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***Original Research Article***

# Evaluation of Selected Physicochemical Parameters to Assess Quality Status of Drinking Water in Delhi, India

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## ABSTRACT

Water is one of the most vital and critical natural resources on the planet that all living organisms require for survival. Unfortunately, there is a continuous decline in potable water quality due to the population burden on water resources, industrial and agricultural interference. Consumption of impure water is impacting the survival rate and it is important to develop strategies for sustainable management of water as this crucial resource is a vehicle for many deadly diseases, if remain untreated. Therefore, it is essential to generate awareness regarding the source and quality of drinking water to avoid any health risk. The present pilot study was undertaken to determine the quality of drinking water (ground/ handpump/ submersible water-14 samples and MCD/ NDMC supplied tap water-17 samples) from various zones of Delhi (North, East, West, South & Central) for human consumption. The 31 water samples were tested for selected physical (Colour, Turbidity, Odour, Taste and TDS) and chemical parameters (pH, DO, free $CO_2$, alkalinity, chloride ion concentration, and total hardness) using standard titrimetric procedures. Some samples had high levels of various parameters, indicating a decrease in primary and secondary standard of potable water. It is mandatory to do necessary analysis before consuming the water from any resource for any purpose at regular intervals and offer sustainable and resource-efficient water solutions.

**Keywords:** Delhi, Drinking, Ground water, Health, Potable

## 1. INTRODUCTION

Clean, safe, and uncontaminated water is vital to the survival of all living organisms and the smooth functioning of ecosystems, communities, and economies (Kassegne & Leta, 2020). Access to safe drinking water in terms of physical, chemical and bacteriological parameters is a prerequisite for quality health, socio-economic growth and achieving environmental sustainability. Groundwater is one of the most dependable sources of drinking water in rural and urban India (Jain & Pahade, 2023). Consumption of untreated groundwater having any contamination poses serious health risks and is responsible for various waterborne diseases with immediate manifestation. Therefore, it is imperative to check the quality of potable water regularly (Sitaram, 2022).

The poor management of water resources and contamination essentially due to population growth and the resultant increase in waste discharge from various anthropogenic activities has been a significant concern in sustaining a safe water supply (Kanase et al., 2016). Also, untreated industrial and agricultural discharge leads to the heavy load of chemical contaminants to the groundwater, the primary source of water for domestic use in many parts of the cities (Ojekunlea et al., 2020). Contrary to that, the presence of chemical impurities results in a long-lasting impact on general well-being (Daud et al., 2017). Water contamination can be found not only at the source but also in supply chain. As the water flows through the supply system, chemical by-products can be formed from the material used for pipeline construction (Reda, 2016). Before describing water as potable, it must comply with specific physical, chemical and microbiological standards, which are designed to ensure that it is drinkable and safe for drinking (Ottong & Ekanem, 2021). There is a need for urgent care of all water chain supplies, namely the reservoir outlets, taps and fountains, and general awareness about water contamination (Bancessi et al., 2020). Every year, people die from the consequences of unsafe water, and the most significant impacts are on children under the age of five. The physico-chemical analysis is primarily a matter of evaluating water quality for best use, such as drinking, irrigation, fishing and industrial use, and understanding complex processes, the interaction of climate and biological water processes (Chouhan et al., 2021). Drinking water supplied to the consumers should be of prescribed physico-chemical and microbiological quality (Mulamattathil et al., 2015). Any variation that is beyond the established standards makes water contaminated and unfit for any use for which it is intended (Akaho et al., 2022). According to WHO, 1 in 3 people or 2.2 billion people worldwide lack safe drinking water (WHO, 2019). Water available for human consumption is safe as long as it does not cause any significant health risks to the population. Safe drinking water is an essential requirement and a primary concern in developing countries. According to WHO, drinking or potable water is defined as the water having the acceptable quality of its physical, chemical and bacteriological parameters to be safely used for human consumption (WHO, 2011). Therefore, it becomes a matter of primary concern to do a physico-chemical analysis of potable water at regular intervals to protect public health. Quality assessment of groundwater is of great concern for mankind because it directly influences human life (Ibrahim et al., 2019). Rural groundwaters' physico-chemical and microbial quality is severely affected by gardening activities, lack of management of household waste and wastewater systems (Adamou et al., 2020). Given that variation in water quality is a continuous process, updated water quality data are necessary for water quality assessment (Rahmanian et al., 2015). The present study was undertaken to analyse the quality of potable water samples (ground/ handpump/ submersible water and MCD/ NDMC supplied tap water) with respect to few selected parameters from different regions in the capital city of Delhi using standard laboratory procedures.

## 2. MATERIALS AND METHODS

### 2.1. Water Samples

31 water samples (ground/ handpump/ submersible water and MCD/ NDMC supplied tap water) were collected in pre-labeled 1L polyethylene sampling bottles with necessary precaution (avoiding contamination) from randomly selected sites. Sampling was done from five different zones (North, East, West, South and Central) of the Delhi region.

### 2.1.1. Sample Codes for MCD/ NDMC Supplied Tap Water

NS-1-3 North Delhi Samples 1-3, ES-1-4 East Delhi Samples 1-4, WS-1-3 West Delhi Samples 1-3, SS-1-3 South Delhi Samples 1-3, CS-1-3 Central Delhi Samples 1-3.

