are a threat to life. It is reported that globally 250 million cases of waterborne diseases are recorded and 25 million people die yearly being victims of waterborne diseases. Waterborne diseases like diarrhea, typhoid, cholera, dysentery, meningitis, hepatitis, encephalitis, salmonellosis, poliomyelitis, legionellosis, giardiasis, pulmonary illness, and leptospirosis are commonly found in people drinking contaminated water [1].

Pakistan being a developing country, is also facing the issue of access to safe drinking water. In Pakistan, it has been reported that 30% of all diseases and 40% of all deaths are caused by drinking contaminated water. In Pakistan, diarrhea, a leading waterborne disease, has taken the lives of numerous children and infants. It has been stated that every fifth citizen of the state faces illness or possibly death by drinking polluted and unhygienic water. Estimates show that more than 3 million Pakistani's go through the pain of enduring waterborne diseases every year and unfortunately, out of those victims, 0.1 million dies. In Pakistan, there is an absence of monitoring drinking water quality and control programs. There is a lack of legal framework and well-equipped laboratories for monitoring and testing drinking water quality which has helped provoke the overall situation [9].

The quality of water is of paramount importance for the health of the individuals consuming it. Thus raising the need for this study to analyze the source water of a Residential University to highlight the quality of drinking water and possible causes behind its deterioration, supplied to the

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students and the residents of the University, namely the National University of Sciences and Technology (NUST). This study aimed to investigate the physicochemical and bacteriological quality of raw and chlorinated water at source used for drinking purposes at NUST.

Materials and Methods:

Sampling sites

National University of Sciences and Technology (NUST), Pakistan, was selected as the study site. NUST is divided into three zones. Each zone receives water from tube wells (a total of 9). The water from tube wells is directed to storage tanks (one in each zone). The water is then chlorinated to achieve disinfection and directed to overhead reservoirs entering the drinking water distribution system (DWDS). Raw water samples from storage tanks and water after chlorination from each zone were collected for analysis, as shown in Figure 1. The water samples were obtained in September and October 2019. They were examined for ten physicochemical properties pH, Electrical conductivity (EC), Dissolved oxygen (DO), Turbidity, Hardness, Alkalinity, Total dissolved solids (TDS), Total suspended solids (TSS), Total organic carbon (TOC), Chlorine (free & total) and bacteriological analysis through Most Probable Number technique (MPN).

Sampling:

The samples were collected in 500ml sterile glass bottles according to WHO guidelines to monitor drinking water's microbial and physicochemical parameters (including both raw and chlorinated water). All the samples were stored in an icebox then delivered to the laboratory for analysis. They were analyzed within 1 hour of their collection or stored in a refrigerator and analyzed within 4 hours of their collection. In addition, Triplicate water samples were taken to validate the results. All the procedures were carried out as prescribed in the Standard Methods for the Examination of Water and Wastewater [10].

Physicochemical Properties:

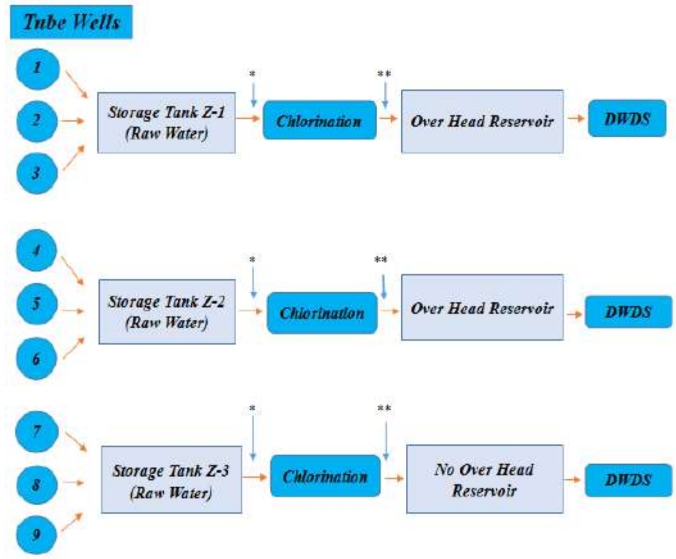
The quality of drinking water is vital for the safety of the inhabitants that consume it. So it is necessary to monitor the physicochemical properties of drinking water to confirm its quality. Some of the parameters were monitored onsite. Like pH (potable HACH 156 pH meter), DO (CrisonOxi 45 DO meter), Free & total chlorine (Hanna HI 96734 Chlorimeter), and EC (Conductivity meter 3210). In laboratory Turbidity (Portable Turbidimeter HACH 2100P), Hardness (Titration), Alkalinity (Titration), TDS, and TSS (Gravimetric method) were analyzed, TOC was determined using the formula suggested by Adam and his coworkers [11]

