ASSESSMENT OF HEAVY METALS AND MICROBIAL PRESENCE IN THE WELL WATER OF DISTRICT BAJAUR, PAKISTAN

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Abstract

Water stands as the most fundamental component for the survival of all living organisms and is typically sourced from two significant reservoirs, namely surface water and groundwater aquifers. It plays a pivotal role in drinking, as the viability of life depends on it. The primary objective of this study was to assess the presence of heavy metals and the microbial content in open well water from three selected Tehsils (Khar, Mamund, and Salarzai) within District Bajaur, situated in the northern regions of Pakistan. A total of 21 well water samples were collected and subjected to analysis. The research findings disclosed a range of heavy metal concentrations, with values as follows: Lead (ranging from 0.0055mg/L to 0.1490mg/L), Chromium (varying from 0.024mg/L to 0.1363mg/L), Nickel (fluctuating from 0.0127mg/L to 0.1063mg/L), and Manganese (spanning from 0.0347mg/L to 0.1560mg/L) across all 21 samples. Furthermore, the Most Probable Number (MPN) for the count of total coliforms and fecal coliforms exhibited mean value ranges of (ranging from 0.00 MPN/100ml to 16.00 MPN/100ml) and (varying from 0.00 MPN/100ml to 15.33 MPN/100ml), respectively. Additionally, the presence of Escherichia coli (E. coli) was detected in 10 out of the 21 water samples. These mean values were compared against the guidelines established by the World Health Organization (WHO, 2011), the United States Environmental Protection Agency (US-EPA, 2018), and the Pakistan Environmental Protection Agency (Pak-EPA, 2008).

INTRODUCTION

The world is abundant with a wide range of natural resources, some of which have been unveiled and are well-known for their advantages, while many others remain undiscovered. Nevertheless, water, among the known natural resources, unquestionably maintains its position as the most crucial resource for all human beings (Khalid et al., 2018). According to the existing data, approximately 96% of the world's total freshwater reserves exist in subterranean forms. As a result, a significant portion of the global population in both urban and rural areas relies exclusively on underground water sources for their drinking water needs (Shakerkhatibi et al., 2014).

In addition to the physicochemical properties, there are other concerning factors affecting groundwater quality. The presence of hazardous metals has raised significant global apprehensions, and findings from various organizations have been disquieting (Farmaki et al., 2016). Water pollution caused by pathogens, as well as heavy metals like cadmium, chromium, cobalt, copper, lead, manganese, nickel, and zinc, along with various anions, poses a serious threat to both the environment and human health (Khan et al., 2016; Shah et al., 2012).

Lead, for instance, has a broad spectrum of harmful effects on humans, including neurological disturbances in both the peripheral and central nervous systems, cardiac issues, and blood toxicity (Morais et al., 2012). Chromium, when present in elevated concentrations in drinking water, is responsible for skin conditions like erythema and swelling, as well as asthma and chronic pharyngitis in humans (Ipeaiyeda et al., 2011).

Prolonged exposure to nickel in drinking water has been linked to several health issues in humans, including lung and sinus cancer, chronic bronchitis, and lung function disorders (Zarei et al., 2018). Manganese, on the other hand, can lead to chronic effects such as nerve damage, Parkinson's disease, lung embolism, and bronchitis (Hernández et al., 2016).

It's essential to maintain the right balance of trace metals like calcium, chromium, copper, iron, magnesium, potassium, sodium, and zinc in the body. A deficiency of these elements can disrupt biological processes and bodily functions, while excess amounts can result in toxicity (Rasool et al., 2016).

Contaminated drinking water, particularly with human and animal waste, can pose a significant health risk, leading to severe infections in humans. Coliform bacteria, which encompass both fecal varieties (commonly found in the intestines and feces of humans and animals), and non-fecal origin bacteria like E. coli, which are part of the fecal coliform group, are typically harmless. However, specific strains, such as E. coli 0157:H7, can cause severe diseases when present in drinking water (Odonkor and Ampofo, 2013).

Raising public awareness about the quality of drinking water is a crucial factor in defining and implementing preventive measures against various diseases. In Lahore, a significant portion of the population (approximately 60%) had limited knowledge regarding waterborne illnesses (Malik et al., 2012). Respondents in the region reported major health issues, including gastroenteritis (40%–50%), diarrhea (47%–59%), dysentery (28–35%), hepatitis A (32%–38%), hepatitis B (16%–19%), and hepatitis C (6-7%) (Khan et al., 2016).