### 2.1.2. Sample Codes for Ground/ Handpump/ Submersible Water

NG-1-3 North Delhi Samples 1-3, EG-1-2 East Delhi Samples 1-2, WG-1-3 West Delhi Samples 1-3, SG-1-4 South Delhi Samples 1-4 CG-1-2 Central Delhi Samples 1-2

### 2.2. Physico-chemical Parameters

Physical properties (Colour, Odour, pH and TDS) were tested (visual appearance/ handheld meters) at the sampling site at the time of collection and chemical parameters (DO, free $CO_2$, alkalinity, chloride ion concentration and total hardness) were investigated in the laboratory using standard lab and titrimetric procedures. All tests were performed in triplicates.

## 3. RESULTS AND DISCUSSION

### 3.1. Colour and Odour

All the tested water samples were colourless and odourless.

### 3.2. Comparative analysis of pH levels

Out of 31 samples studied, 13 water samples (including supply and ground) showed neutral pH. Sixteen water samples (supply and ground) had pH in the range of 7.8 to 8.5. Only one groundwater sample from central (CG-1) Delhi showed a high value of 9.2.

pH is a parameter that guides the status of the acid-alkali balance of the water and serves as an essential index of the degree of pollution (Hussain et al., 2021). Low pH water is inherently acidic, soft and corrosive, while drinking water with a pH above 8.5 indicates the presence of highly alkaline minerals with aesthetic effects (Maskey et al., 2020). Aesthetic water issues are essentially harmless to health and affect only the taste and appearance of water and may make it feel unfit for some people. According to WHO (2011) guidelines, pH values do not directly affect human health but are considered essential parameters of water quality**.**

### 3.3. Comparative analysis of TDS levels

For the water samples studied, values of TDS ranged from 96.22±0.39 to 750.33±0.58 mg/L. Values were not in the desirable range for the four supply water samples (ES-1, SS-2, 3 and CS-2) from east, south and central Delhi (Figure 1A). However, all the supply water samples from the north and west Delhi had TDS values within the limits of WHO prescribed guidelines for drinking water. For groundwater samples, six samples (NG-2, EG-1, 2, SG-1, 2 and CG-2) from the north, east, south and central Delhi were not in the desirable range, 500 mg/L (Figure 1B).

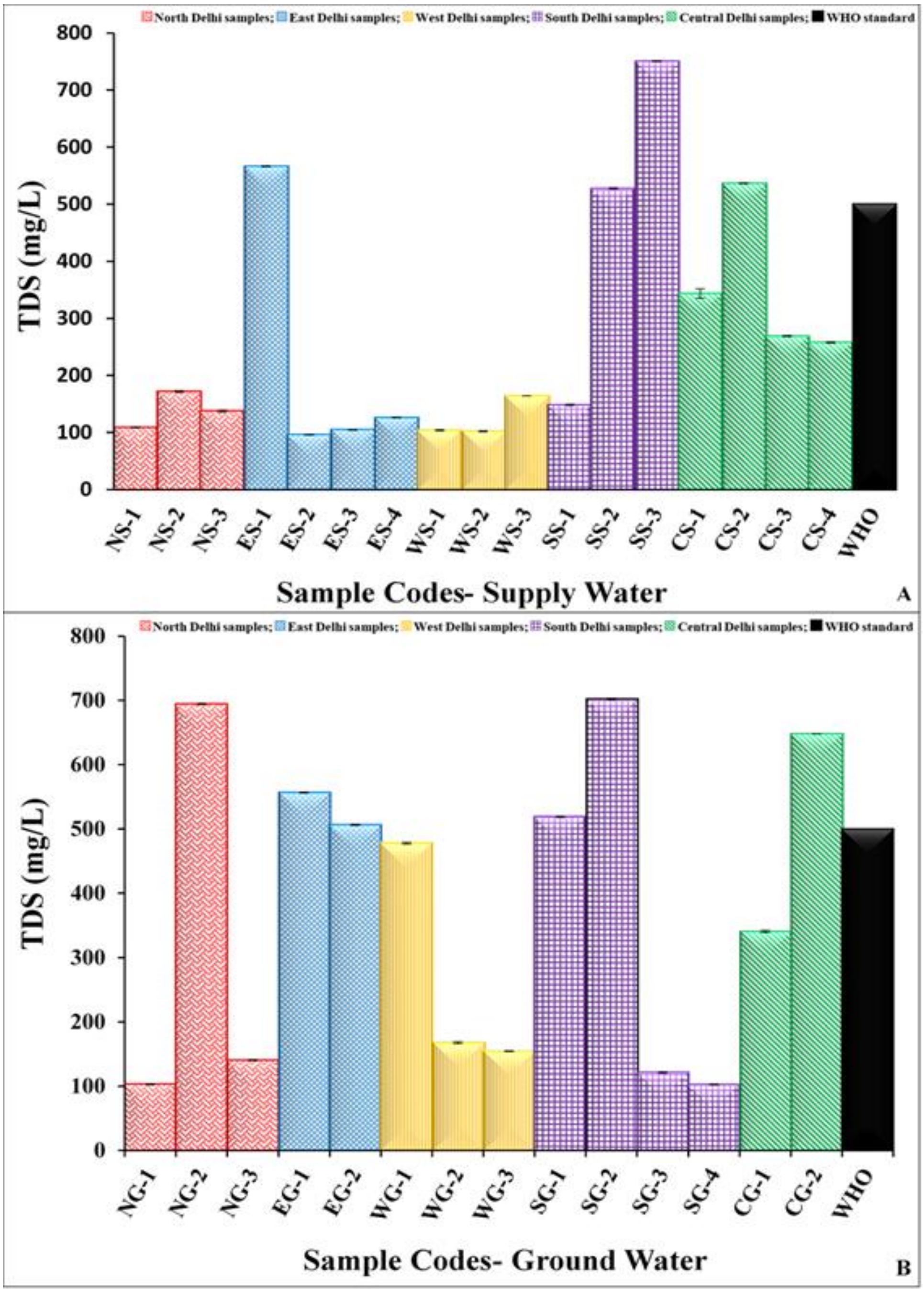


**Figure 1:** Comparative analysis of TDS levels in water samples from various zones of Delhi. (A) Supply water samples (B) Ground water samples.

Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matter dissolved in water and represent mainly carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates, calcium, magnesium sodium, organic ions, and other ions (APHA 2005). High values of TDS (Total Dissolved Solids) and hardness (calcium, and magnesium) indicate the presence of various cations and salts, which is common in the case of groundwater (Singh et al., 2021). It is an important parameter to assess the suitability of water for drinking, and a certain level of these ions is desired in potable water.

### 3.4. Comparative analysis of DO levels

In the samples analysed, the range of DO varied highly from 3.70 to 14.20 mg/L for supply water and from 3.00 to 10.30 mg/L for groundwater. It was found that four supply water samples (NS-3; ES-1 and CS-2, 3) from the north, east and central Delhi (Figure 2A) and five groundwater (WG-1, 2, 3; SG-4 and CG-2) samples from west, south and central Delhi have low values for dissolved oxygen (Figure 2B).

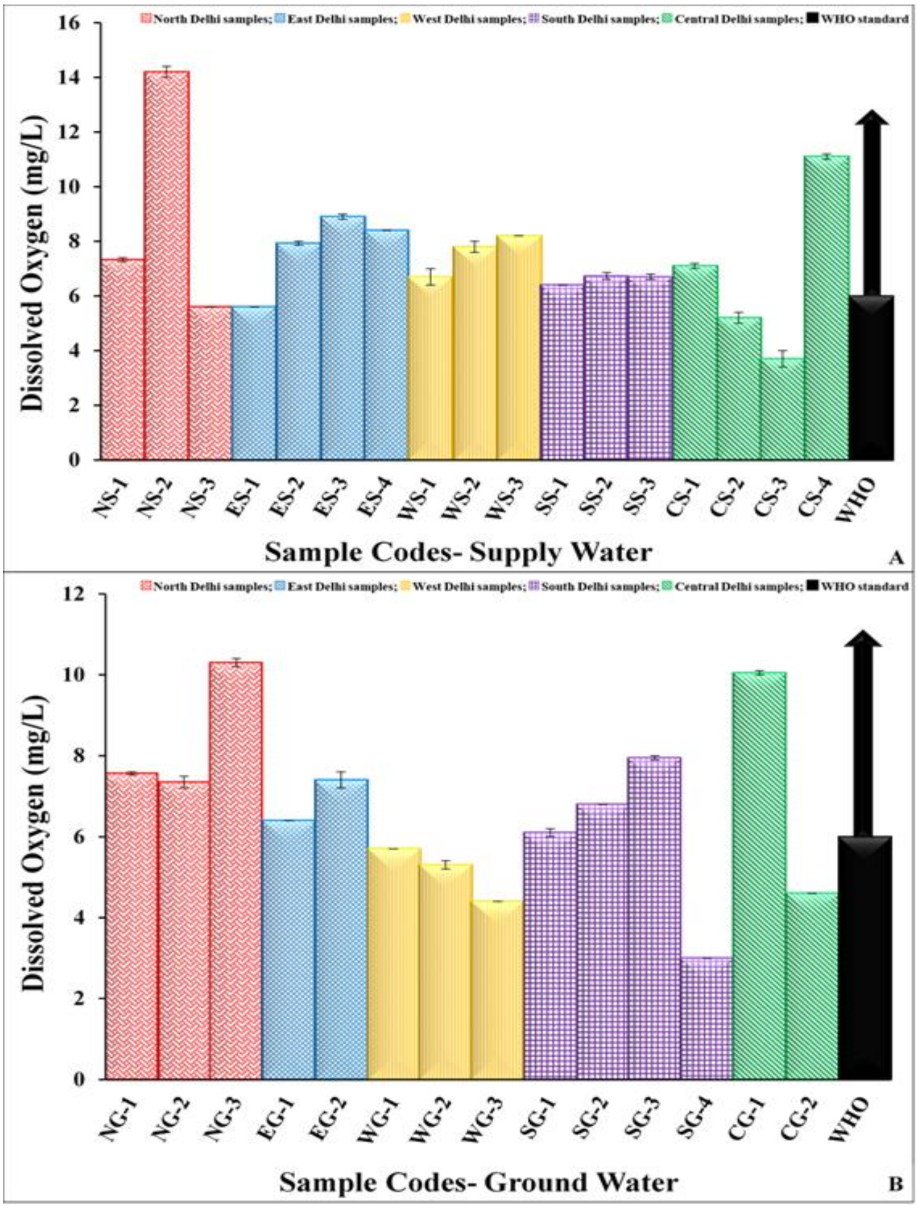


**Figure 2:** Comparative analysis of Dissolved Oxygen (DO) levels in water samples from various zones of Delhi. (A) Supply water samples (B) Ground water samples. Arrows indicate permissible values can be >6mg/L.

