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# Physiochemical analysis of spring water used for drinking purposes in Northern Khyber Pakhtunkhwa, Pakistan

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## Abstract

Majority of the water supply schemes in the Northern Khyber Pakhtunkhwa have natural springs as source of water supply and utilizing it without any physical or chemical treatments except for primary sedimentation. The physiochemical characteristics of these rural sources of water supply are very little understood. This study primarily investigates the water quality of randomly selected springs located in Dir, Malakand, and Swat Districts to check the suitability of spring water for drinking purposes as per National Standards of Drinking Water Quality (NSDWQ) and according to World Health Organization (WHO) guidelines. Water samples from different springs were collected at different time interval and analyzed for physiochemical parameters. The concentrations of the parameters were compared with the NSDWQ and WHO guidelines.

Samples were analyzed for color, electrical conductivity (EC), odor, suspended solids (SS), total dissolved solids (TDS), taste, temperature (T), turbidity, pH, alkalinity, calcium ($Ca^{+2}$), carbonates ($CO_3^-$), chloride ($Cl^-$), zinc ($Zn^{+2}$), dissolved oxygen (DO), fluoride ($F^-$), iron ($Fe^{+2}$), magnesium ($Mg^+2$), manganese ($Mn^{+2}$), nitrate ($NO_3^-$), nitrite ($NO_2^-$), sulfate ($SO_4^{2-}$), calcium hardness (CH), magnesium hardness (MH), and total hardness (TH). Variations from standard values were observed in Temperature (13.10 °C to 21.30 °C), Alkalinity (18.00 mg/L to 162.33mg/L), $CO_3^-$, (0 mg/L to 9.33 mg/L) and DO (5.60 mg/L to 12.60 mg/L). Also, Water samples of districts Swat and Dir were found compliant with NSDWQ and WHO guidelines, however, some of the parameters for Malakand district were higher but still under the acceptable thresholds. These includes T (21.30°C), SS (34 mg/L), $Ca^{+2}$ (75.88 mg/L), DO (9.870), CH (189.33 mg/L), and $Zn^{+2}$ (4.250 mg/L).

*Keywords:* Natural springs, Physiochemical parameters, NSDWQ, WHO.

## 1. Introduction

Water is vital for human survival and other associated activities. Water obtained from different sources must be potable. This potable water must be free from odor, turbidity, color, and microbes and should be aesthetically pleasant (Siwila and Brink, 2019; Vigneswaran, 2009) The quality of important potable sources of water rapidly threatened by fluctuating and increasing physical and chemical contaminations besides declining the discharge of these sources, due to rapid growth in population, unplanned infrastructure, domestic wastes, over exploitation, and pollution (Tularam and Murali, 2015). External factors which affect the quality of water such as pH, TDS, EC, meteorological events, agricultural chemicals, and disposal of wastes, which needing immediate attention (Hussain et al., 2014).

Water pollution is a physical process that occurs due to anthropogenic activities in various water bodies such as reservoirs, wetlands, ground water, and rivers. Water pollution often occurs when toxic chemicals from household waste and industries either encounter water bodies, runoff or leach into different water resources (Agarwal, 2009).

The use of low-quality water ensuing water borne diseases and their spread that contribute about 80% of all diseases and causing 33% of deaths (Daud et al., 2017). Unhygienic activities coupled with contaminated water use cause several diseases such as diarrhea, worm infection, typhoid, giardiasis, cryptosporidium, cholera, dysentery, guinea, gastroenteritis and hepatitis. Children are more susceptible to water borne diseases. Diarrhea, a waterborne illness is the leading cause of death, whereas every fifth person suffers from infection or disease caused using polluted water (Craun, 2018).

Though Pakistan is blessed with enough surface and ground water resources, but due to rapid growth in population, industrialization, and urbanization, the water resources are more under stress (du Plessis, 2019; Park, 2007). According to Pakistan Council of Research in Water Resources (PCRWR), there is no access to clean and safe water for 38.5 million people in Pakistan. In Pakistan, safe drinking water is available only for about 20% of population. Because of contaminated drinking water and a lack of clean and nutritious food, 80% of the population has to use unhealthy drinking water (Daud et al., 2017). In rural areas, ground water plays an important role for drinking purposes (Postel et al., 1996). Generally, the source of drinking water in rural areas are dug wells and hand pumps, while particularly springs and streams in hilly remote rural areas (Sheikh et al., 2013). These sources accounts for 72% of safe potable drinking water. Approximately 30% of diseases and 40% of deaths result from poor drinking water quality recorded in community health studies (PCRWR, 2010). To identify the drinking water problem intensity, about 200,000 children die of diarrheal diseases alone each year in Pakistan (PCRWR, 2010).

