# Bacteriological, inorganic and heavy metal evaluation of drinking water of the specified flood affected areas of Dir (Lower) Pakistan

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### ABSTRACT

In the year 2010, Pakistan was badly hit by devastating flood and about one-fifth of the total area of the country was under the flood water. In this study, an attempt was made to find out whether the portable water sources were still contaminated with various pollutants or not, after two years of the devastating flood. The samples were collected from selected areas of Dir Lower Khyber Pakhthoonkhwa Pakistan in 2012. Different physicochemical parameters like pH, EC, turbidity, alkalinity and hardness, $NO_3^{1-}$, $SO_4^{2-}$, $F^{-1}$, $Cl^{-1}$, Na, K, Ca, Mg, Cr, Ni, Fe and Pb were determined. The samples were also checked for the presence of pathogenic bacteria. The collected water samples were found contaminated with high level of nutritional metals, heavy metals (Cr, Ni, Fe, Pb) and pathogenic bacteria such as coliform, faecal coliform, *E. coli*, *S. aureus*.

*Keywords:* Heavy metals; Nutritional metals; Bacteria; Groundwater

## 1. Introduction

Due to heavy monsoon rainfall in July 2010, flood came in all four provinces of Pakistan and about one-fifth of the total area of Pakistan was under the flood water. However, the two provinces, Khyber Pakhtunkhwa and Punjab were badly affected [1–3]. According to the government of Pakistan statement, about 796,095 square kilometres (307,374 square miles) were under the flood water and 20 million people were affected. Approximately 2000 people died [3–5].

Hankimoon, the United Nations Secretary General, asked initially for a relief fund of US $420 million on emergency basis, and according to him it was the

greatest devastation ever made by flood in the history. According to World Health Organization (WHO), about 10 million people were compelled to drink unsafe contaminated water [6]. In August 2010, the nongovernmental organization, ACTED (Agence d'Aide à la Coopération Technique Et au Développement: Agency for Technical Cooperation and Development) made a survey on the rapid needs assessment in the flood affected areas of Dir Lower. The objectives of the survey were: the assessment of the vulnerability of Lower Dir population after the floods, data collection to focus on access to the area, affected population, shelter needs, water, sanitation and hygiene needs, access to health facilities, education facilities, damages to agriculture key facilities and risk of food security and livelihood [7]. In July 2010, WHO said in his flood

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report on Dir Lower that all the water sources were contaminated with flood and rain fall [8].

The aim of the present study was to evaluate the different water quality parameters of spring, open well, tube well, hand pump and tap water, whether they are fit for drinking or still contaminated.

## 2. Experimental

Hundred samples of drinking water were collected from selected areas of District Dir Lower. The collected samples were from various portable water sources like tube wells, hand pumps, springs, municipal tap water supply and open well. Water samples were brought in 1 l capacity bottles with great precautionary measures. For bacteriological analysis, sterilized containers of 100 ml capacity were used. For the preservation of collected water samples for heavy metals analysis, nitric acid was used while the evaluation of nitrates boric acid was used. The samples were given arbitrary numbers. The samples

collected for microbiological analysis were represented by 1, for heavy metals evaluation by 2, for inorganic constituent such as nitrate and other chemicals determinations by 3 and for physical parameters evaluation by 4.

The concentrations of heavy metals (cadmium, chromium, lead and iron) in the collected samples were determined by atomic absorption spectrometry while sodium, potassium, calcium and magnesium alkali and alkaline earth metals were determined by flame photometry. Different physical parameters and inorganic constituents (nitrate, bicarbonate etc.) were also determined by methods available in literature. The analytical methods used for the determination of different physicochemical parameters are presented in Table 1.

## 3. Results and discussion

The details of the collected samples are given in Table 2.

Table 1
Methodologies used for the determination of physicochemical parameters

| S# | Parameters | Test method |
|---|---|---|
| 1 | Alkalinity (m mol/l as $CaCO_3$) | 2320, standard method (1992) |
| 2 | Bicarbonate | 2320, standard method (1992) |
| 3 | Carbonate | 2320, standard method (1992) |
| 4 | Hardness (mg/l) | EDTA titration, standard method (1992) |
| 5 | Nitrate Nitrogen (mg/l) | Cd, reduction (HACH-8171) by spectrometer |
| 6 | Sulphate (mg/l) | Sulfa Ver4 (HACH-8051) by spectrophotometer |
| 7 | Chloride (mg/l) | Titration (Silver Nitrate), standard method (1992) |
| 8 | Fluoride (mg/l) | 8090, SPADNS method (HACH-8051) by spectrophotometer |
| 9 | Sodium (mg/l) | Flame photometer PFP7, UK |
| 10 | Potassium (mg/l) | Flame photometer PFP7, UK |
| 11 | Calcium (mg/l) | 3500-Ca-D, standard method (1992) |
| 12 | Magnesium (mg/l) | 2340-C, standard method (1992) |
| 13 | pH 25℃ | pH metre (HI 110, Hana) |
| 14 | Turbidity (NTU) | Turbidity metre, Lammote, Model 2008, USA |
| 15 | TDS (mg/l) | 2540C, standard method (1992) |
| 16 | Iron (mg/l) | TPTZ method (HACH-8112) by spectrophotometer |
| 17 | Conductivity (mS/cm) | E.C. Metre, Biochem lab UOM |
| 18 | Chromium (µg/l) | 1,5-Diphenylcarbohydrazide method (Hach-8023) by spectrophotometer |
| 19 | Ni | Flame photometer PFP7, UK |
| 20 | Lead (µg/l) | Dithizone Method (HACH-8033) by spectrophotometer |
| 21 | Total Coliform | MPN tables (APHA 2001) |
| 22 | *E. coli* | Bio.: chem.: tests & *E. Coli* 0157:H7 latex test reagent kit pro lab. Canada (APHA 2001) |
| 23 | *Pseudomonas aeruginosa* (*PA*) | Biochemical tests (APHA 2001) |
| 24 | *Vibrio cholerae* (*VB*) | Bergey's Manual of Determinative Bacteriology, 1994 |
| 25 | *Salmonella* & *Shigella* | Medium XLD |
| 26 | *Staphylococcus aurous* | (Mihdhdir AA. 2009) |