A high DO level in a community water supply is good as it makes drinking water taste better (Gupta et al., 2020). Dissolved Oxygen content for drinking water should be always more than six mg/L (WHO, 2011).

### 3.5. Comparative analysis of free $CO_2$ content

It was observed that the majority of supply water samples, except for four samples (NS-2, ES-3, WS-3, CS-2) fall within the permissible range (Figure 3A). Six samples from groundwater (NG-3, WG-3, SG-2, 4; CG-1, 2) showed a higher value of free carbon dioxide with respect to WHO limits (Figure 3B).

Although the presence of free carbon dioxide in water which is in the form of dissolved gas, increases the acidity of water due to the formation of carbonic acid, the same was not observed in the present study. The upper limit acceptable for drinking water in terms of free carbon dioxide is 22 mg/L (WHO, 2011).

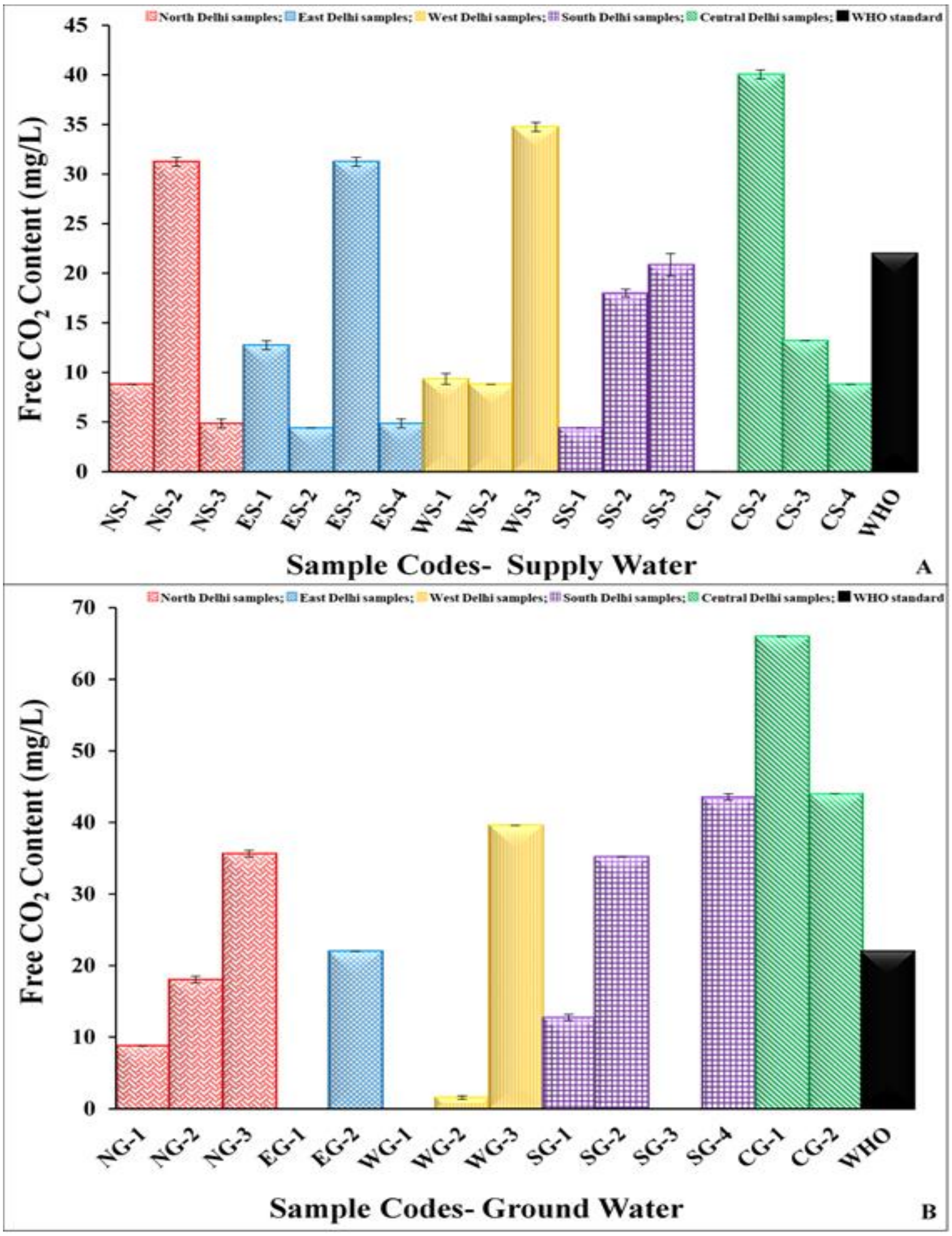


**Figure 3:** Comparative analysis of free $CO_2$ content in water samples from various zones of Delhi. (A) Supply water samples (B) Ground water samples.

### 3.6. Comparative analysis of total alkalinity levels

In the present investigation, the total alkalinity levels were above this range for six supply water samples from the north, east, west, and south Delhi (NS-2; ES-2; WS-2; SS-2, 3& CS-2). Out of fourteen groundwater samples analysed, nine samples (NG-2; EG-1,2; WG-2, 3; SG-1, 2, 4 &CG-2) from all the zones except north Delhi showed a very high level of alkalinity (Figure 4A, B).

