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Quality assessments of spring water available in various Districts of Azad Kashmir

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Authors' Contribution **Aslam, I.** & **H. R. Abid**, designed the study, **Abid, R.** and **Aslam. I** analyzed the methods and results, **Khalid, N.**, **Asghar, W.**, & **Rahman, U.** contributed in results and discussion.

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ABSTRACT

The study was conducted to find out the health of spring water available in different districts of Azad Jammu Kashmir. A total of 8 districts (Muzaffarabad, Kotli, Poonch, Sudhanati, Jhelum Valley, Bagh, Neelum, and Haveli) were selected where spring water is available and people are using that water for drinking purposes. Physiochemical analysis and microbiological analysis were monitored by using standard methods (PSQCA and WHO). The physiochemical analysis of most samples revealed the range as per the standard of PSQCA and WHO. On the other hand, in microbiological analysis, total plate count, coliform, and E. coli were found higher in districts Bagh and Haveli. The results of the microbiological analysis may be influenced by contamination during sample collection or by environmental circumstances.

Keywords: Physiochemical analysis, microbiological analysis, PCA, Azad Kashmir.

INTRODUCTION: For humans to have an appropriate quality of life, water is a crucial component of all living things on the planet. Surface water and groundwater are the major sources of water (Sanjrani *et al.*, 2019). Water from these sources offers aquatic life and is utilized for irrigation and domestic purposes. The majority of countries around the globe struggling with issues related to water contamination and shortage (Shar *et al.*, 2014). On the other side, the ongoing population growth needs a lot of water. WHO predicted that by 2025, half of the world's population would reside in areas with scarce water supplies. Unfortunately, the remaining areas that are left, are under threat from water contamination (Organization, 2020). During the last few years, urbanization and industrialization have strongly influenced water resources all over the world.

Due to inappropriate solid waste disposal and the direct release of chemicals into water bodies, the quality of water has decreased around the world 2.2 billion people do not have access to clean drinking water at home, according to the Joint Monitoring Programme (JMP) report on "Progress on drinking water, sanitation, and hygiene". 431 million people worldwide lack access to basic drinking water services, with 148 million of those people depending on surface water. According to the 35th session of FAO Regional Conference on Asia, (2020), 10 times as many people die from water-related illnesses each year than from any other conflict. Additionally, several studies have shown that a variety of pollutants, including microbial pathogens, heavy metals, minerals (arsenic and chromium), organic (pesticides), and inorganic (heavy metals), are to blame for polluting water (Daud *et al.*, 2017).

Surface and groundwater resources are among the many natural resources that Pakistan has been gifted with. Rapid population growth, industrialization, and urbanization have severely strained the nation's water supply (Shams *et al.*, 2016). The majority of the population in the nation's cities depends on groundwater for sustenance. While Pakistan's present water supply is just roughly 79 percent (Kirby *et al.*, 2017). Furthermore, from 5,600 cubic meters in 1947 to 1,038 cubic meters in 2010, the amount of water available per person has dropped. In 2050, it is anticipated to further decline to 575 cubic feet (Khalid and Begum, 2020).

Likewise, the mingling of urban sewage with water supply lines and the direct dumping of industrial effluent into water bodies have both reduced the quality of water resources. In many parts of the nation, pollutants including heavy metals, viruses, and other hazardous compounds have been discovered. 80 percent of the population is forced to drink dangerous water, while just 20 percent of the population has access to safe drinking water (Zahid, 2018). According to reports, endemic diarrheal illness causes 2.5 million fatalities annually. Out of 122 countries in the world, Pakistan is ranked 80th for water quality (McCormick and Lang, 2016).

The identification of present conditions and long-term trends in effective management depend heavily on water quality monitoring. The hazardous water is one of the main factors influencing the risk of water transmitted diseases. Diverse organic materials, radioactive elements, dangerous compounds, nitrites and nitrates can all be harmful to human health, because there are so many variables to take into account, so monitoring water quality is still an extremely complicated task. Consequently, it is imperative to regularly test the potable water quality (Behmel *et al.*, 2016). A significant amount of the water supply is tainted with diseases, pollutants, and harmful substances. This research work deals with assessing the drinking water quality of different districts of Azad Kashmir in terms of physical, chemical, and microbiological analysis. This work is beneficial for investigating the different sources that could alter the quality of drinking water.

OBJECTIVES: 1) To evaluate the drinking water quality of various district of Azad Kashmir, 2) To assess the levels of various chemicals, minerals and elements present in water, ensuring they are within the acceptable limits.

MATERIAL AND METHODS: The analysis was carried out by using the standard methods of the Pakistan Standard Quality Control Authority (PSQCA) and the World Health Organization (WHO).

Sample collection: Samples were collected from AJK (Azad Jammu and Kashmir) in 8 different districts including Muzaffarabad, Neelum Valley, Jhelum Valley, Bagh, Haveli, Poonch, Sudhanoti, and Kotli (figure 1). The samples were collected in prewashed sterilized bottles that had been previously treated with hydrogen peroxide solution and hot water. The filled bottles were quickly sealed afterward. The samples were collected from 5 different locations for each district mentioned in the map. A total of 40 samples were taken from all the districts and all samples were drawn from the natural springs.