Table 2
Samples information collected from different location of Dir Lower

| S# | Village | Tube well water | Open well water | Tap water | Hand pump water | Spring water |
|---|---|---|---|---|---|---|
| 1 | Ramora | 1 | 1 | 1 | 1 | 1 |
| 2 | Dara | 3 | – | 1 | 1 | 1 |
| 3 | Gulmuqam | 1 | 1 | 1 | 1 | – |
| 4 | Chakdara | 1 | 1 | 1 | 1 | 2 |
| 5 | Badwan | 1 | 1 | | 2 | 1 |
| 6 | Shawa | 2 | – | 1 | – | 2 |
| 7 | Tazagram | 2 | – | 1 | – | 1 |
| 8 | Kityari | 2 | – | 1 | 1 | 1 |
| 9 | Khanpur | 1 | – | – | – | 2 |
| 10 | Asbanr | 1 | 1 | 1 | 1 | 2 |
| 11 | Ouch | 1 | 1 | 1 | 2 | 2 |
| 12 | Khairabad | 2 | – | – | – | 1 |
| 13 | Usakai | 1 | 1 | 1 | 1 | 1 |
| 14 | Talash | 1 | 2 | 1 | 2 | 1 |
| 15 | Timargara | 1 | 1 | 1 | 1 | 1 |
| 16 | Rabat | 1 | – | – | 1 | 2 |
| 17 | Samarbagh | 1 | 1 | 1 | 1 | 1 |
| 18 | Maidan | 1 | 1 | 1 | – | 2 |
| 19 | Gulabad | 1 | 1 | 1 | 2 | – |
| 20 | Sarai Bala | 1 | 1 | 1 | 1 | 1 |
| | Total | 26 | 14 | 16 | 19 | 25 |

## 3.1. Bacteriological analysis

Microbiological or bacteriological analyses were carried out for qualitative determination of pathogenic bacteria in the collected samples. The analysed samples were compared with WHO and PS (dw) (Pakistan Standard for drinking water) standards. The pathogenic bacteria found in the collected samples of tube well water are shown in Table 3.

Table 3 shows that the highest TPC (Total Plate Count) value 780 was noted in the sample collected from Ramora region followed by 645 in the sample of Khairabad Dari while the lowest value 68 was noted in the sample from Maidan area. Coliform bacterial count was found highest (23) in the sample collected from Shawa whereas the least count was recorded somewhat greater than 1.1 in a number of samples. The faecal coliform maximum counts (16) were noted in the samples collected from Ramora, Dara Sharab Kowi and Asbanr. The *E. coli* was recorded positive for 16 samples out of 26, while in case of *S. aureus* the highest value 53 was recorded in the sample collected from Khairabad. *Salmonella* and *Shigella* were positive in 6 and 4 samples out of total 26 samples each. *V. cholera* were not observed in any sample. *Pseudomonas*, *Bacillus* and *Klebsiella* were positive in 7, 3 and 2 samples, respectively.

The bacteriological analyses of open well water samples of selected areas are shown in Table 4. The

highest TPC value 540 was recorded in the sample collected from Chakdara, while the other values were in between 65 to 535. The numbers of Coliform bacteria were found in the range of <1.1–17. *Faecal coliform* was highest (6.9) in the sample collected from Gulmuqam, whereas 4 samples (out of 14 total) showed the least number <1.1. Half of the total samples were positive for *E. coli*, while 8 samples were negative for *Staphylococcus aureus*. The samples of this category were almost free from *Salmonella*, *Shigella*, *V. cholera*, *Pseudomonas*, *Bacillus* and *Klebsiella*.

Table 5 represents the involvement of different bacteria in the collected tap water samples.

The highest value of TPC 640 was recorded in the sample collected from Ouch and the least value 61 was noted for the sample collected from Timargara. The number of coliform bacteria was recorded highest (10) in the sample collected from Sarai Bala whereas the minimum number <1.1 was found in 8 samples out of 16 total collected samples. Six samples were negative for *E. coli* and 13 samples for *S. aureus*. *Shigella* was noted in 5 samples, while *V. cholera* was not detected in any sample. One sample each was recorded positive for *Bacillus* and *Klebsiella* out of 16 total samples.

The bacteria present in hand pump water samples are shown in Table 6. The results indicated that minimum number of TPC 64 was found in the sample

Table 3
Bacteriological analysis of tube well water collected from different location of District Dir Lower