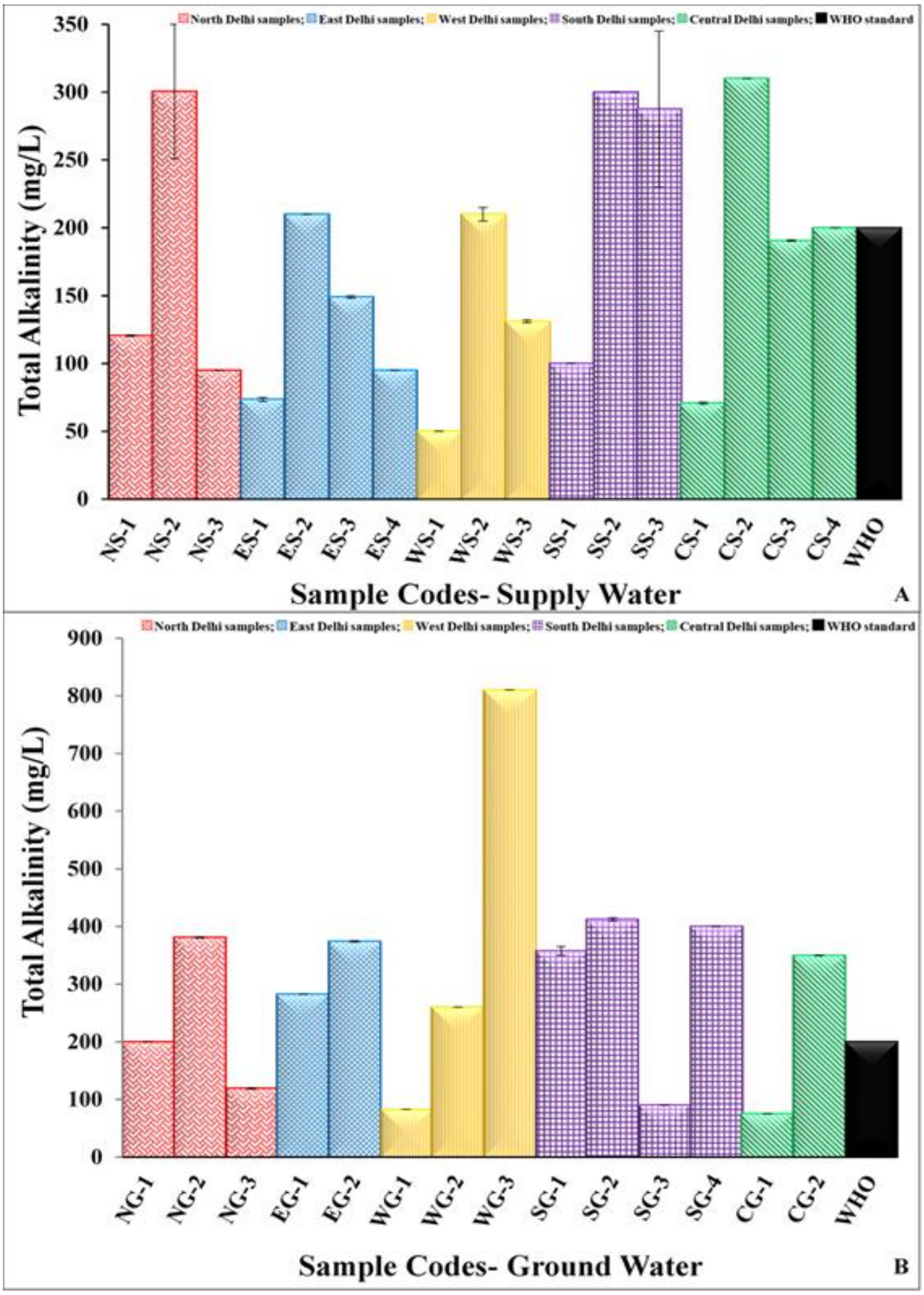


**Figure 4:** Comparative analysis of total alkalinity levels in water samples from various zones of Delhi. (A) Supply water samples (B) Ground water samples.

Alkalinity represents the buffering capacity and potential to maintain a relatively constant pH. The total of all of the alkaline species such as bicarbonates, carbonates, and hydroxides found in a water sample contribute to the hydrogen ion neutralisation resulting in an increased pH (Davis, 2010). Highly alkaline waters are unpalatable and unfit for drinking purposes. The upper limit for alkalinity is 200 mg/L for drinking water.

### 3.7. Comparative analysis of chloride ion content

All the supply water samples depict lower than the standard values given by WHO, 2011 for chloride ions which is 250 mg/L, except one sample from north Delhi (NS-2) (Figure 5A). Only two groundwater samples belonging to the west (WG-2) and central (CG-2) Delhi showed higher values for the same (Figure 5B).