In southern Sindh, Pakistan, contaminated drinking water is accountable for the occurrence of various severe diseases, such as gastroenteritis, diarrhea, vomiting, dysentery, and kidney diseases (Memon et al., 2011). Increasing public awareness about the risks associated with drinking water quality is essential for preventing these health problems.

To achieve this objective, the study involved the identification of heavy metals and the presence of microorganisms in well water from the chosen Tehsils (Khar, Mamund, and Salarzai) within District Bajaur. The data collected through this research can serve as a valuable source of public awareness, particularly highlighting the risks associated with the use of untreated water. This information is especially relevant in the context of the damage inflicted on drinking water resources in conflict-affected areas around the world.

MATERIALS AND METHODS

Sampling selection

The selection of sampling locations was guided by specific criteria, including population density, anthropogenic activities, and a particular focus on regions affected by conflict. These war-affected areas were chosen due to their potential health risks associated with elevated levels of inorganic materials and other heavy metals (Yousaf et al., 2015). A total of 21 water samples from open well systems were collected from various designated locations to conduct the study.

Samples collection

We utilized sterilized, clean, and transparent 1-liter Polyethylene terephthalate (PET) bottles for collecting 21 well water samples from various wells across different areas of District Bajaur. At the time of sample collection, water was carefully drawn from the wells and poured into these bottles. To ensure data accuracy, we collected water samples from each source in three replications, and the average value was then considered as the standard. Subsequently, the bottles' openings were sealed with adhesive tape to maintain an airtight seal. Each bottle containing a water sample was labeled with specific codes, locations, and the sources of the water

Heavy metals

We conducted the analysis of heavy metals, including lead (Pb), chromium (Cr), nickel (Ni), and manganese (Mn), in the collected water samples. This analysis was carried out following the procedure outlined in the AOAC (Association of Official Analytical Chemists) guidelines of 2012. To begin, a 10 ml water sample was measured, and 90 ml of deionized water was added to dilute it, resulting in a final volume of 100 ml. Subsequently, the diluted samples were subjected to evaluation for the presence of the selected heavy metals using an Atomic Absorption Spectrophotometer, specifically the Perkin Elmer 2380 model from the USA.

Microbial analysis

The collected water samples underwent an assessment for microbial contamination, specifically the load of total coliforms, fecal coliforms, and E. coli, in accordance with the prescribed method outlined in APHA (American Public Health Association) guidelines from 2016. The Most Probable Number (MPN) method was employed to determine the count of total coliforms (TCC), as per the method detailed by Dubey et al. in 2011. The counts for both total coliforms and fecal coliforms were calculated using MPN tables as per APHA guidelines from 2016.

For the enumeration of Enterobacteriaceae, MacConkey broth was utilized at the Government Public Health and Food Analysis Laboratory in Hayatabad, Peshawar. In the case of coliforms and fecal coliforms counts, the MPN method was employed, which involved the use of multiple fermentation tubes, as described by (Adetunde et al. in 2011).

Statistical analysis

The data obtained from the well water samples collected from 21 different areas were subjected to statistical analysis using SPSS software. A one-way analysis of variance (ANOVA) with completely randomized design (CRD) was employed for the analysis. Subsequently, the means were compared and separated based on p-values less than 0.05 using the Least Significant Difference (LSD) test, as detailed in Steel and Torrie's work from 1997.

RESULTS

The table below (TABLE NO. 1) presents the levels of heavy metals in the collected well water samples from District Bajaur, which were assessed for Lead, Nickel, Chromium, and Manganese:

Lead

The mean lead concentration in the collected water samples (S1 to S21) ranged from 0.0055 mg/L to 0.1490 mg/L. The highest mean value (0.1490 mg/L) for lead concentration was observed in the drinking water sample from S4 (Loi sum). Conversely, the lowest mean value (0.0055 mg/L) was recorded in the drinking water sample from S20 (Amanatha).

Notably, the mean lead concentration in the drinking water from S2, S10, S18, and S20 fell within the permissible limits (0.01 mg/L) as defined by the guidelines provided by WHO (World Health Organization) in 2011, US-EPA (United States Environmental Protection Agency) in 2018, and Pak-EPA (Pakistan Environmental Protection Agency) in 2008. In contrast, the mean values for lead concentration in the drinking water samples from the remaining areas exceeded the recommended guideline values, as shown in Table No. 1.