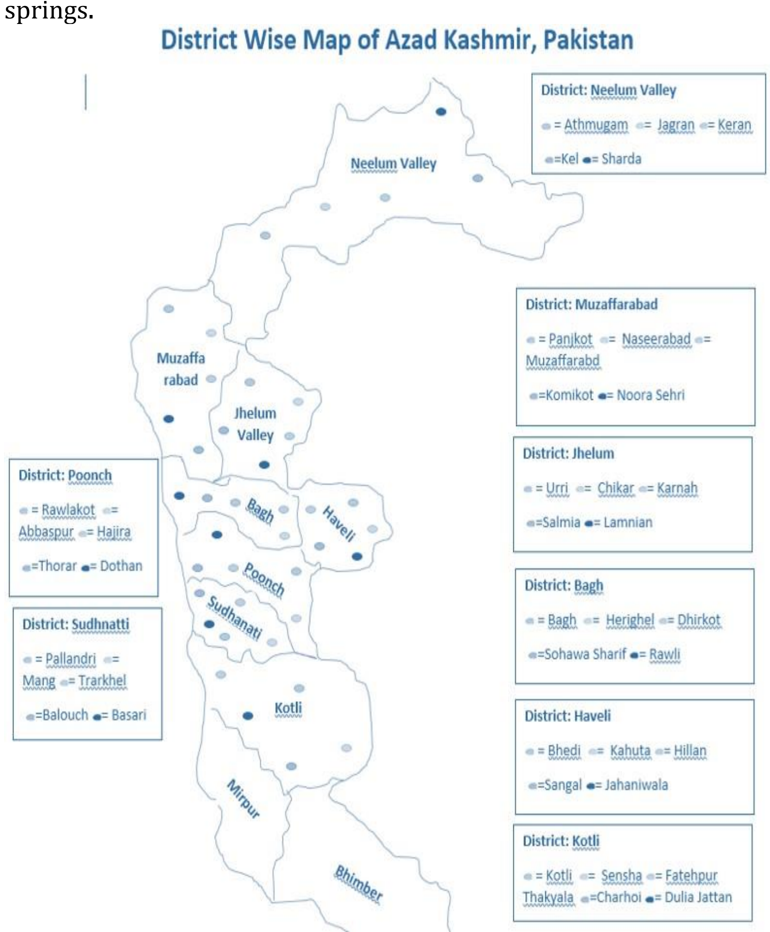

Figure 1: Map exhibits the location, where samples were collected from AJK districts, Pakistan.

The district-wise treatment plan was designed for physiochemical and microbiological analysis (table 1). The samples were immediately stored in the iceboxes and then shifted to the refrigerator at 4°C in the laboratory until analyzed.

Sr. No.	District	Treatment
1	Muzaffarabad	T^1
2	Sudhanati	T^2
3	Kotli	T^3
4	Poonch	T^4
5	Jhelum	T^5
6	Bagh	T^6
7	Neelum	T^7
8	Haveli	T^8

Table 1. District-wise treatments used in physiochemical and microbiological analysis.

Physiochemical analysis: The pH: pH of water samples was determined by pH meter, electrometrically using a glass electrode with a reference electrode (Inolab, WTW Series). The sample size (50 mL) water were taken in the bottle. First, the electrode of the pH meter was cleaned and dried with tissue paper. Then electrode of the pH meter was dipped into the water and readings were noted.

Total dissolved solids (TDS): TDS (total dissolved solids) of all water samples were determined by TDS meter to estimate the total dissolved solids of all types, present in water (ppm) as per the PSQCA standards (PSQCA, 2018). About 50mL samples were taken in beakers. Firstly, the tip of the TDS meter was cleaned and dried with tissue paper. Then the tip of TDS meter was dipped into the water and readings were noted.

Determination of total hardness, calcium, and magnesium: The hardness of water was determined according to the PSQCA standards (PSQCA, 2018), to estimate the capacity of water to precipitate soap, that's caused by the presence of divalent cations of calcium and magnesium. Analysis for hardness was performed in two stages by estimating total and calcium hardness separately and the magnesium hardness was calculated from the difference between the two. 50mL of raw water samples were pipetted into a porcelain dish and dropped into the magnetic rod. 50mL burette was filled up to the mark by 0.01M EDTA solution. 1-2mL of ammonia buffer, 0.2g Eriochrome black T indicator added, and then slowly added 0.01 M EDTA solution until the color of the solution changed from wine red to blue. The volume of the EDTA solution was recorded and total hardness was calculated.

For calcium hardness, 1-2mL of sodium hydroxide buffer and 0.2g murexide indicator were added into 50mL of raw water sample and then 0.01M EDTA solution was slowly added till the color of the solution changed from purple to violet. The volume of the EDTA solution was recorded and calcium hardness was calculated. Total hardness and calcium hardness were calculated by this formula.

Hardness (EDTA) as mg/L $CaCO_3$ = A×B×1000/mL of sample

A= mL EDTA solution used

B= mg $CaCO_3$ equivalent to 1mL EDTA titrant

Magnesium Hardness as mg/L $CaCO_3$ = Total Hardens- Calcium Hardness= ppm

Determination of alkalinity: The alkalinity of water samples was analyzed according to below methods (PSQCA, 2018) to calculate the acid-neutralizing capacity of water samples. 100mL water samples were accurately measured into a 250mL beaker or Erlenmeyer flask. A bar magnet was inserted and samples were placed in a stir plate. The initial pH of samples is recorded and samples were titrated with 0.02N H_2SO_4 until the endpoint pH approached. The final volume needed to reach the endpoint was noted.

Alkalinity (mg $CaCO_3$/L) = A×N×50,000/mL of sample

A= Total volume in mL of standard acid used

N= Normality of standard acid used

Determination of chloride: Chloride ion (Cl^-) in water samples was measured with a test kit according to the PSQCA Standards (PSQCA, 2018). About 25 mL samples were taken in a beaker. Five drops of potassium chromate indicator were added to the test samples. Samples were shaken well and then titrated with 0.01M Silver nitrate ($AgNO_3$) solution. Reading from burette recorded when endpoint (brick red color) reached.

Chloride ion (Cl^-)= Reading from burette × 14.2= ppm

Determination of heavy metals and sodium: Heavy metals (Arsenic) were determined by using a kit. Sodium was determined by using a flame photometer (PSQCA, 2018).

Determination of sulphate: Sulphate content was determined by following the PSQCA standard method (PSQCA, 2018). A 50 mL water sample was taken in an Erlenmeyer flask. 2.5mL sulphate conditioning reagent and 0.5g barium chloride were added. Stir it continuously for 1min and then absorbance was measured at 420nm by using Spectrophotometer (UV1100). **Determination of nitrites:** For the determination of nitrites, a 25mL water sample was taken in an Erlenmeyer flask. 1mL Nessler reagent and 1 drop of EDTA reagent were added. This solution was left for 10min and then absorbance was measured at 425nm by using Spectrophotometer (UV1100).

Bacterial analysis of drinking water: The total plate count of all water samples was conducted as per standard microbial testing of drinking water. Moreover, total coliforms were counted on selective eosin methylene blue agar using the standard microbial protocol. During microbial analysis, all standards and precautionary steps of PSQCA No. 4639-2018 were followed (PSQCA, 2018).