| S# | Sample ID | TPC | Coliform bacteria (MPN/100 ml) | Faecal Coliform | Staphylococcus aurous | E. coli | Salmonella | Shigella | V. cholera | Pseudomonas aeruginosa | Bacillus SPP | Klebsiella |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ramora | 780 | >23 | 16 | 35 | 11 | 00 | 00 | 00 | 00 | 00 | 00 |
| 2 | Dara Faqirabad | 100 | >1.1 | >1.1 | 09 | 00 | 00 | 00 | 00 | 00 | 1 | 00 |
| 3 | Dara Spinakhawra | 210 | 1.1 | >1.1 | 03 | 00 | 00 | 4 | 00 | 00 | 00 | 00 |
| 4 | Dara Sharab Kowi | 500 | >23 | 16 | 47 | 10 | 00 | 00 | 00 | 5 | 00 | 00 |
| 5 | Gulmuqam | 530 | 16 | 5.1 | 17 | 8 | 3 | 00 | 00 | 00 | 00 | 00 |
| 6 | Chakdara | 470 | 9.2 | 3.6 | 74 | 10 | 00 | 3 | 00 | 00 | 1 | 00 |
| 7 | Badwan | 190 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 1 | 00 | 00 |
| 8 | Shawa | 248 | 23 | 12 | 00 | 12 | 2 | 00 | 00 | 00 | 00 | 00 |
| 9 | Shawa Tandodag | 412 | 16 | 12 | 09 | 9 | 00 | 00 | 00 | 00 | 00 | 00 |
| 10 | Tazagram | 472 | 3.6 | 2.2 | 00 | 6 | 1 | 6 | 00 | 00 | 00 | 00 |
| 11 | Tazagram Jango | 552 | 16 | 6.9 | 10 | 9 | 00 | 6 | 00 | 00 | 00 | 00 |
| 12 | Kityari | 148 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 13 | Kityari Batan | 322 | 5.1 | 3.6 | 47 | 13 | 00 | 00 | 00 | 00 | 1 | 00 |
| 14 | Khanpur | 195 | 2.2 | <1.1 | 00 | 00 | 00 | 00 | 00 | 3 | 00 | 00 |
| 15 | Asbanr | 532 | >23 | 16 | 12 | 10 | 00 | 00 | 00 | 00 | 00 | 00 |
| 16 | Ouch | 180 | 12 | <1.1 | 00 | 00 | 00 | 00 | 00 | 2 | 00 | 00 |
| 17 | Khairabad | 550 | 12 | 5.1 | 53 | 5 | 1 | 00 | 00 | 00 | 00 | 00 |
| 18 | Khairabad Dari | 645 | 2.2 | 2.2 | 00 | 7 | 00 | 00 | 00 | 00 | 00 | 1 |
| 19 | Usakai | 449 | 9.2 | 3.6 | 00 | 10 | 00 | 00 | 00 | 00 | 00 | 00 |
| 20 | Talash | 90 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 21 | Timargara | 78 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 22 | Rabat | 430 | 2.2 | 2.2 | 00 | 10 | | 00 | 00 | 1 | 00 | 00 |
| 23 | Samarbagh | 230 | 5.1 | 3.6 | 09 | 10 | 00 | 00 | 00 | 00 | 00 | 00 |
| 24 | Maidan | 68 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 25 | Gulabad | 168 | 5.1 | <1.1 | 00 | 00 | 1 | 00 | 00 | 00 | 00 | 00 |
| 26 | Sarai Bala | 340 | 12 | 2.2 | 12 | 8 | 00 | 2 | 00 | 4 | 00 | 1 |

Note: A = absent and TPC = total plate count.

Table 4
Bacteriological analysis of open well water collected from different areas of Dir Lower

| S# | Sample ID | TPC | Coliform bacteria (MPN/100 ml) | Faecal Coliform | Staphylococcus aurous | E. coli | Salmonella | Shigella | V. cholera | Pseudomonas aeruginosa | Bacillus SPP | Klebsiella |
|----|-----------|-----|-------------------------------|-----------------|-----------------------|---------|------------|----------|------------|------------------------|--------------|------------|
| 1 | Ramora | 32 | <1.1 | <1.1 | 28 | 1 | 00 | 00 | 00 | 00 | 00 | 00 |
| 2 | Dara | – | – | – | – | – | – | – | – | – | – | – |
| 3 | Gulmuqam | 535 | 17 | 6.1 | 18 | 1 | 1 | 00 | 00 | 00 | 00 | 00 |
| 4 | Chakdara | 540 | 16 | 6.9 | 23 | 8 | 00 | 00 | 00 | 00 | 00 | 1 |
| 5 | Badwan | 460 | 12 | 4.9 | 00 | 6 | 00 | 00 | 00 | 00 | 00 | 00 |
| 6 | Asbanr | 453 | 3.6 | 3.6 | 15 | 3 | 00 | 00 | 00 | 00 | 00 | 00 |
| 7 | Usakai | 510 | 12 | 2.2 | 00 | 4 | 00 | 00 | 00 | 00 | 00 | 00 |
| 8 | Talash | 250 | 9.2 | 3.6 | 10 | 6 | 00 | 00 | 00 | 00 | 00 | 00 |
| 9 | Talash Banda | 85 | 2.2 | 2.2 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 10 | Timargara | 175 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 11 | Samarbagh | 90 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 12 | Maidan | 88 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 13 | Gulabad | 382 | 6.9 | 3.6 | 00 | 3 | 00 | 00 | 00 | 1 | 00 | 00 |
| 14 | Sarai Bala | 65 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |

Table 5
Bacteriological analysis of tap water collected from different areas of Dir Lower