Organic carbon (%) $=\frac{VS\ (\%TS)}{1.8}$.

The results of TOC were converted into mg/L for drinking water. All the procedures were carried out as prescribed in the Standard Methods for the Examination of Water and Wastewater [10].

Bacteriological Properties:

Bacteriological analysis of drinking water samples was conducted through the Most Probable Number technique to determine the presence or absence of total & fecal coliform and E.coli.



Z-Zone 1, 2, 3.
* Sampling location for raw water (from Storage Tanks)
** Sampling location for chlorinated water (Raw water after chlorination).

Fig. 1: Schematic diagram of water pathway in NUST.

Results and Discussion:

Physicochemical Analysis:

The results indicate that pH, EC, Turbidity, DO, Hardness, Alkalinity, and TDS were within the permissible limits of World Health Organization (WHO) and Pakistan Standards for Drinking water quality (PSDWQ). However, TSS was found to exceed the permissible limits. In addition, free and Total Chlorine was detected to be less than WHO's permissible standards.

pH is one of the most critical water quality parameters. Variations in optimum pH can increase or decrease the number of toxic poisons in water bodies. Any shift from neutral pH 7.0 is the cause of bicarbonate/carbonate or carbon dioxide balance [12]. An increase in temperature can cause fluctuations in the value of pH as it can suppress CO_2 solubility in water [5]. In this study, the pH of raw water in storage tanks of the three zones ranged from 7.32-7.82, and the pH after chlorination ranged from 7.60-7.96, respectively. The storage tank containing raw water in zone 2 was found to have the highest pH of 7.82, whereas, after chlorination, the water in zone 1 was found to have the highest pH of 7.96. The raw water in zone 1 was found to have the lowest pH of 7.32, but the water in zone 3 after chlorination was the lowest pH of 7.59. Whereas, the pH of the water before and after chlorination in all three zones was found within the permissible limits set by WHO and PSDWQ that is 6.5-8.5, as shown in Figure 2.

There was no such significant difference in the value of pH in raw water and water after chlorination. Therefore, the only possible reason for slight fluctuations in pH values in raw and chlorinated water could be temperature change.

According to a similar study carried out by Amin et al., physicochemical parameters of storage tank water of 10 locations in Peshawar were accessed. The pH value ranged from 6.65-7.91, respectively, which was also found lying within the range set by WHO and PSDWQ standards [5].

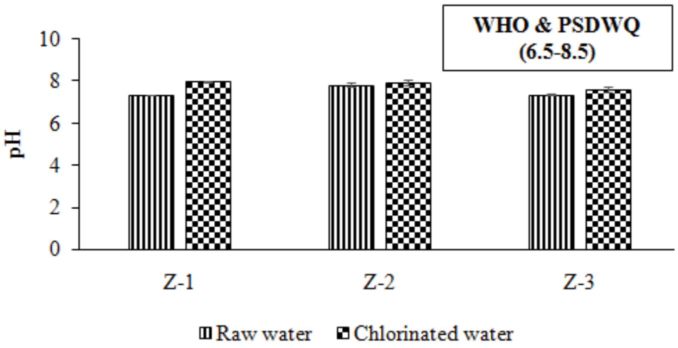


Fig.2: pH profiles of Raw and Chlorinated water of three respective zones.