Statistical analysis: The data obtained were analyzed through statistical tools using a completely randomized design (CRD) using the Minitab 18 statistical program and interpreted by Steel (1997). All measurements were performed threefold and findings are stated as mean ± standard deviations. For the measurement of the level of consequence, statistical analysis was conducted using variance analysis (ANOVA) Principal component analysis (PCA) was used to analyze the relationship between water samples (treatments) and physiochemical parameters using Minitab Statistical Software (Version 16.0, Minitab Inc., Enterprise Drive State College, PA).

RESULTS AND DISCUSSION:

Natural springs usually contribute as the main source of drinking water in these mountainous areas, so all samples were taken from the natural springs. For each district, samples were collected from 5 different areas of the same district e.g. District Muzaffarabad (Panjkot, Naseerabad, Muzaffarabad, Komikot, Noora Sehri) District Neelum Valley (Athmugam, Jagran, Keran, Kel, Sharda) District Jhelum (Urri, Chikar, Karnah, Salmia, Lamnian) District Bagh (Bagh, Herighel, Dhirkot, Sohawa Sharif, Rawli) District Haveli (Bhedi, Kahuta, Hillan, Sangal, Jahaniwala), District Kotli (Kotli, Sensha, Fatehpur, Thakyala, Charhoi, Dulia Jattan), District Poonch (Rawalakot, Abbaspur, Hajira, Thorar, Dothan) and District Sudhanoti (Pallandri, Mang, Trarkhel, Balouch, and Basari). The results of all the districts for physio-chemical analysis depicted that all treatments were in the range of the PSQCA standard limit (table 2) for safe drinking water.

Quality parameter	Maximum permissible concentration
TDS	500 ppm
pH	6.5-8.5
Total Hardness	100-150 ppm
Calcium	100 ppm
Magnesium	50 ppm
Alkalinity	50 ppm
Chloride	250 ppm
Sodium	50 ppm
Nitrite	1 ppm
Sulphate	250 ppm
Arsenic	0.01 ppm
Total coliforms	0 cfu/250 mL
Total viable plate count	< 10 cfu/1 mL

Table 2. Maximum permissible standard limits of the quality parameters of drinking water (PSQCA, 2018).

* ppm = parts per million, cfu = colony forming unit, mL = milliliter

The microbiological analysis for a few districts Sudhnati, Neelum, Haveli, Bagh, and Muzaffarabad were not in the range of PSQCA standards and can be categorized as unfit for human consumption.

Physio-chemical analysis: The pH: The results of all treatments were in the range of 6.40-7.41. Although all the results were within the limits of WHO and PSQCA's safe drinking water significant differences exist among all the treatments. The highest value of pH was observed in T^4 while the lowest was in T^7. The treatments T^2, T^5, and T^8 showed non-significant differences among each other (figure 2).

Total dissolved solids (TDS): The permitted range of TDS is 500 ppm as per the PSQCA. The results shown by all the treatments were within the limits of WHO and PSQCA's safe drinking water. The TDS of all treatments was in the range of 115-447ppm. T^2 exhibited the highest TDS among all while T^7 showed the lowest among all the treatments. Statistical analysis revealed that all treatments showed significant differences except T^5 and T^4 which showed non-significant differences (figure 3). High TDS levels in water are mostly caused by inorganic salts of magnesium, calcium, sodium, potassium, nitrates, sulphates, and chlorides. Dizziness, paralysis, irritability, and problems with the central nervous system are all linked to higher TDS levels. High TDS of the treatments especially in

T^2, may be due to the presence of accumulated ions in the area. Overall, all the water samples are non-saline as per the salinity classification and can be considered fit for drinking purposes. Derdour *et al.* (2021) revealed a similar pattern of TDS levels in water in their studies regarding drinking water quality assessment in mountainous areas.

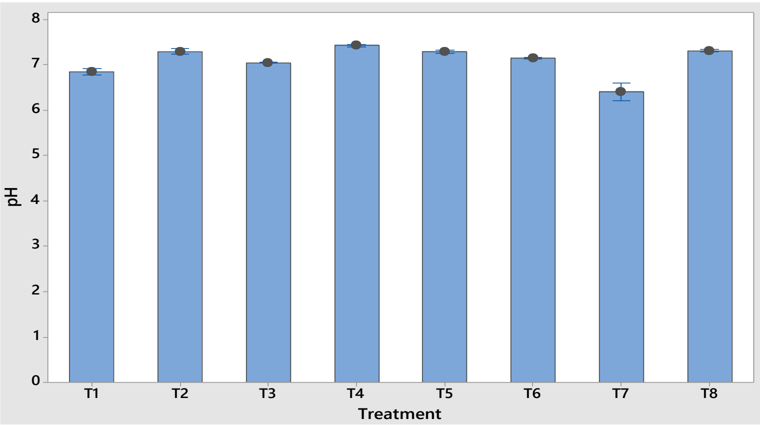

Figure 2: Interval plot of pH.

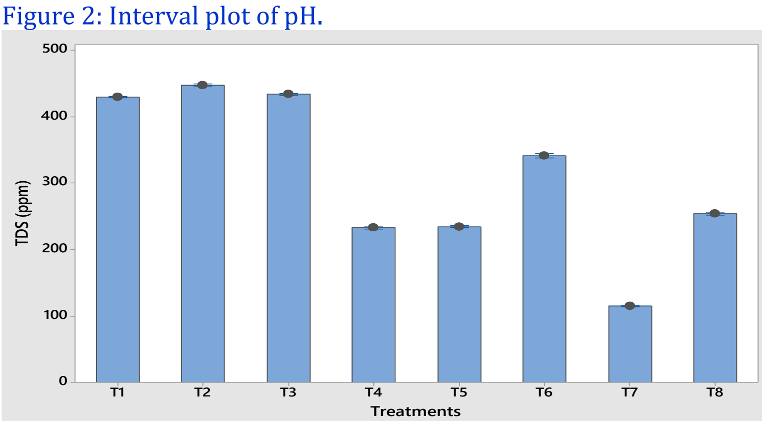

Figure 3: Interval plot of total dissolved solids (ppm)

Water's pH may be used to determine how hard or soft it is. Toxic effects, skin rashes, mucosal membrane irritation, and bitter tastes are all linked to pH extremes. Acidic water also corrodes pipelines, causing the discharge of harmful metals into the water. The difference in pH from all the treatments of the Azad Kashmir region might be due to variations in salts/acidic contents in spring water from different areas. Similar trends in pH were observed by Anonna *et al.* (2022) in their water quality assessment protocols.