| S# | Sample ID | TPC | Coliform bacteria (MPN/100 ml) | Faecal Coliform | Staphylococcus aurous | E. coli | Salmonella | Shigella | V. cholera | P. aeruginosa | Bacillus SPP | Klebsiella |
|----|-----------|-----|-------------------------------|-----------------|-----------------------|---------|------------|----------|------------|---------------|--------------|------------|
| 1 | Ramora | 500 | >23 | 3.6 | 201 | 1 | 1 | 00 | 00 | 00 | 00 | 00 |
| 2 | Dara | 280 | <1.1 | <1.1 | 87 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 3 | Gulmuqam | 325 | 16 | 9.2 | 18 | 9 | 00 | 00 | 00 | 00 | 00 | 00 |
| 4 | Chakdara | 200 | 2.2 | <1.1 | 09 | 1 | 00 | 1 | 00 | 00 | 00 | 00 |
| 5 | Shawa | 128 | 9.2 | <1.1 | 00 | 00 | 1 | 1 | 00 | 00 | 00 | 00 |
| 6 | Tazagram | 142 | 3.6 | <1.1 | 10 | 1 | 00 | 1 | 00 | 00 | 00 | 00 |
| 7 | Kityari | 314 | 12 | 5.1 | 31 | 9 | 00 | 1 | 00 | 00 | 00 | 00 |
| 8 | Asbanr | 209 | 12 | <1.1 | 08 | 00 | 00 | 00 | 00 | 1 | 1 | 00 |
| 9 | Ouch | 640 | 9.2 | 3.5 | 15 | 5 | 00 | 00 | 00 | 00 | 00 | 00 |
| 10 | Usakai | 479 | 16 | 6.9 | 24 | 3 | 1 | 00 | 00 | 00 | 00 | 00 |
| 11 | Talash | 86 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 12 | Timargara | 61 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 13 | Samarbagh | 63 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 14 | Maidan | 231 | 5.2 | 3.4 | 09 | 1 | 00 | 00 | 00 | 00 | 00 | 00 |
| 15 | Gulabad | 522 | 6.9 | 5.2 | 12 | 2 | 00 | 00 | 00 | 00 | 00 | 00 |
| 16 | Sarai Bala | 345 | 10 | 2.1 | 11 | 1 | 00 | 1 | 00 | 1 | 00 | 1 |

Table 6
Bacteriological analysis of hand pump water collected from different areas of Dir Lower

| S# | Sample ID | TPC | Coliform bacteria (MPN/100 ml) | Faecal Coliform | Staphylococcus aurous | E. coli | Salmonella | Shigella | V. cholera | P. aeruginosa | Bacillus SPP | Klebsiella |
|----|-----------|-----|-------------------------------|-----------------|-----------------------|---------|------------|----------|------------|---------------|--------------|------------|
| 1 | Ramora | 230 | 2.1 | <1.1 | 40 | 00 | 00 | 00 | 1 | 00 | 00 | 00 |
| 2 | Dara | 381 | 1.1 | 2.3 | 62 | 1 | 1 | 00 | 00 | 00 | 00 | 00 |
| 3 | Gulmuqam | 140 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 4 | Chakdara | 530 | 3.6 | 2.2 | 00 | 1 | 1 | 00 | 00 | 00 | 00 | 00 |
| 5 | Badwan Kuz | 770 | 12 | 3.6 | 73 | 1 | 00 | 00 | 00 | 1 | 00 | 00 |
| 6 | Badwan Bar | 463 | 13 | 9.4 | 00 | 2 | 00 | 00 | 00 | 00 | 00 | 00 |
| 7 | Shawa | 128 | 9.2 | <1.1 | 00 | 00 | 1 | 1 | 00 | 00 | 00 | 00 |
| 8 | Kityari | 475 | 3.8 | 2.3 | 12 | 1 | 1 | 00 | 1 | 00 | 00 | 00 |
| 9 | Asbanr | 468 | >23 | 12 | 00 | 5 | 00 | 00 | 00 | 00 | 00 | 00 |
| 10 | Ouch | 643 | 9.3 | 3.7 | 17 | 2 | 00 | 00 | 00 | 00 | 00 | 00 |
| 11 | Usakai | 445 | 9.3 | 3.8 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 12 | Talash | 93 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 13 | Talash Ziarat | 88 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 14 | Timargara | 80 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 15 | Rabat | 432 | 2.1 | 2.1 | 00 | 1 | 1 | 00 | 00 | 1 | 00 | 00 |
| 16 | Samarbagh | 86 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 17 | Maidan | 64 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 18 | Gulabad | 167 | 5.2 | <1.1 | 00 | 00 | 1 | 00 | 00 | 00 | 00 | 00 |
| 19 | Gulabad Barorai | 384 | 6.7 | 5.2 | 00 | 3 | 00 | 00 | 00 | 00 | 00 | 00 |
| 20 | Sarai Bala | 344 | 14 | 2.3 | 13 | 1 | 00 | 00 | 00 | 00 | 00 | 00 |

collected from Maidan, while in case of coliform bacteria, <1.1 was recorded in 6 samples out of 20 total collected samples. Maximum number (12) of *Faecal coliform* was found in the sample collected from Asband area, whereas the other values recorded were in the range of <1.1–9.4. Nine samples were recorded negative for *E. coli* presence while 5 samples were found positive for *S. aureus. Salmonella* and *Shigella* were positive in 5 and 1 samples, respectively, while 2 samples each were positive for *V. cholera* and *pseudomonas*. All the samples were negative for *Bacillus* and *Klebsiella*.

The contamination of pathogenic bacteria in spring water samples are shown in Table 7. TPC value was 648 in the sample collected from Khairabad Dari followed by 555 in sample collected from Tazagram Jango while the minimum value of TPC 66 was determined in the samples collected from Maidan. The *faecal coliform* was in range of >1.1–18. *E. coli* was absent in 9 samples out of 25 total collected samples, while the highest number of *S. aureus* 72 was recorded in the sample collected from Chakdara. *Salmonella* was present in 5 samples and the remaining 20 samples were found free from *Salmonella. Shigella* was present in 3 samples, whereas *V. cholera* was found in 1 sample. *Pseudomonas* was present in 3 samples while *Klebseilla* only in 1 sample.

Faecally polluted water is the cause of many infectious diseases. Enteric pathogens such as bacteria, viruses and parasites are the agents causing waterborne diseases. The spread of these waterborne infectious diseases by pathogens depends on several important factors such as the growth boosting environment, the effective concentration level of these microorganisms for a particular infection, quality of drinking water with respect to microbiological contamination and physicochemical parameters, the presence or absence of water treatment facilities and climatic conditions of the environment of the area [9,10].