Electrical conductivity (EC) is the capacity of water to carry electric current. It is directly related to the amount of total dissolved solids (TDS) in water. The larger the amount of TDS, the greater the value of EC [13]. The EC of raw water ranged from 869-923µS/cm and the EC of water after chlorination ranged from 868-951µS/cm. The storage tank containing raw water in zone 2 was found to have the highest EC of 923µS/cm and after, chlorination the water of the same zone (Z-2) was found to have the highest EC of 951µS/cm. The raw water and water after chlorination in zone 3 were observed to have the lowest EC of 869µS/cm and 868µS/cm, respectively. Although zone 2 was found to have the highest EC before and after chlorination, the EC of all the zones (raw & chlorinated water) were found to be within the permissible limits set by WHO that is 2500µS/cm, as shown in Figure 3.

There was no significant difference in the value of EC in raw water and water after chlorination. Only in zone 2, the value of EC increase slightly after chlorination which could be due to any factor like change in temperature or salinity but was within the permissible limits. This also indicates that the raw and chlorinated water of zone 2 will have the highest values of TDS. According to a similar study carried out by Amin et al., physicochemical parameters of storage tank water of 10 locations in Peshawar were accessed. The value of EC ranged from 548-897µS/cm, which was also found within the range set by WHO respectively [5].

Water having conductivity greater than 2500µS/cm is considered unacceptable for drinking. It has many negative impacts on human health, like stone formation in the intestines and kidneys, thus eventually leading to kidney failure. In addition, many studies confirm hypertension in people consuming water having high electrical conductivity [14].

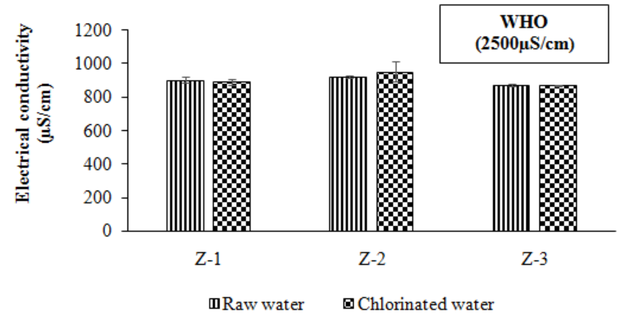


Fig.3: Electrical conductivity profiles of Raw and Chlorinated water of three respective zones.

The turbidity of water is the amount of suspended solid particles in water [15]. Usually, it is because of the colloidal and exceptionally fine dispersions [13]. The turbidity of raw water in all three zones ranged from 0.86-1.21NTU and water turbidity after chlorination ranged from 1.03-1.77NTU. The raw water of the storage tank in zone 2 was found to have the highest turbidity of 1.21NTU. However, water after chlorination in zone 1 was found to have the highest turbidity of 1.77NTU. The lowest turbidity of raw water was found in zone 1 with 0.86NTU, the lowest turbidity was observed in zone 3 with 1.03NTU. But the turbidity of all the zones before and after chlorination was found to be within the permissible limits set by WHO and PSDWQ that is <5NTU, as shown in Figure 4. Turbidity of water after chlorination increased in zone 1, which could be due to some settleable solids which would have become suspended but were within the required limits.

According to a similar study carried out by Meride and Ayenew, the quality of drinking water supplied to the Wondo genet campus Ethiopia residents was accessed. The mean value of turbidity obtained was 0.98NTU which was also found within WHO's limit [15].

In this study, the value of turbidity was greater than required for effective disinfection (<0.5NTU). Water with a large amount of turbidity is considered to harbor more pathogens, thus contaminating the water and giving rise to many waterborne diseases like vomiting, diarrhea, and abdominal cramps, etc. Water having high turbidity is also challenging to disinfect [16].

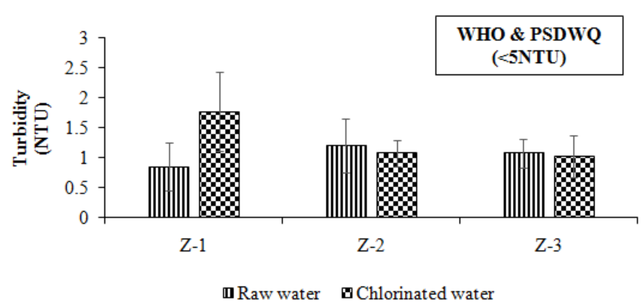


Fig.4: Turbidity profiles of Raw and Chlorinated water of three respective zones.