Chromium

The mean concentration of chromium in the drinking water samples collected from areas (S1 to S21) in District Bajaur ranged from 0.024 mg/L to 0.1363 mg/L. The highest mean value

(0.1363 mg/L) for chromium concentration was observed in the drinking water sample from S4 (Loi sum). Conversely, the lowest mean value (0.024 mg/L) was found in the drinking water sample collected from S18 (Malangy).

It's worth noting that the mean chromium concentration in the drinking water samples from areas S3, S4, S5, S7, S8, S9, S13, S14, S15, S16, and S21 exceeded the permissible limits (0.05 mg/L) as outlined by WHO (World Health Organization) in 2011, US-EPA (United States Environmental Protection Agency) in 2018, and Pak-EPA (Pakistan Environmental Protection Agency) in 2008. In contrast, the mean chromium concentrations in the drinking water samples from the remaining areas adhered to the guideline standards, as shown in Table No. 1.

Nickel

The mean concentration of nickel in the drinking water samples collected from areas (S1 to S21) in District Bajaur ranged from 0.0127 mg/L to 0.1063 mg/L. The highest mean value (0.1063 mg/L) for nickel concentration was observed in the water sample from S4 (Loi sum), while the lowest mean value (0.0127 mg/L) was found in the drinking water samples collected from S12 (Laradagai).

It's important to note that the mean nickel concentration in the drinking water samples from areas S3, S4, S7, S8, S9, S17, and S21 exceeded the standard guideline value (0.07 mg/L) set by WHO (World Health Organization) in 2011, US-EPA (United States Environmental Protection Agency) in 2018, and Pak-EPA (Pakistan Environmental Protection Agency) in 2008. Conversely, the mean nickel concentration in the drinking water samples from the remaining areas fell within the permissible guidelines, as indicated in Table No. 1.

Manganese

The mean concentration of manganese in the water samples collected from various areas of District Bajaur fell within the range of 0.0347 mg/L to 0.1560 mg/L. The highest mean value (0.1560 mg/L) for manganese concentration was recorded in the water sample from S4 (Loi sum). In contrast, the lowest mean value (0.0347 mg/L) for manganese concentration was observed in the water samples collected from S14 (Kotki).

It's worth noting that the mean manganese concentration in the drinking water samples from areas S1 to S21 adhered to the standard limits (0.04 mg/L) outlined by WHO (World Health

Organization) in 2011, US-EPA (United States Environmental Protection Agency) in 2018, and Pak-EPA (Pakistan Environmental Protection Agency) in 2008, as presented in Table No. 1.

Table No 1. Heavy metals concentrations in the water samples evaluated for lead, chromium, nickel and manganese

Samples code	Area name	Lead mg/L	Chromium mg/L	Nickel mg/L	Manganese mg/L
S_1	Zubandar	0.0103j	0.0430s	0.0250s	0.0650f
S_2	Tangi	0.0065k	0.0450hi	0.0153o	0.0363i
S_3	Sheikh Kaly	0.1457b	0.0950c	0.0980b	0.0963b
S_4	Loi Sum	0.1490a	0.1363a	0.1063a	0.1560a
S_5	Inayat kaly	0.0123hij	0.0747e	0.0357jkl	0.0757e
S_6	Patak	0.1170e	0.0450hi	0.0467i	0.0847cd
S_7	Khar	0.1333c	0.1130b	0.0870c	0.0370i
S_8	Taly	0.0527g	0.0737e	0.0813d	0.0650f
S_9	Raghagan	0.1060f	0.0550g	0.0710g	0.0370i
S_{10}	Derakai	0.0046k	0.0390i	0.0367jk	0.0530g
S_{11}	Pashat	0.0105ij	0.0440hi	0.0227n	0.0453h
S_{12}	Laradagai	0.0107ij	0.0450hi	0.0127o	0.0370i
S_{13}	Ridawan	0.0127hi	0.0630f	0.0273mn	0.0550g
S_{14}	Kotki	0.1160e	0.0927c	0.0307lm	0.0347i
S_{15}	Umary	0.0140h	0.0840d	0.0610g	0.0763e
S_{16}	Sewai	0.1153e	0.0950c	0.0667f	0.0657f
S_{17}	Dabar	0.0105ij	0.0450hi	0.0750e	0.0863c
S_{18}	Malangy	0.0065k	0.0240k	0.0407j	0.0550g
S_{19}	Kharkai	0.0102j	0.0327j	0.0527h	0.0750e
S_{20}	Amanatha	0.0055k	0.0453h	0.0350kl	0.0823d
S_{21}	Nakhtar	0.1250d	0.0950c	0.0847cd	0.0673f
WHO standards (WHO, 2011)		0.01	0.05	0.07	0.4
US EPA limits (USEPA, 2018)		0.015	0.05	≤0.07	0.1-0.4
Pak EPA (Pak-EPA, 2008)		0.05	0.05	≤0.07	≤0.5