### 3.2. Heavy metal analysis of water samples

The heavy metal contamination in tube well water samples are shown in Table 8. The maximum concentration of Cr 88 mg/l was noted in the sample collected from Dara Sharab Kowi while the minimum value 12 mg/l was recorded in the sample collected from Shawa. The concentration of Ni 198 mg/l was found the highest followed 192 mg/l in the samples collected from Dara Spinakhawra and Dara Faqirabad, respectively, while the lowest concentration of Ni 11 mg/l was recorded in the samples collected from Shawa. The concentration of Fe was in the range of

18–119 mg/l. In 11 samples, the Pb concentrations were beyond the WHO acceptable values.

Heavy metal contaminations in open well samples are shown in Table 9. The concentration of Cr was noted high; 85 mg/l in the sample collected from Chakdara followed by 81 mg/l in the sample from Badwan region. The minimum value of Cr 12 mg/l was recorded in the sample from Usakai area. The values of Ni were found above the limit of WHO (15 mg/l) in 12 samples out of 14 total collected samples. Fe concentration maximum value was 117 mg/l in the sample collected from Asbanr region. The highest concentration of Pb 15 mg/l was found in the sample from Chakdara while 7 mg/l in the sample collected from Ramora.

Table 10 shows the heavy metal concentrations in tap water. The highest concentration of Cr was 86 mg/l in water samples collected from Chakdara region followed by 81 mg/l in the sample collected from Shawa. The minimum concentration of Cr 11 mg/l was noted in the sample collected from Asbanr. Highest Ni concentration was 198 mg/l in the sample of Gulmuqam, whereas Fe concentration was 18 mg/l in the sample collected from Ramora. The highest value of Pb 18 mg/l was recorded in the sample of Kityari while in other samples, its concentrations were in range of 5–14 mg/l.

The concentrations of heavy metals in hand pump water samples are shown in Table 11. The highest concentration of Cr noted was 89 mg/l in the sample of Chakdara region while in 2 samples collected from Kityari and Shawa (15 and 17 mg/l respectively), the Cr concentration was below the WHO standard value. The highest Ni concentration 198 mg/l was noted in the sample collected from Gulmuqam while 15 mg/l was the minimum value determined in the sample collected from Kityari region. The maximum value 120 mg/l of Fe was noted in the sample from Badwan Bar, whereas in 2 samples Fe contents were within the WHO acceptable value. Maximum concentration of Pb (15 mg/l) was found in the sample collected from Talash Ziarat while in the samples collected from Talash and Usakai, Pb contents were 14 and 13 mg/l, respectively.

The spring water heavy metals analyses are shown in Table 12. The highest concentration of Cr was 83 and 81 mg/l in the samples collected from Dara Sharab Kowi and Gulmuqam, respectively. Minimum concentration of Ni 10 mg/l was observed in the sample from Dara Sharab Kowi. The highest Fe content (113 mg/l) was noted in the sample collected from Chakdara while minimum 17 mg/l was recorded in the sample collected from Ramora region. The

Table 7
Bacteriological analysis of spring water collected from different areas of Dir Lower

| S# | Sample ID | TPC | Coliform bacteria (MPN/100 ml) | Faecal Coliform | Staphylococcus aurous | E. coli | Salmonella | Shigella | V. cholera | P. aeruginosa | Bacillus SPP | Klebsiella |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ramora | 234 | 2.3 | <1.1 | 42 | 00 | 00 | 00 | 1 | 00 | 00 | 00 |
| 2 | Dara Faqirabad | 102 | >1.1 | >1.1 | 08 | 00 | 00 | 00 | 00 | 00 | 1 | 00 |
| 3 | Dara Spinakhawra | 209 | 1.1 | >1.1 | 02 | 00 | 00 | 1 | 00 | 00 | 00 | 00 |
| 4 | Dara Sharab Kowi | 503 | >23 | 18 | 48 | 11 | 00 | 00 | 00 | 2 | 00 | 00 |
| 5 | Gulmuqam | 533 | 17 | 5.2 | 16 | 9 | 3 | 00 | 00 | 00 | 00 | 00 |
| 6 | Chakdara | 468 | 9.3 | 3.8 | 72 | 2 | 00 | 00 | 00 | 00 | 1 | 00 |
| 7 | Badwan | 188 | <1.1 | <1.1 | 00 | 00 | 00 | 1 | 00 | 1 | 00 | 00 |
| 8 | Shawa | 249 | 24 | 14 | 00 | 8 | 3 | 00 | 00 | 00 | 00 | 00 |
| 9 | Shawa Tandodag | 414 | 15 | 14 | 09 | 11 | 00 | 00 | 00 | 00 | 00 | 00 |
| 10 | Tazagram | 474 | 3.5 | 2.3 | 00 | 1 | 1 | 00 | 00 | 00 | 00 | 00 |
| 11 | Tazagram Jango | 555 | 17 | 7.1 | 10 | 3 | 00 | 1 | 00 | 00 | 00 | 00 |
| 12 | Kityari | 147 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 13 | Kityari Batan | 325 | 5.2 | 3.7 | 48 | 1 | 00 | 00 | 00 | 00 | 2 | 00 |
| 14 | Khanpur | 197 | 2.3 | <1.1 | 04 | 00 | 00 | 00 | 00 | 1 | 00 | 00 |
| 15 | Asbanr | 534 | >23 | 16 | 14 | 7 | 00 | 00 | 00 | 00 | 00 | 00 |
| 16 | Ouch | 175 | 14 | <1.1 | 02 | 0 | 00 | 00 | 00 | 1 | 00 | 00 |
| 17 | Khairabad | 548 | 10 | 5.2 | 54 | 2 | 1 | 00 | 00 | 00 | 00 | 00 |
| 18 | Khairabad Dari | 648 | 2.5 | 2.4 | 00 | 1 | 00 | 00 | 00 | 00 | 00 | 1 |
| 19 | Usakai | 444 | 9.4 | 3.5 | 00 | 5 | 00 | 00 | 00 | 00 | 00 | 00 |
| 20 | Talash | 95 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 21 | Timargara | 75 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 22 | Rabat | 436 | 2.3 | 2.3 | 00 | 1 | 1 | 00 | 00 | 1 | 00 | 00 |
| 23 | Samarbagh | 234 | 5.0 | 3.8 | 09 | 2 | 00 | 00 | 00 | 00 | 00 | 00 |
| 24 | Maidan | 66 | <1.1 | <1.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 25 | Sarai Bala | 164 | 5.2 | <1.1 | 00 | 00 | 1 | 00 | 00 | 00 | 00 | 00 |