In assessing water quality, dissolved oxygen is an important parameter; it portrays the biological and physical conditions present in the water [13]. It is highlighted in many studies that the amount of DO decreases during the months of summer and increases during the months of winter, indicating its reverse relation with temperature. The DO of raw water in all the three zones ranged from 6.2-7.7mg/L and the value of DO after chlorination ranged from 7.9-8.1mg/L, respectively. The raw water in zone 2 was found to have the highest DO of 7.6mg/L and the water of zone 2 & 3 after chlorination was found to have the highest DO of 8.1mg/L. Whereas the raw water of zone 3 was found to have the lowest DO of 6.2mg/L and after chlorination, zone 1 was observed to have the lowest DO of 7.9mg/L. However, DO of all the three zones (including both raw & chlorinated water) were found within limits, which is 6-8mg/L, as shown in Figure 5. Thus, dissolved oxygen increased in water after chlorination but was within the required limits.

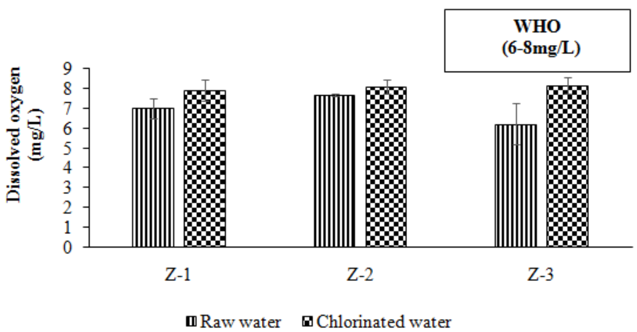


Fig.5: Dissolved oxygen profiles of Raw and Chlorinated water of three respective zones.

Hardness is the quality of water that inhibits lather development with soap. Additionally, it elevates the boiling point of water. Water hardness is the amount of magnesium and calcium salts in water [13]. The hardness of raw water in the storage tanks of all the zones ranged from 376.7-404.7mg/L and water after chlorination had hardness ranged from 362-375.3mg/L, respectively. The raw water in zone 1 was observed to have the highest hardness of 404.7mg/L, whereas, after chlorination, zone 2 was observed to have the highest hardness of 375.3mg/L. The raw water in zone 2 was found to have the lowest hardness of 376.6mg/L and after chlorination, the water in zone 3 was found to have the lowest hardness of 362mg/L. But the hardness of all the three zones (including raw and chlorinated water) was found within the permissible limits set by WHO and PSDWQ which is <500mg/L, as shown in Figure 6. No major difference in the values of hardness was observed in raw water and water after chlorination.

According to a similar study carried out by Adegboyega et al., water samples were collected from four wells within Idi Ayunre, Ibadan, Oyo State, Nigeria. The hardness of water samples was in the range 58.97-345.67mg/L, respectively. They were found within the set acceptable standards of WHO. Hard water is not fit for agricultural and domestic purposes. Drinking water with hardness greater than 500mg/L is considered not fit for people with kidney and bladder stones [17].

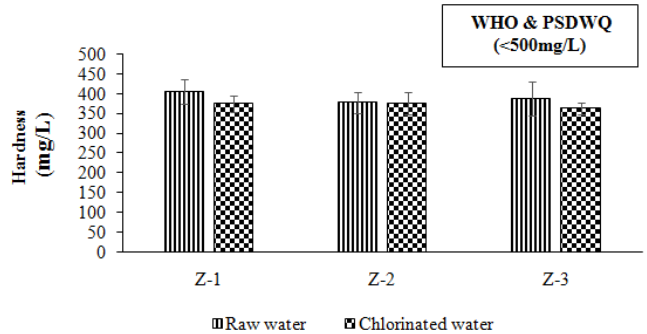


Fig.6: Hardness profiles of Raw and Chlorinated water of three respective zones.