The Khyber Pakhtunkhwa (KP) northern areas are mostly mountainous, consisting of the Hindu Kush hills, the Himalaya mountains, Dir, Swat, and Kohistan ranges. In all its social and natural settings, these regions have remarkable diversity. The proportion of the rural population is around 80%, while the remaining 20% is in the urban areas (Rahman et al., 2011). In Northern areas of KP, population is widely spread in hilly areas due to clean and safe environment and less availability of plain areas in urban cities. Water resources in the northern rural KP are largely surface water resources and springs which accounts about 72% of potable drinking water, and their quality is very low because of poor sanitation which requires immediate attention (Bangash and Khan, 2001). In these regions, about 46% of the rural population relies on the natural springs for their daily demands of water (Rahman et al., 2011). Nevertheless, due to population pressure, unplanned development, garbage disposal, and shifting patterns of land use, these springs water not only is polluting but also reduces their discharge. The level of drinking water degradation and deterioration of its quality in the northern rural areas of KP is of immediate concern.

Spring water is the main source of water providing life in mountainous region. The contamination of these natural water sources is increasing day by day due to anthropogenic activities. So, the analysis of spring water quality is very important to preserve the natural sources of water. In context of the above scenario, this study attempted to primarily investigate the quality of spring water for drinking purposes in the districts of Dir, Malakand and Swat. The outcome of this research will provide strategic guidelines for locals and those responsible for water supply schemes in the region. This study will be a baseline for upcoming studies to investigate the impact of population and climate change on the physiochemical properties of these natural drinking water sources.

## 2. Materials and methods

### *2.1. Study area*

Northern areas of KP have varying landscaping from rugged mountains, valleys, hills to dense agricultural farms. These areas consist of 13 districts and lies between latitude of 34°00' to 36°20' N and longitude of 71°50' to 75°40' E with an altitude from 900 to 2600 m above the mean sea level.

The districts Dir (Lower), Malakand and Swat are primarily mountainous areas of KP. Lower Dir has a population of 1.436 million in 1582 $km^2$ having mean monthly temperature in summer from 15 to 33°C and in winter from –3 to 16°C. The average annual rainfall varies from 800 to 1600 mm. The Malakand district formed in 1970 with a total area of 952 $Km^2$ and has a population of 720, 295. This district is a gate way to district Bajaur, Chitral, Dir and Swat having mean monthly temperature in summer from 22 to 35$^{\circ}$C whereas in winter it varies between 2 and 15$^{\circ}$C. The annual mean rainfall ranges between 800 and 1200 mm. The district Swat was a princely state before it dissolved in the KP in 1969. Until dissolving in the KP in 1969, district Swat was princely state. The total area of Swat district is 5337 $km^2$ with a population of 2.31 million. In Swat district, mean monthly temperature in summer varies from 12 to 35$^{\circ}$C, whereas in winter it ranges between –3 and 12$^{\circ}$C. The mean annual rainfall is from 1000 to 1800 mm (Pakistan Bureau of Statistics, 2017). Sample collection points are shown in Figure 1.

*2.2. Water sampling*

Drinking water samples (three from each spring) were collected from four springs randomly selected in Dir (Lower), Malakand, and Swat as shown in Figure 2 from the representative locations. Geographical information of these selected sample points is given in Table 1.

*2.2.1. Spring at village Shin Tehsil Khwazakhela District Swat*

According to the residents, this spring is about 50 years old. The soil type near the spring is mostly rocky type covered with Eucalyptus and Pine trees. The topography is mostly with no population near the spring. Similarly, there is no other source of water in the surroundings. The water is mostly used for drinking purposes due to its pure nature (as per the residents). The point from where water is coming out is shown in Figure 2(a).