Table 8
Heavy metals analysis of tube well water samples collected from different areas of Dir Lower

| S# | Sample ID | Cr: mg/l (WHO Standard: 25 mg/l) | Ni: mg/l (WHO Standard: 15 mg/l) | Fe: mg/l (WHO Standard: 35 mg/l) | Pb: mg/l (WHO Standard: 10 mg/l) |
|---|---|---|---|---|---|
| 1 | Ramora | 63 | 52 | 18 | 07 |
| 2 | Dara Faqirabad | 62 | 192 | 48 | 11 |
| 3 | Dara Spinakhawra | 54 | 198 | 43 | 13 |
| 4 | Dara Sharab Kowi | 88 | 13 | 54 | 15 |
| 5 | Gulmuqam | 82 | 19 | 55 | 05 |
| 6 | Chakdara | 55 | 22 | 119 | 10 |
| 7 | Badwan | 15 | 27 | 55 | 19 |
| 8 | Shawa | 12 | 11 | 68 | 07 |
| 9 | Shawa Tandodag | 63 | 55 | 66 | 08 |
| 10 | Tazagram | 60 | 57 | 50 | 09 |
| 11 | Tazagram Jango | 44 | 60 | 30 | 11 |
| 12 | Kityari | 45 | 70 | 35 | 13 |
| 13 | Kityari Batan | 30 | 50 | 40 | 14 |
| 14 | Khanpur | 35 | 110 | 45 | 06 |
| 15 | Asbanr | 40 | 112 | 70 | 07 |
| 16 | Ouch | 43 | 98 | 50 | 06 |
| 17 | Khairabad | 42 | 95 | 24 | 05 |
| 18 | Khairabad Dari | 42 | 76 | 40 | 09 |
| 19 | Usakai | 45 | 120 | 41 | 11 |
| 20 | Talash | 39 | 130 | 60 | 12 |
| 21 | Timargara | 28 | 112 | 25 | 11 |
| 22 | Rabat | 20 | 50 | 20 | 09 |
| 23 | Samarbagh | 19 | 65 | 70 | 06 |
| 24 | Maidan | 18 | 70 | 80 | 08 |
| 25 | Gulabad | 30 | 55 | 65 | 04 |
| 26 | Sarai Bala | 35 | 51 | 30 | 12 |

Table 9
Heavy metals analysis of open well water samples collected from different areas of Dir Lower

| S# | Sample ID | Cr: mg/l (WHO Standard: 25 mg/l) | Ni: mg/l (WHO Standard: 15 mg/l) | Fe: mg/l (WHO Standard: 35 mg/l) | Pb: mg/l (WHO Standard: 10 mg/l) |
|---|---|---|---|---|---|
| 1 | Ramora | 61 | 55 | 19 | 07 |
| 2 | Dara | 65 | 195 | 44 | 12 |
| 3 | Gulmuqam | 55 | 196 | 44 | 13 |
| 4 | Chakdara | 85 | 13 | 56 | 15 |
| 5 | Badwan | 81 | 20 | 57 | 06 |
| 6 | Asbanr | 56 | 22 | 117 | 10 |
| 7 | Usakai | 12 | 28 | 57 | 18 |
| 8 | Talash | 15 | 11 | 69 | 08 |
| 9 | Talash Banda | 65 | 56 | 68 | 09 |
| 10 | Timargara | 62 | 58 | 50 | 10 |
| 11 | Samarbagh | 46 | 64 | 35 | 12 |
| 12 | Maidan | 49 | 71 | 35 | 14 |
| 13 | Gulabad | 31 | 59 | 39 | 14 |
| 14 | Sarai Bala | 34 | 125 | 38 | 09 |

concentration of Pb was maximum (17 mg/l) in the sample collected from Badwan, whereas the other values were in the range of 3–12 mg/l.

Pakistan was badly affected by the heavy flood of 2010, which significantly deteriorated water quality. The increasing contamination of drinking water is a

Table 10
Heavy metal analysis tap water samples collected from different areas of Dir Lower

| S# | Sample ID | Cr: mg/l (WHO Standard: 25 mg/l) | Ni: mg/l (WHO Standard: 15 mg/l) | Fe: mg/l (WHO Standard: 35 mg/l) | Pb: mg/l (WHO Standard: 10 mg/l) |
|---|---|---|---|---|---|
| 1 | Ramora | 66 | 54 | 18 | 07 |
| 2 | Dara | 65 | 195 | 48 | 15 |
| 3 | Gulmuqam | 56 | 198 | 45 | 12 |
| 4 | Chakdara | 86 | 12 | 52 | 14 |
| 5 | Shawa | 81 | 19 | 52 | 06 |
| 6 | Tazagram | 53 | 21 | 116 | 08 |
| 7 | Kityari | 13 | 26 | 56 | 18 |
| 8 | Asbanr | 11 | 11 | 66 | 06 |
| 9 | Ouch | 61 | 54 | 64 | 07 |
| 10 | Usakai | 59 | 56 | 50 | 08 |
| 11 | Talash | 42 | 58 | 30 | 10 |
| 12 | Timargara | 44 | 66 | 34 | 13 |
| 13 | Samarbagh | 30 | 40 | 39 | 12 |
| 14 | Maidan | 33 | 108 | 45 | 05 |
| 15 | Gulabad | 38 | 111 | 70 | 06 |
| 16 | Sarai Bala | 42 | 96 | 50 | 05 |