Values with same letter(s) in each column are not significantly different from each other at $p < 0.05$.
Pb: Lead; Cr: Chromium; Ni: Nickel; Mn: Manganese.

Some selected microbial characteristics of the water samples evaluated for Total coliforms, Fecal coliforms and E.coli

The selected microbial characteristics of the water samples, including Total coliforms, Fecal coliforms, and E. coli, have been summarized in Table No. 2.

Total coliforms

The mean microbial count for Total coliforms in the water samples collected from various areas (S1 to S21) of District Bajaur ranged from 0.00 MPN/100ml to 16.00 MPN/100ml. The highest mean microbial count (16.00 MPN/100ml) for Total coliforms was observed in sample S7 (Khar). Conversely, the lowest mean microbial count (0.00 MPN/100ml) for Total coliforms was found in the water samples from S1, S9, S12, S18, and S19.

It's noteworthy that the mean microbial counts for Total coliforms in the drinking water samples from S1, S9, S12, S18, and S19 were in line with the guideline value (0.00 MPN/100ml) as stipulated by WHO (World Health Organization) in 2011, US-EPA (United States Environmental Protection Agency) in 2018, and Pak-EPA (Pakistan Environmental Protection Agency) in 2008. Conversely, the mean Total coliform count in the drinking water samples from the remaining studied areas exceeded the guideline value of 0.00 MPN/100ml. Out of the 21 samples analyzed for Total coliform count, seven samples were found to fall within the safe limit of less than 2 MPN/100ml, as indicated in Table No. 2.

Fecal coliforms

The mean microbial count for fecal coliforms in the water samples collected from different areas (S1 to S21) in District Bajaur ranged from 0.00 MPN/100ml to 15.33 MPN/100ml. The highest mean microbial count (15.33 MPN/100ml) for fecal coliforms was observed in sample S21 (Nakhtar). Conversely, the lowest mean microbial count (0.00 MPN/100ml) for fecal coliforms was found in the water samples from S1, S9, S10, S11, S13, and S21.

It's important to note that the mean microbial counts for fecal coliforms in the drinking water samples from S3, S4, S10, S11, S13, and S21 adhered to the guideline value of 0.00

MPN/100ml, which is consistent with the standards outlined by WHO (World Health Organization) in 2011, US-EPA (United States Environmental Protection Agency) in 2018, and Pak-EPA (Pakistan Environmental Protection Agency) in 2008. In contrast, the mean fecal coliform counts in the drinking water samples from the remaining areas exceeded the guideline value of 0.00 MPN/100ml. Among the 21 samples evaluated for the microbial count of fecal coliforms, nine samples were found to be within the safe limit of less than 2 MPN/100ml, as indicated in Table No. 2.

E. Coli

The water samples collected from various areas (S1 to S21) were also subject to analysis for the presence of E. coli. The mean microbial count for E. coli was indicated as either "+ive" (Present) or "ND" (not detected). E. coli was found in the drinking water samples from the following areas: S3, S4, S6, S7, S10, S14, S15, S16, S20, and S21. Conversely, E. coli was not detected in the water samples from the remaining studied areas.

The water samples in which E. coli was detected were considered to be above the guideline (-ive) provided by WHO (World Health Organization) in 2011, US-EPA (United States Environmental Protection Agency) in 2018, and Pak-EPA (Pakistan Environmental Protection Agency) in 2008. On the other hand, water samples in which E. coli was not detected were considered to be within the permissible limits, as indicated in Table No. 2.