*2.2.2. Spring at village Fatehpur Tehsil Madyan District Swat*

This spring is approximately 40 years old and its outlet is shown in Figure 2(b). The soil type near the spring is mostly rocky type with up to one meter depth of clayey soil which is used for cultivation of different crops like wheat and maize. This spring is near to the populated area. The water is used by the locals for drinking as well as other domestic purposes.

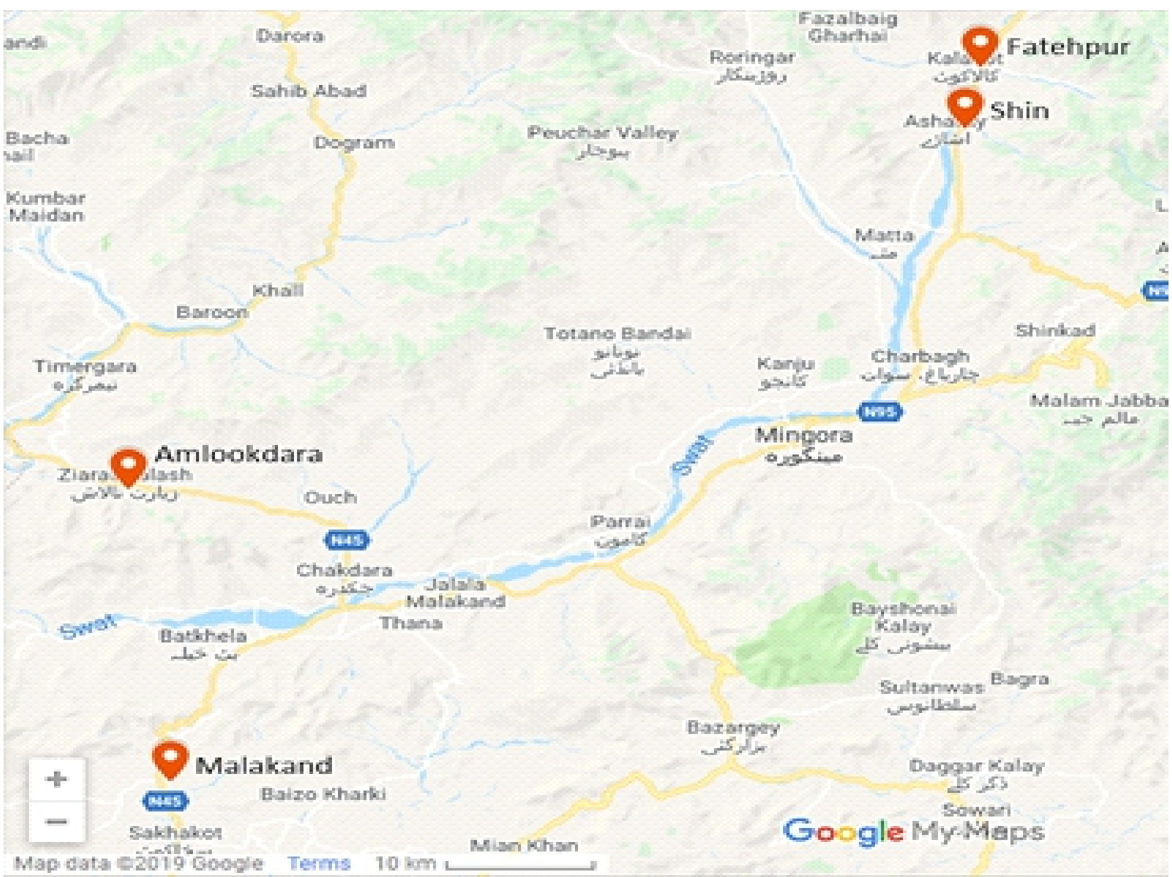


Fig. 1. Locations of the collected representative samples.