Table 11
Heavy metals analysis of hand pump water samples collected from different areas of Dir Lower

| S# | Sample ID | Cr: mg/l (WHO Standard: 25 mg/l) | Ni: mg/l (WHO Standard: 15 mg/l) | Fe: mg/l (WHO Standard: 35 mg/l) | Pb: mg/l (WHO Standard: 10 mg/l) |
|---|---|---|---|---|---|
| 1 | Ramora | 60 | 49 | 19 | 07 |
| 2 | Dara | 65 | 193 | 49 | 12 |
| 3 | Gulmuqam | 55 | 198 | 45 | 13 |
| 4 | Chakdara | 89 | 15 | 57 | 15 |
| 5 | Badwan Kuz | 86 | 23 | 55 | 07 |
| 6 | Badwan Bar | 58 | 22 | 120 | 10 |
| 7 | Shawa | 17 | 29 | 58 | 19 |
| 8 | Kityari | 15 | 15 | 69 | 09 |
| 9 | Asbanr | 66 | 56 | 68 | 08 |
| 10 | Ouch | 63 | 59 | 53 | 10 |
| 11 | Usakai | 46 | 60 | 36 | 13 |
| 12 | Talash | 45 | 74 | 37 | 14 |
| 13 | Talash Ziarat | 34 | 54 | 42 | 15 |
| 14 | Timargara | 44 | 111 | 46 | 07 |
| 15 | Rabat | 44 | 116 | 73 | 08 |
| 16 | Samarbagh | 46 | 99 | 53 | 06 |
| 17 | Maidan | 44 | 98 | 28 | 08 |
| 18 | Gulabad | 46 | 78 | 47 | 09 |
| 19 | Gulabad Barorai | 49 | 121 | 45 | 12 |

matter of great concern. The high concentration of the heavy metals can cause acute or chronic disorders. The major sink for heavy metals is soil from where these enter into food chain through leaching into groundwater. The toxicity of heavy metals causes brain damage, thus reducing the efficiency of central nervous system. Alterations in DNA have also been reported [11–13].

### 3.3. Nutritional metal analysis of water samples

The nutritional metals present in tube well water samples are shown in Table 13. The Na concentration was 365 mg/l (maximum) in the sample collected from Dara Sharab Kowi. K concentration was 70 mg/l (minimum) in the sample from Gulabad region. The

Table 12
Heavy metals analysis spring water samples collected from different areas of Dir Lower

| S# | Sample ID | Cr: mg/l (WHO Standard: 25 mg/l) | Ni: mg/l (WHO Standard: 15 mg/l) | Fe: mg/l (WHO Standard: 35 mg/l) | Pb: mg/l (WHO Standard: 10 mg/l) |
|---|---|---|---|---|---|
| 1 | Ramora | 59 | 50 | 17 | 07 |
| 2 | Dara Faqirabad | 62 | 190 | 47 | 10 |
| 3 | Dara Spinakhawra | 53 | 196 | 43 | 12 |
| 4 | Dara Sharab Kowi | 83 | 10 | 50 | 10 |
| 5 | Gulmuqam | 81 | 16 | 51 | 04 |
| 6 | Chakdara | 50 | 21 | 113 | 10 |
| 7 | Badwan | 15 | 24 | 51 | 17 |
| 8 | Shawa | 12 | 10 | 65 | 05 |
| 9 | Shawa Tandodag | 60 | 52 | 61 | 06 |
| 10 | Tazagram | 58 | 55 | 49 | 09 |
| 11 | Tazagram Jango | 41 | 56 | 27 | 11 |
| 12 | Kityari | 42 | 66 | 35 | 12 |
| 13 | Kityari Batan | 28 | 50 | 37 | 12 |
| 14 | Khanpur | 33 | 109 | 45 | 05 |
| 15 | Asbanr | 40 | 111 | 66 | 07 |
| 16 | Ouch | 40 | 90 | 50 | 04 |
| 17 | Khairabad | 40 | 90 | 22 | 03 |
| 18 | Khairabad Dari | 40 | 73 | 40 | 07 |
| 19 | Usakai | 41 | 114 | 40 | 09 |
| 20 | Talash | 37 | 125 | 55 | 12 |
| 21 | Timargara | 25 | 110 | 24 | 11 |
| 22 | Rabat | 19 | 56 | 18 | 08 |
| 23 | Samarbagh | 16 | 63 | 67 | 03 |
| 24 | Maidan | 15 | 64 | 77 | 06 |
| 25 | Sarai Bala | 29 | 52 | 64 | 03 |

highest concentration of Ca (345 mg/l) was observed in the sample collected from Dara Sharab Kowi followed by 321 mg/l in the sample collected from Dara Spinakhawra region. The lowest concentration of Mg (21 mg/l) was observed in the sample from Dara Faqirabad area, while in other samples Mg contents were in the range of 70–245 mg/l.

The concentrations of nutritional metals in open well samples are given in Table 14. The highest Na concentration was 334 mg/l in the water sample from Chakdara region followed by 300 mg/l in the sample from Sarai Bala. In the remaining samples, Na contents were in the range of 128–250 mg/l. Potassium concentration was 155 mg/l (maximum) in the sample collected from Asbanr. The highest content of Mg was 242 mg/l in the sample collected from Gulmuqam and the least 20 mg/l was found in the sample from Dara region.

Table 15 represents the nutritional metal concentrations in the collected tap water samples. The concentration of Na was 362 mg/l (maximum) in the sample collected from Chakdara while highest K content was 146 mg/l in the sample collected from Tazagram. The

concentrations of Ca in all samples were within the WHO acceptable range. The highest values were 250 mg/l in the samples collected from Gulmuqam and Chakdara regions. The maximum concentration of Mg was 243 mg/l in the sample collected from Gulmuqam, whereas the other values were in between 21 and 224 mg/l.