Water containing carbonate, hydroxide, and bicarbonate compounds of sodium, calcium, and potassium makes water's total alkalinity. The alkalinity of water is the capacity of water to neutralize a strong acid [13]. The alkalinity of raw water of all the zones ranged from 371.3-430mg/L and the alkalinity of water after chlorination was found to range from 381.3-416.7mg/L, respectively. The raw water and water after chlorination of zone 1 was found to have the highest alkalinity of 430mg/L and 416.7mg/L. The lowest alkalinity was observed in the raw and chlorinated water of zone 2, which was 371.3mg/L and 381.3mg/L. However, the alkalinity of all the three zones (including raw and chlorinated water) was found within the permissible limits set by WHO and PSDWQ that is <500mg/L, as shown in Figure 7. No major difference in the values of alkalinity was observed in raw water and water after chlorination.

According to Sila's similar study, various physicochemical parameters of dams, furrows, rivers, wells, springs, rainwater, and borehole water were analyzed. The alkalinity was found in the range of 59-196.3mg/L, which was found within WHO's permissible limit [16]. It is reported that water having alkalinity greater than 500mg/L has an unpleasant taste [18].

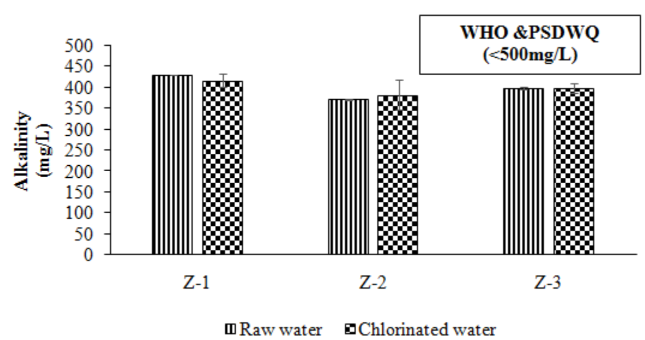


Fig.7: Alkalinity profiles of Raw and Chlorinated water of three respective zones.

Total suspended solids are considered major pollutants in water as they provide an area of attachment for microbes and pathogens, thus leading to water contamination. Many waterborne diseases are a result of high TSS and turbidity in water [5]. The TSS in the raw water of all the zones ranged from 3.3-14.3mg/L. After chlorination, the amount of TSS ranged from 8.7-12.7mg/L, respectively. The raw water of zone 2 was found to have the highest TSS of 14.3mg/L. Whereas, after chlorination, both zone 1 and 3 were found to have the highest TSS of 12.6mg/L. Raw water with the lowest TSS was found in zone 3 with 3.3mg/L of TSS and after chlorination, the lowest amount of TSS was found in zone 2 with 8.6mg/L of TSS. Therefore, raw water of zone 1&2 and water after chlorination in all three zones was more than the limits set by WHO that is 5mg/L, as shown in Figure 8.

In this study, as TSS was found above the permissible limit, water is likely to be loaded with microbes because of more surface area provided by TSS for microbe attachment. Thus this water, even after chlorination, is not fit for drinking purposes. The possible reason for high TSS in raw water could be the weathering of soil and rocks as the water is extracted from groundwater aquifers than through tube wells reach storage tanks. The increase in TSS after chlorination in zone 1 and zone 3 could be due to some of the settleable solids at the bottom of the storage tank, which could have become suspended during chlorination when the samples were collected. According to a similar study carried out by Amin et al., TSS of storage tank water from 10 locations in Peshawar was accessed. It was found in the range of 4-23mg/L with a mean value of 7.5mg/L, also found above WHO's permissible limit [5].

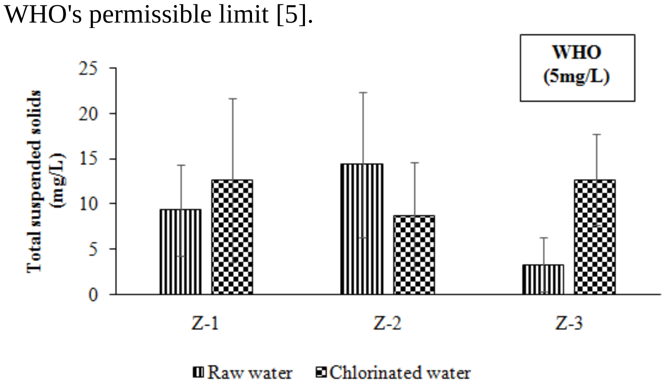


Fig. 8: Total suspended solid profiles of Raw and Chlorinated water of three respective zones.