Table 1. Geographical Information of Springs Sites.

| S.# | Spring Site | Latitude (N) | Longitude (E) | Elevation (masl) |
|---|---|---|---|---|
| **1** | Shin Khwazakhela, Swat | 35º01'13" | 72º28'19" | 1590 |
| **2** | Fatehpur Madyan, Swat | 35º04'56" | 72º29'45" | 1690 |
| **3** | Amlookdara Talash, Dir(L) | 34º44'12" | 71º52'33" | 1450 |
| **4** | Malakand Top | 34º33'12" | 71º54'43" | 1350 |

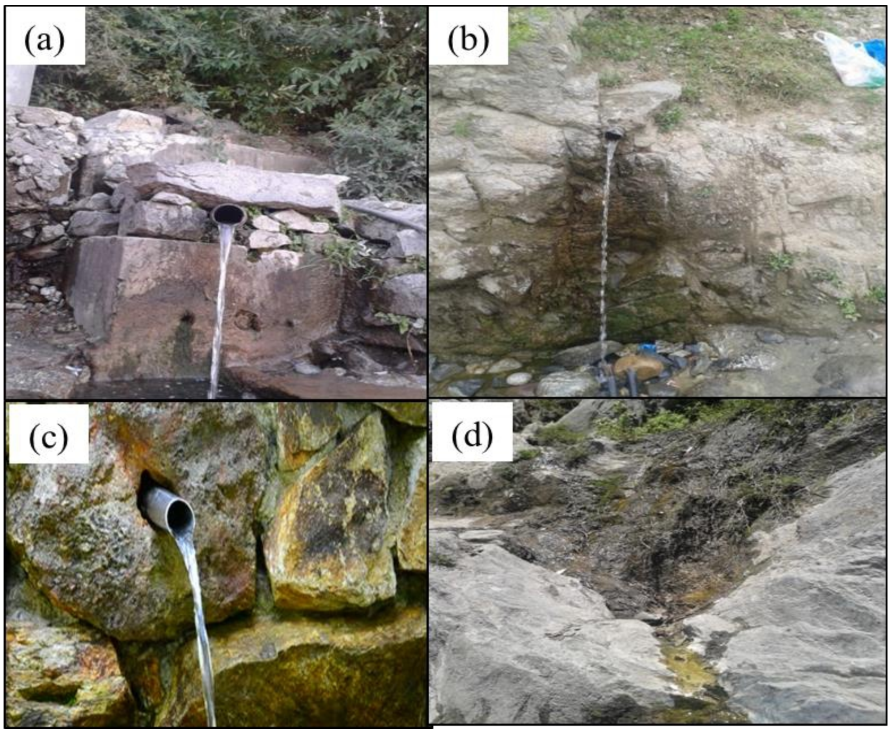


Fig. 2. Springs at (a) Shin Tehsil Khwazakhela District Swat, (b) Fatehpur Tehsil Madyan District Swat, (c) Amlookdara Talash Tehsil Timergarah District Dir (L), (d) Malakand Top District Malakand.

*2.2.3.Spring at Village Amlookdara Ziarat Talash Tehsil Timergarah District Dir (L)*

This spring yield a good amount of water and the people use it for drinking as well as irrigation purposes. This spring is also 50 years old. The water of this spring is too cold in summer season while in winter its water is hot. This spring is in rocky formation surrounded by some trees. The discharging point of the spring is shown in Figure 2©.

*2.2.4.Spring at Malakand top District Malakand*

According to the residents, water of this spring is very suitable for sugar patients considering it as anti-sugar. This spring is about 3 years old. There is bare rocky mountain and no soil available near the area as shown in Figure 2(d). It is surrounded by some natural plants.

The random representative water samples were collected with one-hour intervals from different open springs as shown in Figure 2. All water sample were collected in 1.5 liters capacity of clean high-density polyethylene (HDPE) bottles and were immediately covered tightly after collection (Vicki and Keller-McNulty, 1998). The bottles and cap were rinsed three times before filling the 1.5-liter capacity bottles with water samples. Some parameters were determined on site as given in Table 2. For the remaining parameters, the samples were brought to the laboratory in a cooler with ice to maintain temperature below 4 oC (Greenberg et al., 1992). The parameters were tested within 24 hours after collection. This process was repeated for the four selected sampling points.