Table No 2. Some selected microbial characteristics of the water samples evaluated for Total coliforms, Fecal coliforms and E.coli

Samples code	Area name	Total Coliform (MPN/100ml)	Fecal Coliform (MPN/100ml)	E-coli
S_1	Zubandar	0.0000f	0.0000f	ND
S_2	Tangi	7.0000e	7.0000e	ND
S_3	Sheikh Kaly	15.000ab	14.333ab	+ive
S_4	Loi Sum	12.000bcd	9.0000cde	+ive
S_5	Inayat kaly	5.6667e	2.0000f	ND
S_6	Patak	15.000ab	10.667cd	+ive
S_7	Khar	16.000a	14.333ab	+ive
S_8	Taly	1.3333f	0.6667f	ND
S_9	Raghagan	0.0000f	0.0000f	ND
S_{10}	Derakai	15.000ab	11.333c	+ive
S_{11}	Pashat	1.3333f	0.0000f	ND
S_{12}	Laradagai	0.0000f	0.0000f	ND
S_{13}	Ridawan	11.000d	6.6667e	ND
S_{14}	Kotki	13.000abcd	10.000cd	+ive
S_{15}	Umary	11.000d	8.3333de	+ive
S_{16}	Sewai	14.333abc	11.667bc	+ive
S_{17}	Dabar	5.3333e	1.3333f	ND
S_{18}	Malangy	0.0000f	0.0000f	ND
S_{19}	Kharkai	0.0000f	0.0000f	ND
S_{20}	Amanatha	11.667cd	7.0000e	+ive
S_{21}	Nakhtar	15.000ab	15.333a	+ive
WHO standards (WHO, 2011)		0MPN/100ml	0MPN/100ml	-ive
US EPA limits (USEPA, 2009)		0MPN/100ml	0MPN/100ml	-ive
Pak EPA (Pak-EPA,2008)		0MPN/100ml	0MPN/100ml	-ive

Values with the same letter(s) in each column are not significantly different from each other at $p < 0.05$. MNP: Most Probable Number; ND: Not Detected; +ive: Positive/Detected; E.coli: Escherichia coliforms.

DISCUSSION

Lead is a trace metal that is widely distributed in the environment, present in bodies of water, soils, vegetation, animals, and food. Although it's not abundant in the Earth's crust, lead can be found in the form of sulfide galena. In recent times, the primary sources of environmental lead contamination have been lead storage batteries and gasoline antiknock additives like tetraethyl lead (Joshi et al., 2015). Prolonged exposure to lead can lead to severe health hazards, including kidney failure, metabolic disorders, coma, and neurological issues that can range from impaired intelligence to convulsions and even death, affecting both adults and children (Morais et al., 2012). Furthermore, inorganic lead compounds have been classified as probably carcinogenic to humans, according to the evaluation by the International Agency for Research on Cancer (Nawab et al., 2016).

The mean value range (0.0055 mg/L to 0.1490 mg/L) for lead concentration in this study is comparable to the findings of Bacha et al. (2010), who reported a mean value of 0.15 mg/L for lead and an overall mean value of 0.142 mg/L for lead in the drinking water of Peshawar. Similarly, Aremu et al. (2002) observed lead levels ranging from 0.06 mg/L to 0.44 mg/L in the Warri region of Nigeria. Statistical analysis confirmed that the geographical area had a significant impact ($P < 0.05$) on the lead concentration in the water samples collected from District Bajaur.

The mean value range for chromium concentration in this research study (0.024 mg/L to 0.1363 mg/L) aligns with the findings of Shah et al. (2012), who reported a mean value range of 0.051 mg/L to 0.3186 mg/L while analyzing the concentrations of heavy metals in water samples and their impact on human health in District Mohmand. Similarly, Nawab et al. (2016) observed a mean value range of chromium concentration (0.0326 mg/L to 0.0476 mg/L) in drinking water from mining-impacted areas in Pakistan. The statistical analysis confirmed that the geographical area had a significant influence ($P < 0.05$) on the chromium concentration in the drinking water samples collected from District Bajaur.

The mean value range for nickel concentration in this research (0.0127 mg/L to 0.1063 mg/L) is consistent with the mean value range (0.020 mg/L to 0.1410 mg/L) reported by Shah et al. (2012) when studying the quality of drinking water in Mohmand District. Additionally, Alinejad et al. (2016) noted the highest mean value (0.124 mg/L) for nickel concentration in the drinking water of Kohgiluyeh, Iran. The statistical analysis confirmed that the geographical area had a significant impact ($P < 0.05$) on nickel concentration in the drinking water samples collected from District Bajaur.