Total hardness: The tests taken from the Azad Kashmir region efficiently complied with the WHO and PSQCA requirements that the total hardness in water samples should not be higher than 250 ppm. The results revealed that the hardness of all the samples was in the range of 81 to 210 ppm. The highest hardness was observed in T^1 while T^8 showed the least hardness among all. Statistical analysis revealed that all treatments showed significant differences except T^7 and T^4 which showed non-significant differences (figure 4).

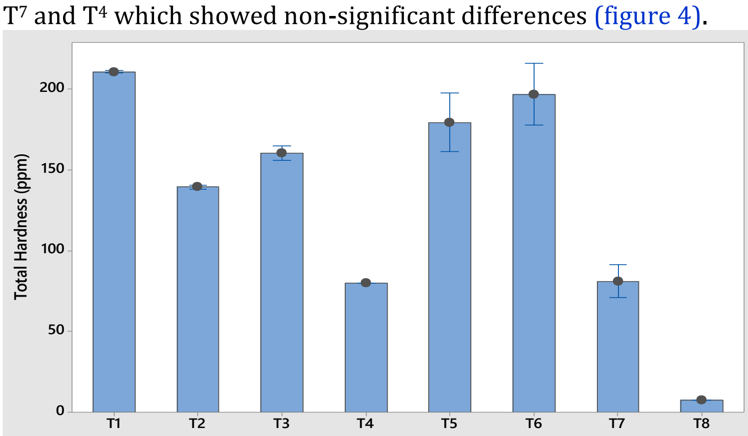

Figure 4: Interval plot of total hardness (ppm)

The hard water is difficult to digest, calcifies the arteries, and is linked to kidney diseases. The concentration of calcium, magnesium, salts, and ions has a major impact on hardness. The primary naturally occurring sources of metallic ions are sedimentary rocks, leaching, and soil runoff. As per the classification of water based on hardness, no water samples are considered soft water, and the majority of samples fall under the category of moderately hard water (75%) While few samples come in the category of hard water (25%). Singh *et al.* (2016) observed somewhat similar results in the total hardness in their water samples of spring water to drink water quality assessment.

Calcium: The permissible limit set by WHO and PSQCA is < 100 ppm and all the research samples collected contain calcium within the permissible limit. Results depicted that the highest calcium was present in T^8 (179ppm) and lowest in T^4 (58ppm). Statistical analysis revealed that all treatments showed significant differences with each other. The treatments T^5, T^7, and T^4 showed non-significant differences with each other while T^2 and T^3 showed non-significant differences with each other. T^1 and T^6 also exhibited non-significant differences with each other (figure 5). The availability of iron, zinc, and phosphorous is decreased as a result of the larger amount of Ca interfering with their absorption in the intestine. Additionally, Ca contributes to the development of kidney stones. That is why calcium content in water is important. These results revealed that all the treatments are fit for drinking purposes. The results obtained were near Anonna *et al.* (2022).

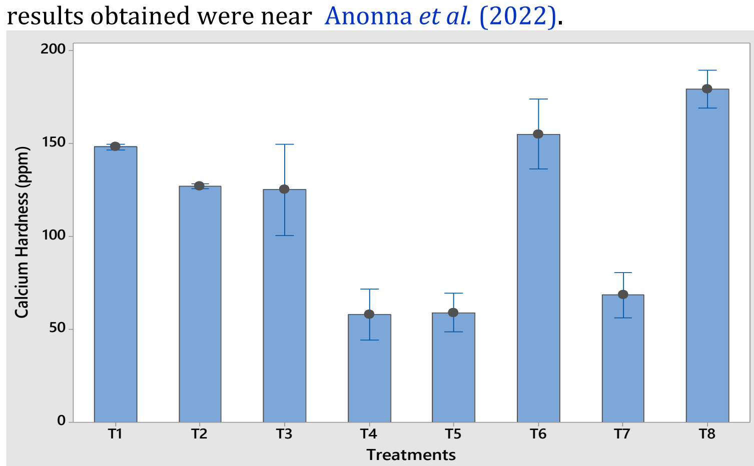

Figure 5: Interval plot of the calcium content of water samples (ppm)

Magnesium: Results indicate that all the treatments except T^5 were within the permissible limit of magnesium content (less than 100 ppm) as per the WHO and PSQCA Standards. The highest magnesium was present in T^5 (120ppm) while T^7 (12ppm) contained the least. All treatments were significantly different from each other as per their statistical analysis (figure 6).

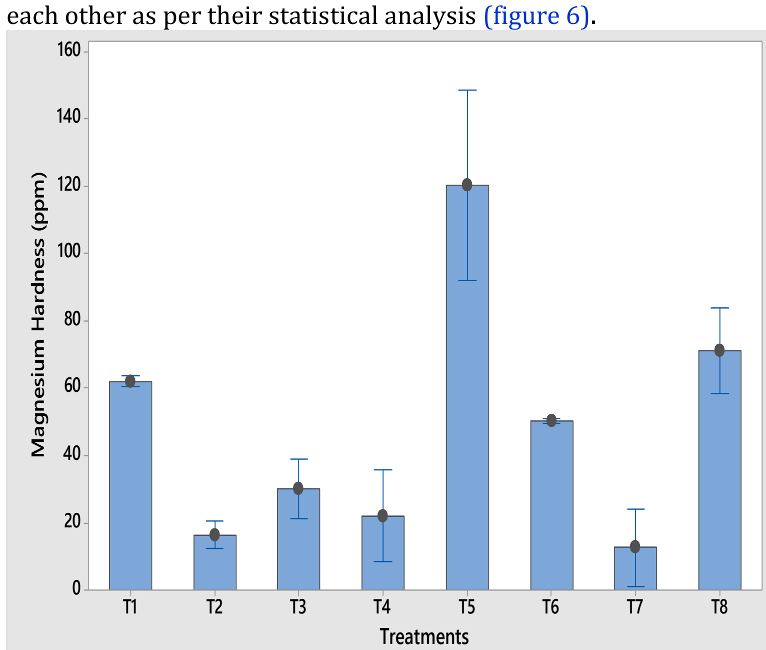

Figure 6: Interval plot of the magnesium content of water samples (ppm)

Higher Mg levels in the water suggest harder water, which is linked to specific health problems like diarrhea, vomiting, and muscle weakness. The treatment's T^5 value of magnesium indicates that it doesn't comply with WHO and PSQCA standards of safe drinking water terms of magnesium. Weathering of rocks might be the reason for high Mg in the spring water however, the concentration varies with the changing geography.