The time of samples collection are given below;

i. Spring 1: Village Shin Khwazakhela, District Swat; 08:00 am, 09:00am, 10:00 am
ii. Spring 2: Village Fatehpur Madyan, District Swat; 10:00 am, 11:00am, 12:00pm
iii. Spring 3: Village Amlookdara Talash, District Dir (L); 04:00 pm, 05:00 pm, 06:00 pm
iv. Spring 4: Malakand Top, District Malakand; 12:00 pm, 01:00 pm, 02:00 pm

### *2.3. Physiochemical analysis*

For testing, the samples were brought to the Laboratory of Agricultural Engineering Department, University of Engineering and Technology Peshawar. Physiochemical analysis was carried out in line with the standard methods (Jain and Bhatia, 1988; Greenberg et al., 1992) as soon as the samples were carried to the laboratory. Different tests were performed to determine the concentration of different physical and chemical parameters in potable drinking water of the springs. The methods, equipment and chemicals used during the analysis for different parameters are given in Table 2.

Table 2. Methods, equipment and chemicals used during analysis.

| S # | **Parameters** | **Method/Equipment Used** | **Chemicals/Reagents Used** |
|---|---|---|---|
| | | **Physical** | |
| 1 | Color | Spectrophotometer (on site) | ----- |
| 2 | EC | Conductivity/TDS meter (on site) | ----- |
| 3 | Odor | Visual and Organoleptic Method (on site) | ----- |
| 4 | SS | Spectrophotometer | ----- |
| 5 | Taste | Visual and Organoleptic Method (on site) | ----- |
| 6 | T | Celsius Thermometer (on site) | ----- |
| 7 | Turbidity | Turbidity meter | ----- |
| | | **Chemical** | |
| 8 | Alkalinity | Titration Method | Phenolphthalein, Methyle Orange |
| 9 | $Ca^{+2}$ | Titration Method | NaOH, Muroxide, EDTA* (0.01 N) |
| 10 | CH | Titration Method | NaOH, Muroxide, EDTA (0.01 N) |
| 11 | $CO_3^-$ | Calculated from Alkalinity Test | ----- |
| 12 | $Cl^{-1}$ | Titration Method | Silver Nitrate (0.0141 N), Potassium |
| 13 | DO | Titration Method | Alakli Iodide Azide, $MnSO_4$, $H_2SO_4$, |
| 14 | $F^{-1}$ | Spectrophotometer | Fluoride Tablets |
| 15 | $Fe^{+2}$ | Photometer | Iron Tablets |
| 16 | $Mg^{+2}$ | Calculated from Magnesium Hardness | ----- |
| 17 | MH | Calculated from Total Hardness | ----- |
| 18 | $Mn^{+2}$ | Spectrophotometer | Manganese Tablets |
| 19 | $NO_3^-$ | Spectrophotometer | Nitrate Tablets |
| 20 | $NO_2^-$ | Spectrophotometer | Nitrite Tablets |
| 21 | pH | pH meter | KCL |
| 22 | $SO_4^{2-}$ | Photometer | Sulphate Tablets |
| 23 | TH | Titration Method | Ammonia Buffer Solution, |
| 24 | TDS | TDS/Conductivity meter | ----- |
| 25 | $Zn^{+2}$ | Photometer | Zinc Tablets |

***EDTA; Ethylene-Diamine-Tetraacetic Acid***

## 3. Results and discussion

The average values of physiochemical characteristics for the given samples collected from Dir, Malakand and Swat are shown in Figure 3 and given in Table 3 along with NSDWQ and WHO guidelines. The bold values represent variations from standards values.

Odor and tastes for all samples were non-objectionable. The sample color, EC, pH, turbidity, TDS, $Cl^{-1}$, $F^{-1}$, $Fe^{+2}$, $Mg^{+2}$, $Mn^{+2}$, $NO_3^-$, $NO_2^-$, $SO_4^{2-}$, MH and TH were within the permissible range of NSDWQ and WHO guidelines for all springs water.

Temperature of springs 1 and 3 were within the range of standards values but for temperature of springs 2 and 4 were higher than the WHO guidelines and NSDW. Concentrations of $CO_3^-$ in all samples were less than the standard values as given in Table 3. Carbonates ions combined with $Ca^{+2}$ and $Mg^{+2}$ ions and form calcium carbonates ($CaCO_3$) and magnesium carbonates ($MgCO_3$) respectively which are the major constituents of hardness in water (Moel et al., 2013).