Water has the potential to dissolve a broad length of organic and inorganic minerals [15]. The high amount of TDS in water gives an unpleasant taste to water and can give rise to many health issues [19]. TDS in the raw water of storage tanks in all the three zones ranged from 483.3-570mg/L and the TDS of water after chlorination was found to range from 516.7-686.7mg/L, respectively. The raw water and water after chlorination in zone 2 was found to have the highest TDS of 570mg/L and 686.6mg/L. The lowest amount of TDS was found in the raw and chlorinated water of zone 1 with 483.3mg/L and 516.6mg/L of TDS. TDS in the raw and chlorinated water of all the zones was within the permissible limits prescribed by WHO that is <1000mg/L, as shown in Figure 9. The values of TDS in all three zones were found to increase in water after chlorination remaining within the prescribed limits.

According to a similar study carried out by Meride and Ayenew in which drinking water quality of Wondo genet campus in Ethiopia was accessed. The mean value of TDS was found within the permissible standards 118.19mg/L. There are negative effects of drinking water having TDS greater than 1000mg/L, especially on heart and kidney diseases. Some studies have also confirmed that people drinking water with high TDS suffer from constipation (Meride and Ayenew, 2016). Water with high TDS can also form scales in heaters, water pipes, household appliances, and boilers [9].

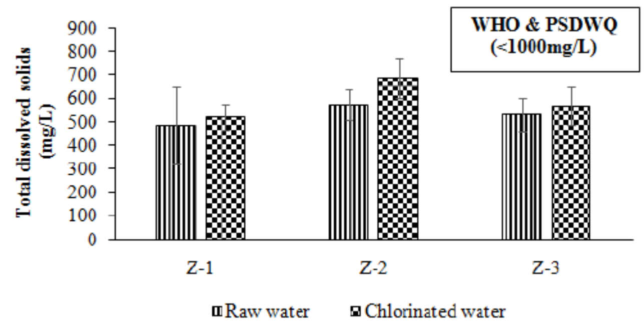


Fig. 9: Total dissolved solid profiles of Raw and Chlorinated water of three respective zones.

Total organic carbon is often considered a non-specific indicator of water quality. The value of TOC in water should be low as it provides nutrients that support microbial growth, which in turn reduces the dissolved oxygen in water, which is essential for aquatic life [20]. TOC in the raw water of all the three zones ranged from 0.10-0.82mg/L. After chlorination, the TOC in water was found to range from 0.08-0.18mg/L. The highest TOC was observed in the raw water of zone 3 with a value of 0.82mg/L and zone 1 was found to have the highest TOC after chlorination with a value of 0.18mg/L. The lowest TOC was observed in the raw water of zone 2 with a value of 0.10mg/L. The lowest amount of TOC in water after chlorination was found in zone 3 with a value of 0.08mg/L, respectively, as shown in Figure 10. Thus, the total organic carbon in raw water was found to be more than in the water after chlorination. Low values of TOC in water after chlorination is beneficial for water quality as low or negligible values of TOC allow less bacterial growth and production.

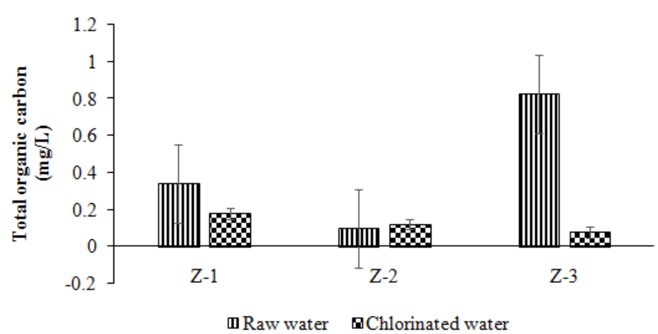


Fig. 10: Total organic carbon profiles of Raw and Chlorinated water of three respective zones.