Alkalinity: The alkalinity of drinking water should not exceed more than 50 ppm as per guidelines of WHO and PSQCA. All the samples collected from the district did not follow the trend of PSQCA standards. The values of treatment T^6 and T^7 ranged from 10-50 ppm as per the guidelines of standards while T^1, T^2, T^3, T^4, T^5, and T^8 ranged from 108-186 ppm which did not align with the standards (figure 7). Alkalinity varies from area to area and remains comparable within the same areas as a result of the geological strata of the region. Alkalinity is primarily influenced by the ions of chlorides, bicarbonates, and sulphates. Higher pH and dissolved solids levels are characteristics of more alkaline water (Shafi *et al.*, 2018).

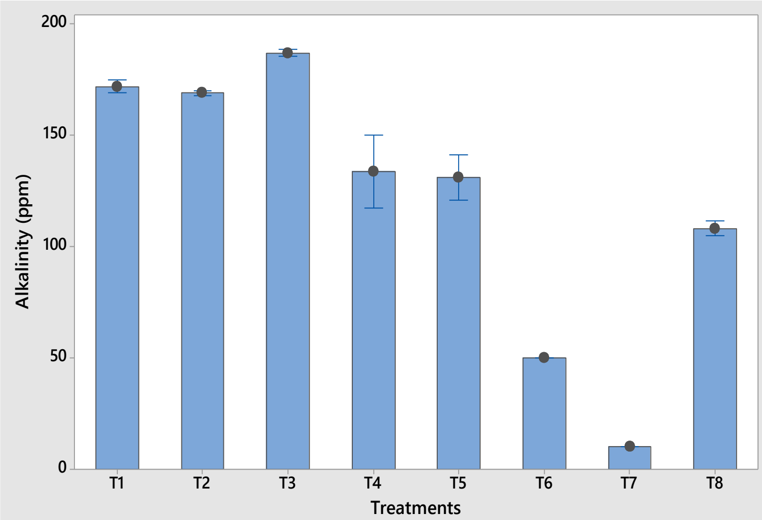

Figure 7: Interval plot of alkalinity content of water samples (ppm)

Chloride (Cl): The maximum permissible concentration of Cl in drinking water is 250 ppm as per the guidelines of WHO and PSQCA. The water samples collected from all the districts of AJK exhibited Cl in the range of 6 ppm to 32 ppm which effectively meets the PSQCA standard. T^6 exhibited a high concentration of Cl among all while T^7 exhibited the lowest concentration among all the treatments (figure 8).

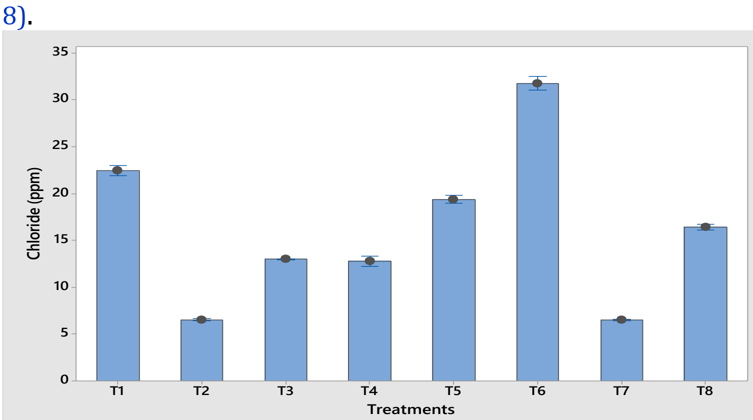

Figure 8: Interval plot of chloride content of water samples (ppm)

Alam *et al.* (2019) also observed low chloride in the spring water samples. These results revealed that all the treatments are fit for drinking purposes. The increase in digestive issues like diarrhea, nausea, and irritable bowel syndrome have been linked to greater concentrations of Cl and sulphate in drinking water (Bashir *et al.*, 2012). A taste of salt is produced by water with a chloride content of 250–500 mg/L. It occurs naturally as salts of calcium chloride ($CaCl_2$), potassium chloride (KCl), and sodium chloride (NaCl) (Rahman *et al.*, 2019).

Sodium (Na): The concentration of Na in most water samples ranged from 17 to 67 ppm. The sample of T^2 and T^3 did not comply with the PSQCA standard and exhibited more than 50 ppm Na (figure 9). The recommended value of Na is 50 ppm as per the standard of WHO and PSQCA. The higher concentration of Na in drinking water may have severe side effects include cerebral and pulmonary oedema, seizures, nausea, vomiting, muscle twitching, and rigidity. The increase in the concentration of sodium might be the weathering of minerals. Health hazards including high blood pressure and hypertension are linked to the greater Na concentration. Furthermore, it also contributes to the salinity of water when sodium chloride and sodium sulphate are present (Azizullah *et al.*, 2011).