Alkalinity values for springs 2 and 3 were less, while for springs 1 and 4 were within the allowable limits. Alkalinity is an opposite term to acidity and neutralizes the acids. Alkalinity directly affect organism and indirectly effect toxicity of the pollutants in water (Addy et al., 2004). Alkalinity is not considered as a pollutant, it is used in the interpretation and control of water and wastewater treatment processes (Malik et al., 2010).

Dissolved Oxygen in springs 1, 3 and 4 were higher than permissible values, but for spring 2 were within the limits. Investigating water quality, DO is a major parameter and design of waste water treatment plants are based on removal of oxygen demanding materials so as the concentration of DO is maintained (Naresh e al., 2013).

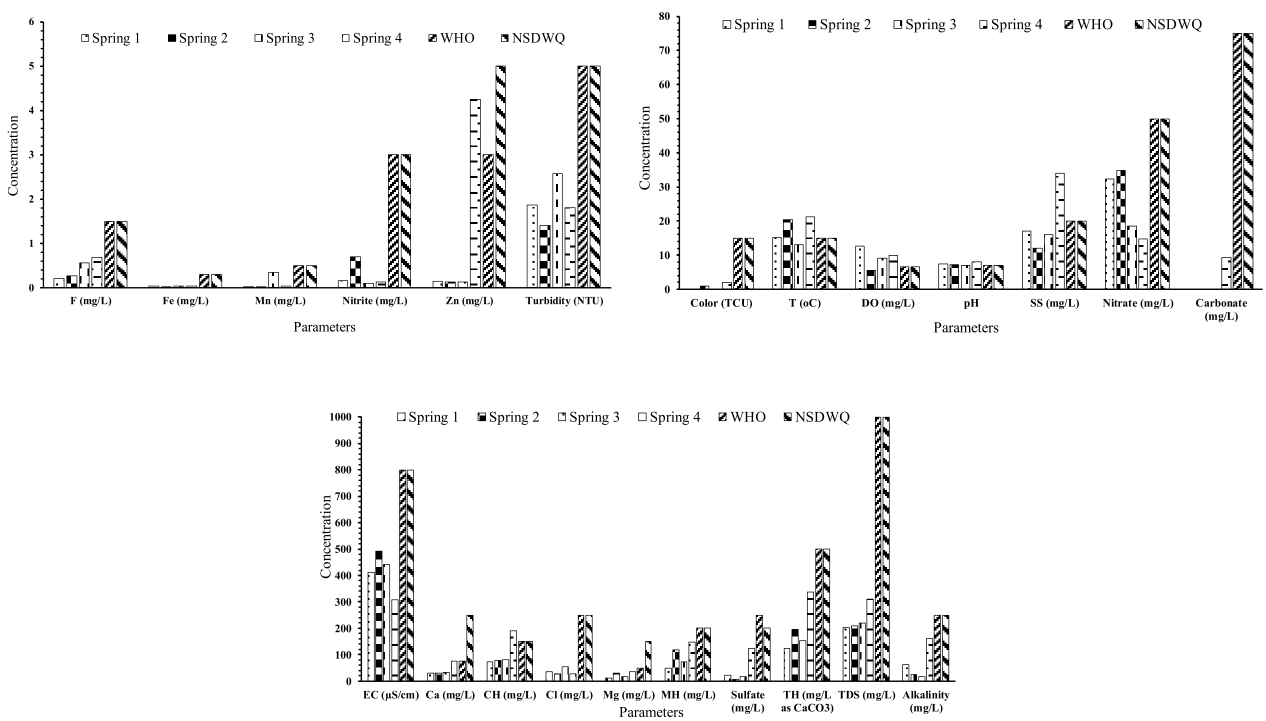


Fig. 3. Comparison of the observed physiochemical parameters with the WHO and NSDWQ guidelines.