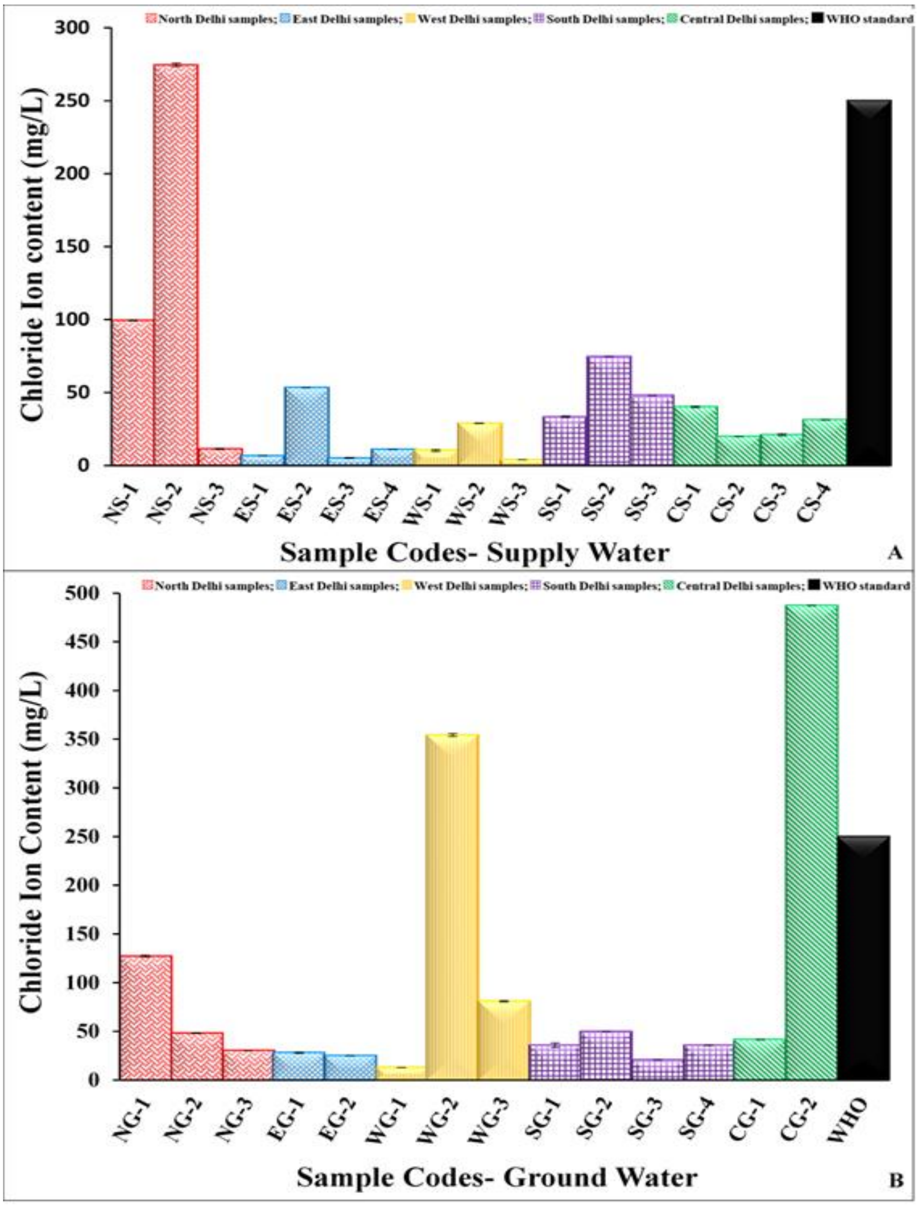


**Figure 5:** Comparative analysis of chloride ion content in water samples from various zones of Delhi. (A) Supply water samples (B) Ground water samples.

Chloride ions are found naturally in the surface as well as groundwater bodies. In drinking water, chlorides may be higher due to the treatment process where chlorine is used as a cleaner. Excessive chloride ion concentrations increase corrosion rates of metals in the distribution system due to an increase in electrical conductivity. This can lead to increased concentrations of other metallic ions in the supply water and an unpleasant taste.

### 3.8. Comparative analysis of hardness levels

Out of 31 samples studied, 29 of the water samples both from supply as well as ground showed total hardness values lower than the maximum limit (200 mg/L) prescribed by WHO, 2011 (Figure 6A, B). Only three groundwater samples, one each from the west, north (WG-1; NG-2) and central (CG-2) Delhi, showed higher values (Figure 6B).