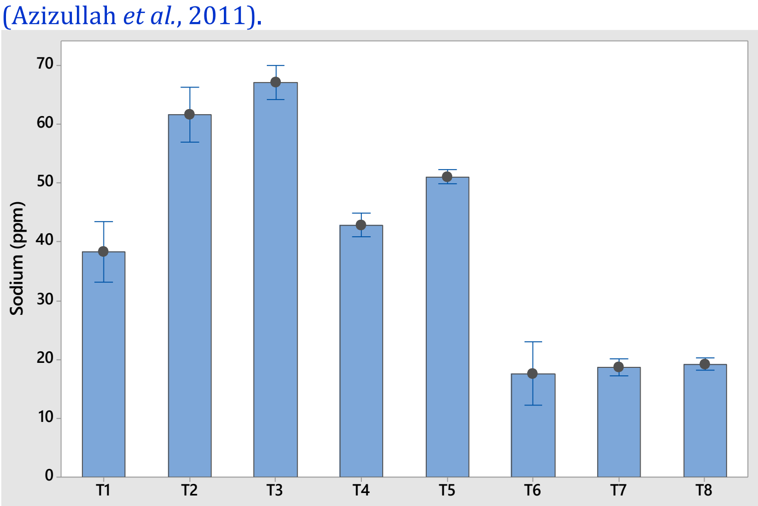

Figure 9: Interval plot of sodium (Na) (ppm).

Sulphate (SO_4): The level of SO_4 in water should not exceed 250 ppm as per the guidelines of WHO and PSQCA. The water samples collected from all the districts of AJK exhibited sulphate in the range of 9.60 ppm to 45.40 ppm which effectively meets the PSQCA standard (figure 10). The maximum value was observed in T^3 (45 ppm) and the minimum was observed in T^7 (9.609). There was a significant difference observed between all the treatments. Natural waterways typically include sulphate ions, and many sulphate compounds are easily soluble in water. Sulphate consumption in combination with magnesium can have an improved laxative effect when water contains a high percentage of sulphate (Thangiah, 2019). Maximum samples collected from different locations exhibited similar results with SO_4 values below 250 ppm (Alam *et al.*, 2019).

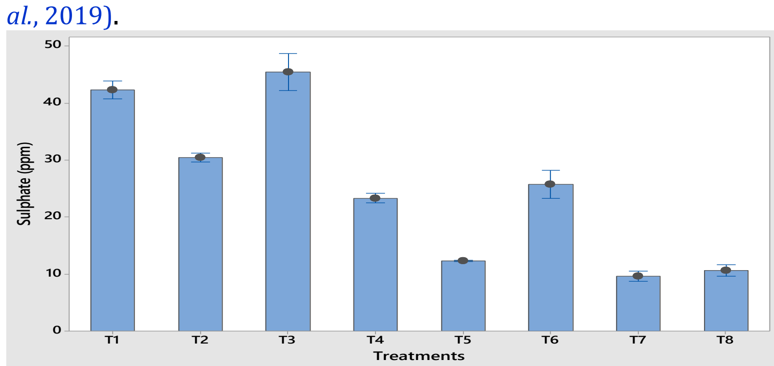

Figure 10: Interval plot of sulphate (SO_4) (ppm).

Nitrite (NO_2): The WHO and PSQCA suggest that NO_2 levels in drinking water be kept to a limit of 1 ppm. The values of samples collected from all districts of AJK ranged between 1.296 and 0.1968. T^1 value exceeded more than 1 which was not in the range of PSQCA and WHO standards. All the values of other treatments ranged within the permissible limits of PSQCA and WHO (figure 11). For the human body, consuming nitrate ions provides several benefits, including, for instance, enhanced blood flow, lowered blood pressure, and cardio-vaso-protective benefits. However, high consumption of nitrate ions, especially in drinking water, can have harmful consequences on the human body, including Parkinson's, cancer, and gastrointestinal disorders. Methemoglobinemia, a condition that lowers blood oxygen levels, can cause "blue baby syndrome" in infants. Less than six-month-old newborns are affected (Alahi and Mukhopadhyay, 2018). In 15 water samples taken from Abbottabad, Pakistan, a greater concentration of NO2, > 1 ppm, was found (Khalid *et al.*, 2011). Improper sewage disposal and higher application of fertilizers might be the reason behind the higher concentration of NO_2 in the samples.

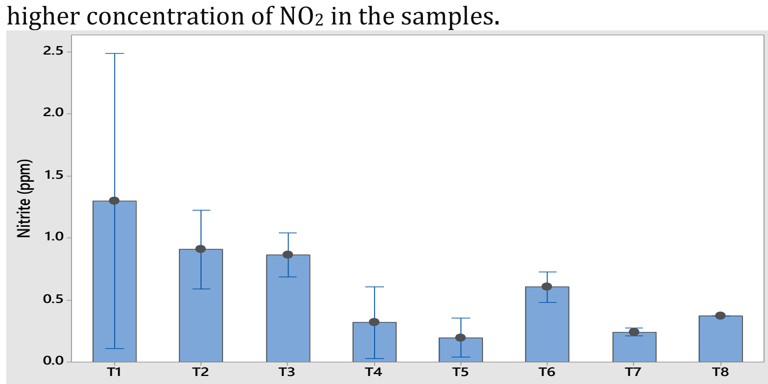

Figure 11: Interval plot of nitrite (NO2) (ppm)

Arsenic: The level of arsenic in drinking water should not exceed 0.01 ppm as per WHO and PSQCA. All the samples did not find the concentration of As except T^5. The level of As found in T^5 was 0.1 ppm. This limit is not in the range of PSQCA standards (figure 12).

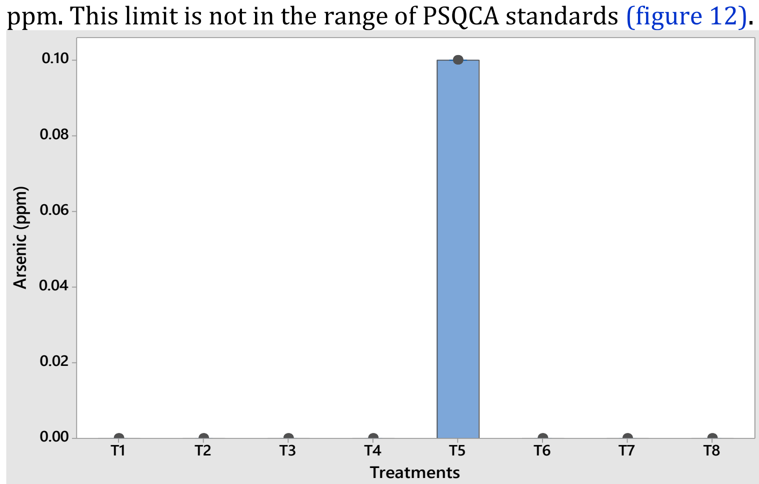

Figure 12: Interval plot of arsenic in water samples (ppm)

The same trend was observed in Zeb *et al.* (2021). Children between the ages of 5 and 10 are adversely affected by the presence of arsenic (As) in drinking water. People who have been exposed to As may have impairment in their higher neurological functions. Children exposed to As have decreased learning and memory, disturbed sleep, abnormalities, and hearing issues (Rahman *et al.*, 2019).