Table 3. Physiochemical parameters that exceeds or below the threshold values when compared with the NSDWQ and WHO Guidelines. The out ranged values are highlighted bold.

| S # | Physiochemical Properties | Average Experimental Values | | | | WHO | NSDWQ |
|---|---|---|---|---|---|---|---|
| | | Spring* | | | | Guidelines | |
| | | 1 | 2 | 3 | 4 | | |
| 1 | SS (mg/L) | 17.0 | 12.0 | 16.0 | **34.0** | 20 | 20 |
| 2 | T (ºC) | 15.17 | **20.47** | 13.10 | **21.30** | 15 | 15 |
| 3 | Alkalinity (mg/L) | 61.67 | **25.33** | **18.00** | **162.33** | 50 – 250 | 50 – 250 |
| 4 | CH (mg/L) | 73.87 | 78.40 | 80.00 | **189.33** | 150 | 150 |
| 5 | $CO_3^-$ (mg/L) | **0.0** | **0 .0** | **0.0** | **9.33** | 75 – 150 | 75 – 150 |
| 6 | DO (mg/L) | **12.60** | 5.60 | **9.03** | **9.87** | 6.5 | 6.5 |
| 7 | $Zn^{+2}$ (mg/L) | 0.14 | 0.12 | 0.12 | **4.25** | 3.0 | 5.0 |

***Spring 1** : Village Shin Khwazakhela, District Swat; **Spring 2** : Village Fatehpur Madyan, District Swat; **Spring 3** : Village Amlookdara Talash, District Dir (L); **Spring 4:** Malakand Top, District Malakand, # TCU: True Color Unit; µS/cm: Micro-Siemen per Centimeter; NTU: Neplometric Turbidity Unit; N.O: Non-Objectionable; NSDWQ (2008); WHO (1996)

For spring 4, SS, and CH were found higher than the NSDWQ and WHO guidelines, while Zn+2 and Ca+2 concentrations was higher than the WHO guideline but within the limits recommended by the NSDWQ. In the rest of samples these parameters were within the potability ranges. Temperature regulate many of beneficial uses of water up to some extent such as it can be used as catalyst, an activator, a depressant, a stimulator, a trigger, a restrictor, a killer and is one of the most important characteristics of water quality (Trivedi et al., 2010). Suspended solids are the descriptive term of organic (algae, bacteria) and inorganic (silt, clay) particulate matter present in potable water. Suspended solids interfere with effective drinking water treatments (Trivedi et al., 2010). Calcium hardness is the hardness characteristic that represent the calcium ion concentration in water. It is the major cause of hardness. Calcium combine with bicarbonates, carbonates, sulphate and silica to forms a heat retarding, insulating scale in boilers and other heat exchange equipment (Wurts et al., 1992). Water with zinc concentration of more than 5 mg/L can begin to appear chalky with noticeable taste deterioration. But it is an essential nutrient for growth and development of the skin. Drinking water, however, can lead to cramps of the stomach, nausea, and vomiting (Malik et al., 2010).

Manganese in spring 3 (0.34 mg/L) were higher than spring 1 (0.003 mg/L), 2 (0.02 mg/L), and 4 (0.03 mg/L). Similarly, concentrations of sulphate (122.67 mg/L) and alkalinity (162.33 mg/L) in spring 4 were significantly higher than in spring 1, 2, and 3 respectively.

## 4. Conclusion

In this study 12 samples collected from 4 springs (3 from each) of districts Dir, Malakand, and Swat KP were evaluated to check the appropriateness of spring water for drinking purposes. It was found that all samples were almost within the threshold limits of NSDWQ and WHO guidelines. However, some parameters showed variations in different water samples. For example, carbonates contents were less in all water samples, alkalinity in springs 2 and 3 were less, and dissolved oxygen in springs 1, 3, and 4 were higher than the NDWQS and WHO guidelines. Similarly, for the samples collected from Malakand district, the temperature, suspended solids, dissolved oxygen, and calcium hardness were higher than the standards values, while the contents of Zinc were higher than that of the WHO guidelines but within the permissible limit of the NDWQS.

The existence of certain parameters in high or low amounts than the standard guidelines demonstrated that the drinking water quality may affect the human health and represent the poor quality of water. To provide clean drinking water to the community, it is therefore necessary to check the spring water quality periodically.

***Author's Contribution***

*Daulat Khan, proposed the main concept and supervised the research project, Arshad Ali has collected field data and wrote the manuscript. Tariq Mahmood Khalil contributed in data analysis and its interpretation. Muhammad Ajmal contributed in editing and revising the manuscript critically for important intellectual content. Mahmood Alam Khan was involved in writing the literature review and proofreading.*

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