The mean values range for manganese concentration in this research (0.0347 mg/L to 0.1560 mg/L) closely resembles the mean value range (0.0518 mg/L to 0.2870 mg/L) reported by Nawab et al. (2016) while studying the impact of heavy metals on drinking water in District Mohmand. In contrast, Ilyas et al. (2013) and Alam et al. (2008) found manganese concentrations with overall mean values of 0.16 mg/L and 0.0428 mg/L, respectively, in the drinking water of Palosi, Peshawar, and District Swat. The statistical analysis confirmed that the geographical area had a significant impact (P-values < 0.05) on the concentrations of manganese in well water samples obtained from District Bajaur.

The presence of total coliforms in water samples serves as a crucial indicator of microbial contamination in drinking water. Detecting bacteriological contaminants like total coliforms is a top priority for assessing water quality (LeChevallier et al., 2011). In Pakistan, a study conducted by UNICEF (Pak-SECA, 2006) revealed that 20% to 40% of hospital beds are occupied by patients suffering from water-borne illnesses.

The mean value range for total coliform count in drinking water in District Bajaur (ranging from 0.00 MPN/100ml to 16.00 MPN/100ml) is similar to the mean value range (<1.1 MPN/100ml to >23 MPN/100ml) reported by Ali et al. (2013) while analyzing hand pump, open well, and tube well water in rural areas of Peshawar. In contrast, Butt et al. (2012) observed a mean value range (11.00 MPN/100ml to 350.00 MPN/100ml) for total coliforms in groundwater quality analysis near Lahore, Pakistan. The statistical analysis confirmed that the geographical area had a significant impact ($P < 0.05$) on the total coliform count in the water samples collected from District Bajaur.

Contaminated drinking water continues to be a major cause of waterborne illnesses, leading to significant health issues. In Pakistan, fecal contamination of drinking water is responsible for 30% of all reported deaths, accounting for 40% of the total mortality (Draft South Asia–Water Vision 2025, Country Report, Pakistan, 2009). Waterborne diseases resulting from fecal coliform contamination include typhoid fever, dysentery, viral and bacterial gastroenteritis, and hepatitis-A (Aziz et al., 2010).

The mean value range for fecal coliforms in this research study (ranging from 0.00 MPN/100ml to 15.33 MPN/100ml) is similar to the mean value range (<1.1 MPN/100ml to 23 MPN/100ml) reported by Ali et al. (2013) during their bacteriological analysis of open well water in rural areas of Peshawar, Pakistan. Conversely, Yasin et al. (2015) observed a mean value range (0.53 MPN/100ml to 105.93 MPN/100ml) for fecal coliform count in the bacteriological analysis of drinking water sources in the Jimma zone, Southwest Ethiopia. The statistical analysis confirmed that the geographical area had a significant impact ($P < 0.05$) on the fecal coliform count in the water samples collected from District Bajaur.

In this investigation of E. coli in the drinking water of District Bajaur, ten out of twenty-one water samples tested positive for E. coli. Similarly, Ali et al. (2013) observed seven water samples that tested positive for E. coli out of ten water samples from an open well. On the other hand, Khalid et al. (2018) found only two water samples that tested positive for E. coli out of a total of forty-two water samples from various sources of drinking water in District Vehari, Punjab, Pakistan. The statistical analysis confirmed that the geographical area had a significant impact ($P < 0.05$) on E. coli concentrations in the water samples collected from District Bajaur.

CONCLUSION

The primary objective of this research was to assess the levels of heavy metals and detect microbial contamination in well water samples from the three tehsils (Khar, Mamund, and Salarzai) in District Bajaur. The analysis revealed that heavy metals such as lead, chromium, and nickel exceeded the permissible standards set by (WHO, 2011; US-EPA, 2018, and Pak-EPA, 2008). However, the concentration of manganese in the well water samples was within acceptable limits.

Microbial contamination was detected in all water samples collected from the study area except for Kharkai, Malangy, Laradagai, Taly, Raghaghan, Pashat, and Zubandar. Based on the analysis of heavy metals and microbial content, the water samples from Malangy, Laradagai, Taly, Raghaghan, Pashat, and Zubandar were deemed suitable for drinking purposes. In contrast, water samples from the remaining study areas were considered unsuitable for human consumption, as they did not meet the guidelines established by (WHO, 2011; US-EPA, 2018, and Pak-EPA, 2008).

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