Microbiological Analysis: Microbiological analysis of drinking water samples indicated that T^6 and T^8 exhibited a higher concentration of total plate counts while all the other treatments exhibited less than 100 cfu per 100 mL thus making the water unfit for consumption and unhealthy for children. As per the standard of WHO and PSQCA, there should be < 100 cfu per 100 mL TPC per plate. Waterborne illnesses in children such as gastroenteritis, typhoid, diarrhea, and dysentery are largely caused by microbial contamination of drinking water (Azizullah *et al.*, 2011; Nabeela *et al.*, 2014). In the present study, total coliform and E.coli was also detected and it was observed that there were no coliform and E.Coli in treatments T^2, T^3, T^4, and T^5 while other treatments ranged from 2 to 9 cfu per 100 mL of sample (table 3).

Sr.No	Test Parameters	Permissible Limits (cfu)	T^1	T^2	T^3	T^4	T^5	T^6	T^7	T^8
1	Total Plate Count (TPC)	<100	11	4	1	0	2	TNTC	10	TNTC
2	E.Coli	0	5	0	0	0	0	5	3	9
3	Total Coliform	0	5	0	0	0	0	5	3	9

Table 3: Microbiological analysis of all districts.
*TNTC = Too numerous to count

The total coliform count in water should be 0 cfu per 100 ml as per the regulations of WHO and PSQCA which makes the presence of even a single coliform colony in water unfit for consumption. 50% of samples exhibited coliform and E. coli. A similar kind of water analysis conducted in Islamabad reported the presence of coliform in all of the water samples while in 50% of the samples E. coli were also detected. The presence of E.coli in drinking water is an indicator of fecal contamination and the possible presence of pathogenic microbes in groundwater (Khalid *et al.*, 2018). Khalid *et al.* (2011) and Ahmed *et al.* (2015) also detected a high number of coliform colonies in the water samples of Abbottabad, Rawalpindi, and Islamabad respectively.

Principal component analysis*:* Data were analyzed using PCA to establish a relationship between water samples (Treatments) and quality parameters for drinking water quality. The score plots generated from PCA of Treatments and quality parameters are presented in Figure A. The distribution of quality parameters in space defined by the first and second PCA dimensions is shown in Figure 13 (A) and (B).

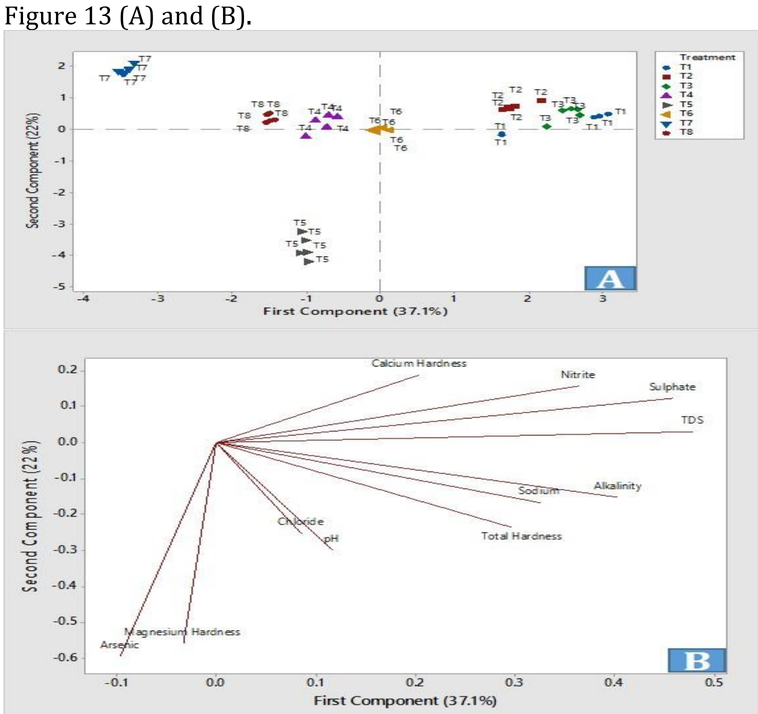

Figure 13 (B): Principal component analysis of water samples of different districts (treatments) depicting (A) the location of processing treatments and (B) the location of quality parameters.

The sum of principal components 1 and 2 (PC1 and PC2) accounted for 59.1% of variations among Treatments. PC1, the first component contributed 37.1% of the total variation and the second component accounted for 22% of the total variation. PC1 was positively correlated with pH, TDS, Hardness, Calcium and magnesium hardness, nitrate, sulphate, and chloride while negatively correlated with arsenic.

CONCLUSION: In recent years, water quality has drastically declined all around the world. Drinking contaminated water causes a variety of health problems in a developing nation like Pakistan. This study was designed to evaluate the quality assessment of spring water available in different districts of Azad Kashmir. All the samples were collected from different locations in each district. Most of the sample's values were found in the safer limits in physicochemical analysis and they were lacking the limits of microbiological analysis. The results of the microbiological analysis may be affected because of contamination during sample collection or maybe environmental conditions may be affected.

The study evaluating spring water quality in Azad Kashmir highlights satisfactory physicochemical parameters but raises concerns about microbiological contamination, potentially due to sampling or environmental factors. This underscores the critical need for comprehensive water quality management strategies. Recommendations include improving monitoring practices, implementing community awareness programs, upgrading infrastructure, and targeting interventions based on contamination levels. These measures are essential for safeguarding public health and ensuring access to clean water in the region.