Chlorine is an effective disinfectant in the water. Chlorine is added to drinking water to eliminate bacterial populations and make it fit for consumption. The amount of Chlorine added will interpret the quantity of residual Chlorine at the consumer end [21]. Free Chlorine in the raw water of storage tanks in all three zones ranged from 0.04-0.09mg/L and free Chlorine in water after chlorination was found to range from 0.06-0.07mg/L, respectively. The highest amount of free Chlorine was detected in the raw water of zone 1 with a value of 0.09mg/L and zone 3 was found to have the highest amount of free Chlorine with the value of 0.07mg/L. The lowest amount of Free Chlorine in raw water was observed in zone 3 with a value of 0.04mg/L and zone 1 was found to have the lowest amount of free Chlorine after chlorination with a value of 0.05mg/L. Therefore, free Chlorine in all three zones (including raw and chlorinated water) was below the limits set by WHO and PSDWQ. That is, at source, it should be 0.5-1.5mg/L and at the consumer end, it should be 0.2-0.5mg/L, respectively, as shown in Figure 11.

The amount of Total Chlorine in the raw water of storage tanks in all three zones ranged from 0.10-0.09mg/L and after chlorination, the value of total Chlorine ranged from 0.22-0.24mg/L. The highest amount of total Chlorine in raw water was observed in zone 1 and 3 with a value of 0.10mg/L. After chlorination, the highest amount of total Chlorine was observed in zone 3 with a value of 0.24mg/L. The lowest amount of total Chlorine in raw water was observed in zone 2 with a value of 0.09mg/L and after chlorination, the lowest amount of total Chlorine was observed in zone 1 with a value of 0.22mg/L, as shown in Figure 12.

Possible reasons for why the amount of free Chlorine decreased in zone 1 and 2 after chlorination could be that some substances such as hydrogen sulphide, manganese, and iron, if dissolved in the water, may react with Chlorine. Chlorine which reacts in this way, does not contribute to disinfection and is lost. In water, Chlorine can reversibly react with ammonia and organic matter. The compounds formed are weak disinfectants and are referred to as combined Chlorine or residual combined Chlorine. Turbidity <0.5NTU is required for efficient disinfection. If the value of turbidity is greater than 0.5NTU, then higher disinfection doses and contact time will be required to ensure that adequate chlorination is achieved. In this study, turbidity values were greater than 0.5NTU, thus can affect disinfection. The amount of residual Chlorine at the point of application is far below the expected amount. This amount will vanish when the water reaches the consumer end, thus giving rise to the bacterial population in water and making it unfit for consumption.

Bacteriological Analysis:

The total and fecal coliform in raw water in storage tanks ranged from 23 to greater than 23 (according to the MPN index). The total and fecal coliforms in water after chlorination were found to range from 16 to greater than 23 (according to the MPN index). The raw water of zone 2 was found to have the highest total and fecal coliforms greater than 23 according to the MPN index and a 95% probability range of (13-…..). However, the water after chlorination in zone 1 was most contaminated with total and fecal coliforms having an MPN index of greater than 23 and a 95% probability range of (13-…..). The lowest amounts of total and fecal coliforms were detected in the raw water of zone 1 and 3 with MPN index 23 and having a probability range of (8.1-53). The lowest amount of total and fecal coliforms in water after chlorination was found in zone 3 with an MPN index of 16 and a probability range of (5.8-34).

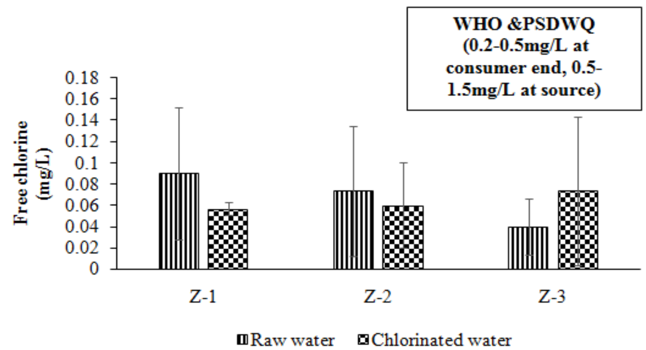


Fig. 11: Free chlorine profiles of Raw and Chlorinated water of three respective zones.