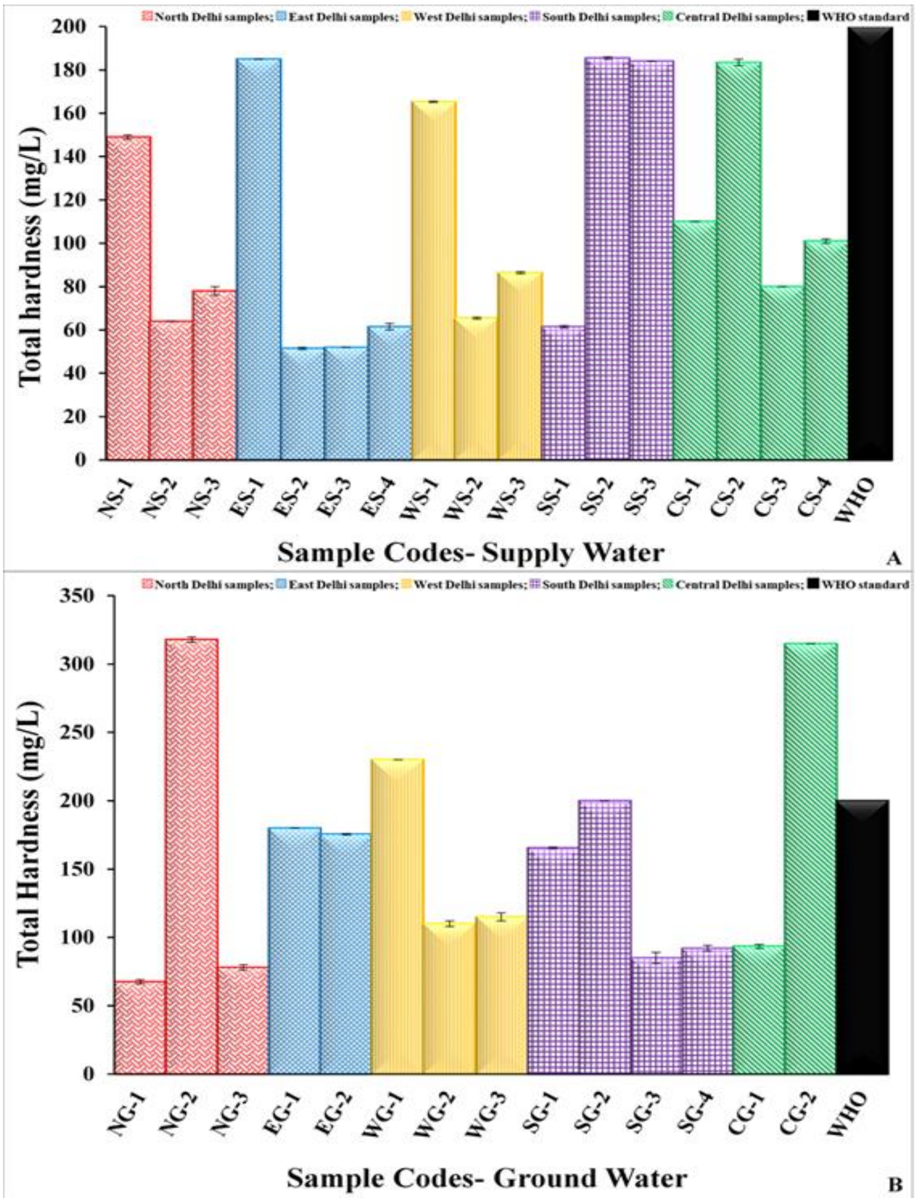


**Figure 6:** Comparative analysis of hardness levels in water samples from various zones of Delhi. (A) Supply water samples (B) Ground water samples.

Total hardness of water is representative of divalent metallic cations like $Ca^{+2}$, $Mg^{+2}$, $Sr^{+2}$, $Fe^{+2}$ and $Mn^{+2}$ and anions like $HCO^{3-}$, $CO_3^{-2}$, $SO_4^{-2}$, $NO_3^-$ and $SiO_3^{-2}$. The major constituents of all the ions responsible for water hardness are calcium and magnesium. Divalent cations of calcium and magnesium combine with anions to form carbonates and bicarbonates and, to a lesser degree, form sulphates and chlorides, resulting in temporary and permanent hardness, respectively. Absolutely soft waters are tasteless, corrosive, and can dissolve metals in solution.

## 4. CONCLUSION

In the present study conducted on potable water samples, most of the parameters were within the permissible range, but some levels crossed the desirable limits. According to the guidelines of BIS (Bureau of Indian Standards), it was found that the pH, chloride ion, and total hardness of almost all the water samples analyzed was within the desirable range. From the analysis, we can conclude that three samples from supply (NS-1, WS-1 and CS-1)and groundwater (NG-1, 3 and SG-3) are within the desirable range for almost all the tested parameters. Ongoing monitoring and good data are the cornerstones of effective efforts to improve water quality. Addressing water quality challenges will mean deploying real-time, low-cost, rapid, and reliable management technologies and building capacity and expertise in sustaining our lifeline. Management of water quality is essentially of great importance for the nation's overall growth. Also, proper evaluation is important to understand its true impact on the health of mankind. The Biological parameters need to be checked in the water samples for analysing the overall quality of water.

## CONFLICT OF INTEREST

The authors have no conflict of interest, financial or otherwise.

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*Annexure 1*

## LIST OF ABBREVIATIONS USED

| | | |
|---|---|---|
| APHA | : | American Public Health Association |
| BIS | : | Bureau of Indian Standards |
| $Ca^{2+}$ | : | Calcium |
| $CO_2$ | : | Carbon Dioxide |
| $CO_3^{2-}$ | : | Carbonate |
| DO | : | Dissolved Oxygen |
| $Fe^{2+}$ | : | Iron |
| $HCO^{3-}$ | : | Bicarbonate |
| MCD | : | Municipal Corporation of Delhi |
| $Mg^{2+}$ | : | Magnesium |
| $Mn^{2+}$ | : | Manganese |
| NDMC | : | New Delhi Municipal Corporation |
| $NO_3^-$ | : | Nitrate |
| pH | : | Potential of Hydrogen |
| $SiO_3^{2-}$ | : | Silicate |
| $SO_4^{2-}$ | : | Sulphate |
| $Sr^{2+}$ | : | Strontium |
| TDS | : | Total Dissolved Solids |
| WHO | : | World Health Organisation |