FUTURE DIRECTIONS: Considering potential avenues for future research, this study could expand its scope by incorporating longitudinal studies to track changes in water quality over time. Additionally, comparative analyses with other regions or water sources would provide valuable insights into the unique challenges faced by Azad Kashmir. Furthermore, investigations into specific sources of contamination and the development of targeted mitigation strategies could enhance our understanding of the underlying factors influencing water quality in the region. These avenues for future research are crucial for advancing our knowledge and improving water quality management practices in Azad Kashmir and beyond.

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REFERENCES: Ahmed, T., S. Imdad and N. M. Butt, 2015. Bacteriological assessment of drinking water of Islamabad Capital Territory, Pakistan. Desalination water treatment, 56(9): 2316-2322.

Alahi, M. E. E. and S. C. Mukhopadhyay, 2018. Detection methods of nitrate in water: A review. Sensors and actuators A: Physical, 280: 210-221.

Alam, I., S. Shehzad and S. Mehmood, 2019. 54 physiochemical analysis of fresh water sources in District Bhimber, Azad Jammu Kashmir. International journal of economic and environmental geology: 54-60.

Anonna, T. A., Z. Ahmed, R. Alam, M. Karim, Z. Xie, P. Kumar, F. Zhang and J. Simal-Gandara, 2022. Water quality assessment for drinking and irrigation purposes in Mahananda River Basin of Bangladesh. Earth systems and environment, 6(1): 87-98.

Azizullah, A., M. N. K. Khattak, P. Richter and D.-P. J. E. i. Häder, 2011. Water pollution in Pakistan and its impact on public health a review. 37(2): 479-497.

Bashir, M. T., S. Ali and A. Bashir, 2012. Health effects from exposure to sulphates and chlorides in drinking water. Pakistan journal of medical and health sciences, 3: 648-652.

Behmel, S., M. Damour, R. Ludwig and M. Rodriguez, 2016. Water quality monitoring strategies—a review and future perspectives. Science of the total environment, 571: 1312-1329.

Daud, M., M. Nafees, S. Ali, M. Rizwan, R. A. Bajwa, M. B. Shakoor, M. U. Arshad, S. A. S. Chatha, F. Deeba and W. Murad, 2017. Drinking water quality status and contamination in Pakistan. BioMed research international, 2017.

Derdour, A., L. Guerine and M. Allali, 2021. Assessment of drinking and irrigation water quality using wqi and sar method in Maâder Sub-basin, Ksour mountains, Algeria. Sustainable water resources management, 7(1): 8.

Khalid, A., A. H. Malik, A. Waseem, S. Zahra and G. P. S. Murtaza, 2011. Qualitative and quantitative analysis of drinking water samples of different localities in Abbottabad District, Pakistan. 6(33):

7480-7489.
Khalid, I. and I. Begum, 2020. Hydro politics in pakistan: Perceptions and misperceptions. South Asian Studies, 28(1).
Khalid, S., B. Murtaza, I. Shaheen, I. Ahmad, M. I. Ullah, T. Abbas, F. Rehman, M. R. Ashraf, S. Khalid and S. Abbas, 2018. Assessment and public perception of drinking water quality and safety in District Vehari, Punjab, Pakistan. Journal of cleaner production, 181: 224-234.
Kirby, M., M. Mainuddin, T. Khaliq and M. Cheema, 2017. Agricultural production, water use and food availability in Pakistan: Historical trends, and projections to 2050. Agricultural water Management, 179: 34-46.
McCormick, B. J. and D. R. Lang, 2016. Diarrheal disease and enteric infections in lmic communities: How big is the problem? Tropical diseases, travel medicine and vaccines, 2(1): 1-7.
Nabeela, F., A. Azizullah, R. Bibi, S. Uzma, W. Murad, S. K. Shakir, W. Ullah, M. Qasim, D.-P. J. E. S. Häder and P. Research, 2014. Microbial contamination of drinking water in Pakistan a review. 21(24): 13929-13942.
Organization, W. H., 2020. Ageing.
PSQCA, 2018. Http://updated.Psqca.Com.Pk/confirmity-assessment-ca/list-of-compulsory-item-to-meet-pakistan-standards/.
Rahman, M., I. A. Jahan, K. S. Ahmed, W. Zaman, I. Ahmad and S. Ahmedº, 2019. Comparison of proximate composition and antioxidant activity of black and green tea available in Bangladesh.
Sanjrani, M., B. Zhou, H. Zhao, S. Bhutto, A. Muneer and S. Xia, 2019. Arsenic contaminated groundwater in China and its treatment options, a review. Applied ecology and environmental research, 17(2): 1655-1683.
Shafi, N., M. Bibi, S. Khalid, T. Akhtar and A. Rauf, 2018. Drinking water quality and possibility of water borne diseases in village Khillah, Muzaffarabad, Azad Jammu and Kashmir, Pakistan. International journal of biology and biotechnology, 15(1): 147-153.
Shams, W. A., U. Siraj, G. Rehman, Z. Ullah, N. Ahmad, M. Miraj, A. Ullah, S. Niaz, K. Khan and H. Alam, 2016. Physiochemical and biological properties of water of Khyber Paktun Khwa District Bannu, Pakistan 2014.
Shar, G. Q., A. R. Shar, W. B. Jatoi, L. A. Shar and W. M. Ghouri, 2014. Assessment of the quality of drinking water of Thari Mirwah Town and surrounding villages, District Khairpur, Sindh, Pakistan. Pakistan journal of analytical & environmental chemistry, 15(2): 21.
Singh, R. K. B., T. C. Singh, T. R. Singh and M. D. Saikia, 2016. Assessment of water quality index of Nambul River, Imphal, Manipur, India. International research journal of engineering and technology, 3(12): 1462-1467.
Thangiah, A. S., 2019. Spectrophotometric determination of sulphate and nitrate in drinking water at asia-pacific International University Campus, Muak Lek, Thailand. Thailand. International research journal of engineering and technology, 12(03): 1503-1508.
Zahid, J., 2018. Impact of clean drinking water and sanitation on water borne diseases in Pakistan.
Zeb, R. A., R. S. Zahoor and A. Farooq, 2021. Inspection of drinking water calibre trait of Bhimber Azad Kashmir, Pakistan. Journal clean water, 5(2): 68-72.