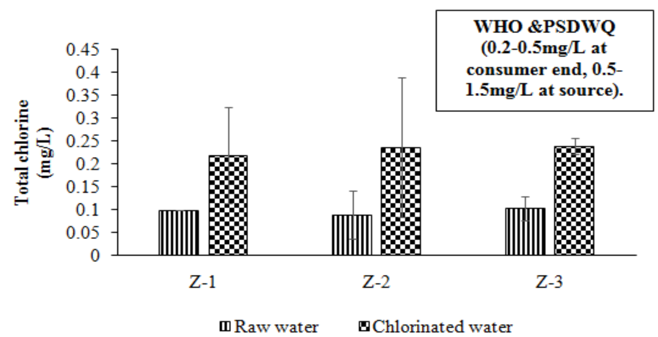


Fig. 12: Total chlorine profiles of Raw and Chlorinated water of three respective zones.

The basic purpose of chlorination in water is to kill or eliminate bacterial contamination to make the water suitable and healthy for drinking. It is expected that after chlorination, the MPN index of the treated water should decrease. However, it was noted that the MPN index of the raw water after chlorination in zone 1 increased instead of decreasing, which clearly showed that chlorination in that zone had negligible effects as compared to other zones thus making zone 1 the most contaminated zone of all the zones. The possible reason could be that the dosage of Chlorine applied is not enough for disinfection purposes. The workers were not educated enough to administer the required amount of Chlorine necessary for disinfection. At the source, it should be 0.5-1.5mg/L, but unfortunately, Chlorine far less than this value was detected in all zones after chlorination. Therefore, the MPN index of zone 1 was increased; for zone 2 and 3, it was reduced but not eliminated. The mixing time provided to Chlorine was less than 15 minutes which should be at least 30 minutes for effective disinfection.

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Table 1. MPN Index of Raw and Chlorinated water of three respective zones.

Sample		MPN Index/100ml (Mean value)	95% Probability range	WHO Limits	PSDWQ
Raw water	**Z-1**	23	8.1-53	0/100ml	0/100ml
	Z-2	>23	13-…….		
	Z-3	23	8.1-53		
Chlorinated water	**Z-1**	>23	13-……		
	Z-2	23	8.1-53		
	Z-3	16	5.8-34		

Proper chlorine dosages should be applied to disinfect water and make it fit for consumption. However, the total and fecal coliforms in raw and chlorinated water in all zones were above the permissible limits set by WHO and PSDWQ, 0/100ml, respectively, as shown in Table 1.

According to a similar study carried out by Amin et al. in which bacteriological analysis of storage tank water of 10 locations in Peshawar was accessed through MPN technique. The MPN index was found in the range of 2.2 to >23 MPN/100ml, which was also found exceeding the permissible limit set by WHO and PSDWQ [5].

In the present study, the presence of E.coli in all samples highlights the entrance of fecal contamination in water. Another study carried out by Sunday et al. showed that microbial analysis of 10 water samples used for domestic purposes in Okada town, Edo state, Nigeria, was examined through the MPN technique. The MPN index was in the range 7-14 MPN/100ml. which was also found above the permissible standards [4]. Water loaded with microbes can cause numerous waterborne diseases

Conclusion:

The results of this study highlight that all the selected physicochemical parameters for raw and chlorinated water were found within the permissible limits set by WHO and PSDWQ except TSS and Chlorine (free & total). TSS for raw and chlorinated water were found above the permissible standard, thus providing more microbial attachment sites. In contrast, Chlorine was found far below the recommended limit required for disinfection. The results of the bacteriological analysis were also found to exceed the permissible limit. Low detection of Chlorine in raw and chlorinated water is directly related to elevated levels of microbial growth in water. Therefore, proper dosages, regular monitoring of Chlorine are highly recommended and advanced filtration techniques should be installed for safe drinking water.

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