*Supplementary Data*

**Table 1:** Physico-chemical characteristics of potable supply water from various zones of Delhi.

| Zone | Sample Code | pH | TDS (mg/L) | D.O. (mg/L) | FREE $CO_2$ (mg/L) | Total Alkalinity (mg/L) | Chloride Ion (mg/L) | Total Hardness (mg/L) |
|---|---|---|---|---|---|---|---|---|
| North | NS-1 | 7 | 108.67±0.58 | 7.33 | 8.8 | 120.50±0.50 | 99.45±0.25 | 149±1 |
| | NS-2 | 7 | 172.00±1.00 | 14.2 | 31.25±0.45 | 300.50±49.50 | 274.50±1.10 | 64 |
| | NS-3 | 7 | 137.6±1.53 | 5.6 | 4.85±0.45 | 95 | 11.25±0.25 | 78±2 |
| East | ES-1 | 8 | 566.55±0.77 | 5.6 | 12.75±0.45 | 73.50±1.50 | 6.6 | 185 |
| | ES-2 | 8 | 96.22±0.39 | 7.93 | 4.4 | 210 | 53.4 | 51.50±0.50 |
| | ES-3 | 7 | 104.83±0.29 | 8.90±0.10 | 31.25±0.45 | 149±1 | 5.05±0.25 | 52 |
| | ES-4 | 7 | 126.17±0.29 | 8.4 | 4.85±0.45 | 95 | 11 | 61.50±1.50 |
| West | WS-1 | 7 | 103.7±1.37 | 6.7 | 9.35±0.55 | 50 | 10.35±0.65 | 165.30±0.30 |
| | WS-2 | 7 | 102.22±1.07 | 7.8 | 8.8 | 210±5 | 28.85±0.15 | 65.50±0.50 |
| | WS-3 | 7 | 164.00±0.00 | 8.2 | 34.75±0.45 | 131±1 | 3.9 | 86.42±0.42 |
| South | SS-1 | 7 | 148.22±1.34 | 6.4 | 4.4 | 100 | 33.25±0.65 | 61.5±0.50 |
| | SS-2 | 8.5 | 527.56±0.96 | 6.73±0.13 | 18±0.40 | 300 | 74.5 | 185.50±0.50 |
| | SS-3 | 8 | 750.33±0.58 | 6.70±0.10 | 20.85±1.15 | 287.50±57.50 | 48 | 184 |
| Central | CS-1 | 7.5 | 343.43±8.56 | 7.10±0.10 | Absent | 70.75±0.75 | 40.15±0.45 | 110 |
| | CS-2 | 8 | 536.33±0.58 | 5.2 | 40.05±0.45 | 310 | 198.8 | 183.50±1.50 |
| | CS-3 | 7 | 268.67±0.58 | 3.7 | 13.2 | 190.50±0.50 | 20.95±0.65 | 80 |
| | CS-4 | 8 | 257.67±1.15 | 11.10±0.10 | 8.8 | 200 | 31.3 | 101±1 |
| BIS* | | 6.5-8.5 | 500 | - | - | 200 | 250 | 200 |
| WHO** | | 6.5-8.5 | 500 | >6 | 0-22 | 200 | 250 | 200 |

*(BIS, 2012); **(WHO, 2011)

*Supplementary data*

**Table 2:** Physicochemical characteristics of potable ground water from various zones of Delhi.

| Zone | Sample Code | pH | TDS (mg/L) | D.O. (mg/L) | FREE $CO_2$ (mg/L) | Total Alkalinity (mg/L) | Chloride Ion (mg/L) | Total Hardness (mg/L) |
|---|---|---|---|---|---|---|---|---|
| North | NG-1 | 7 | 103.10±0.85 | 7.57±0.03 | 8.8 | 200 | 127.20±1.10 | 67.50±1.50 |
| | NG-2 | 8 | 694.33±1.15 | 7.35±0.15 | 18.05±0.45 | 381±1 | 48.25±0.25 | 318±2 |
| | NG-3 | 7 | 140.33±0.58 | 10.30±0.10 | 35.65±0.45 | 119±1 | 30.4 | 78±2 |
| East | EG-1 | 8 | 556.78±0.69 | 6.4 | Absent | 282.5 | 28±0.0 | 180 |
| | EG-2 | 7 | 506.33±0.58 | 7.40±0.20 | 22 | 374±1 | 25.1 | 175±0.50 |
| West | WG-1 | 8 | 478.10±1.15 | 5.7 | Absent | 82.5 | 12.8 | 230 |
| | WG-2 | 8 | 167.67±1.53 | 5.30±0.10 | 1.56±0.24 | 260 | 354.30±1.50 | 110±2 |
| | WG-3 | 8 | 154.33±0.58 | 4.4 | 39.6 | 810 | 80.90±0.60 | 115±3 |
| South | SG-1 | 8 | 519.11±0.84 | 6.10±0.10 | 12.75±0.45 | 357.50±7.50 | 35.75±2.25 | 165.50±0.50 |
| | SG-2 | 7.8 | 702.00±1.00 | 6.8 | 35.2 | 412.50±2.50 | 49.83 | 200 |
| | SG-3 | 6.8 | 121.33±1.15 | 7.95±0.05 | Absent | 90 | 20 | 85±4 |
| | SG-4 | 8 | 102.67±0.58 | 3 | 43.55±0.45 | 400 | 35.80±0.20 | 92±2 |
| Central | CG-1 | 9.2 | 340.67±1.53 | 10.05±0.05 | 66 | 75 | 41.5 | 93.50±1.50 |
| | CG-2 | 8.5 | 648±0.00 | 4.6 | 44 | 349.50±0.50 | 487.3 | 315 |
| BIS* | | 6.5-8.5 | 500 | - | - | 200 | 250 | 200 |
| WHO** | | 6.5-8.5 | 500 | >6 | 0-22 | 200 | 250 | 200 |

*(BIS, 2012); **(WHO, 2011)