The concentrations of beneficial minerals in the hand pump water samples are shown in Table 16. The highest content of Na was 368 mg/l in the sample collected from Chakdara, whereas the highest K concentration was 147 mg/l in the sample collected from Badwan Kuz. The lowest concentration of Ca was 56 mg/l in the sample collected from Badwan Bar and the Mg was 20 mg/l (minimum) in the sample collected from Dara.

Table 17 shows the concentration of some inorganic minerals in spring water samples. The highest Na concentration was 364 mg/l in the sample collected from Dara Sharab Kowi followed by 256 mg/l in the sample collected from Gulmuqam. The lowest concentration of K was 23 mg/l in the sample collected from Badwan. Highest Ca concentration was

Table 13
Analysis of Na, K, Ca and Mg in tube well water samples collected from different areas of Dir Lower

| S# | Sample ID | Na: mg/l (WHO Standard: 200 mg/l) | K: mg/l (WHO Standard: 75 mg/l) | Ca mg/l (WHO Standard: 250 mg/l) | Mg: mg/l (WHO Standard: 150 mg/l) |
|----|-----------|-----------------------------------|---------------------------------|----------------------------------|-----------------------------------|
| 1  | Ramora | 210 | 80 | 248 | 180 |
| 2  | Dara Faqirabad | 205 | 78 | 227 | 20 |
| 3  | Dara Spinakhawra | 120 | 92 | 321 | 244 |
| 4  | Dara Sharab Kowi | 365 | 120 | 345 | 121 |
| 5  | Gulmuqam | 251 | 146 | 98 | 93 |
| 6  | Chakdara | 208 | 148 | 56 | 36 |
| 7  | Badwan | 137 | 23 | 241 | 132 |
| 8  | Shawa | 123 | 103 | 197 | 139 |
| 9  | Shawa Tandodag | 124 | 102 | 150 | 130 |
| 10 | Tazagram | 134 | 104 | 151 | 120 |
| 11 | Tazagram Jango | 140 | 100 | 148 | 111 |
| 12 | Kityari | 150 | 98 | 100 | 66 |
| 13 | Kityari Batan | 151 | 95 | 78 | 70 |
| 14 | Khanpur | 140 | 98 | 80 | 100 |
| 15 | Asbanr | 141 | 100 | 87 | 134 |
| 16 | Ouch | 200 | 112 | 200 | 212 |
| 17 | Khairabad | 180 | 110 | 211 | 244 |
| 18 | Khairabad Dari | 170 | 80 | 200 | 240 |
| 19 | Usakai | 160 | 106 | 222 | 200 |
| 20 | Talash | 209 | 110 | 250 | 212 |
| 21 | Timargara | 250 | 120 | 290 | 213 |
| 22 | Rabat | 200 | 99 | 240 | 116 |
| 23 | Samarbagh | 250 | 100 | 320 | 208 |
| 24 | Maidan | 180 | 111 | 300 | 209 |
| 25 | Gulabad | 215 | 70 | 321 | 117 |
| 26 | Sarai Bala | 280 | 113 | 311 | 120 |

344 mg/l in the samples of water collected from Dara Sharab Kowi, while the other values were in between 85 and 320 mg/l. The Mg level was higher than that of WHO acceptable value (150 mg/l) in 11 samples with maximum value of 244 mg/l in the sample collected from Khair Abad.

### 3.4. Physicochemical parameters of collected water samples

The physicochemical parameters of tube well water samples are shown in Table 18. The highest concentration of nitrate was 6.9 mg/l in the sample collected from Khanpur followed by 6.8 mg/l in the sample collected from Kityari and Kityari Batan. The concentration of sulphate was 20 mg/l (maximum) in the samples collected from Kityari Batan and Kityari, whereas the minimum value observed was 1 mg/l in the sample collected from Faqirabad. Fluoride content (0.44 mg/l) was high in the sample collected from Timargara and the least concentration was 0.10 mg/l in sample collected from Tazagram. The maximum

concentration of Cl was 99.1 mg/l in the sample collected from Maidan followed by 95.0 mg/l in the sample collected from Samarbagh, while in other samples the Cl contents were in the range of 90.2–7.1 mg/l.

The physicochemical parameters of the open well water samples are shown in Table 19. The concentration of nitrate was 6.9 mg/l (maximum) in the sample collected from Sarai Bala followed by 6.8 mg/l in the samples collected from Maidan and Gulabad. The highest concentration of sulphate was 21 mg/l in the samples collected from Maidan and Gulabad whereas in sample collected from Dara its concentration was 1 mg/l. Maximum fluoride contents were 0.41 mg/l in the sample collected from Gulmuqam and Chakdara while the least value 0.10 mg/l were observed in samples collected from Talash Banda and Timargara. The concentration of Cl was 23.3 mg/l (maximum) in the sample collected from Asbanr followed by 21.4 mg/l in the sample collected from Badwan, while in other samples the Cl concentrations were in the range of 13.5–7.1 mg/l.

Table 14
Analysis of Na, K, Ca and Mg in open well water samples collected from different areas of Dir Lower

| S# | Sample ID | Na: mg/l (WHO Standard: 200 mg/l) | K: mg/l (WHO Standard: 75 mg/l) | Ca: mg/l (WHO Standard: 250 mg/l) | Mg: mg/l (WHO Standard: 150 mg/l) |
|----|-----------|------|------|------|------|
| 1 | Ramora | 212 | 90 | 250 | 177 |
| 2 | Dara | 208 | 80 | 225 | 20 |
| 3 | Gulmuqam | 124 | 96 | 317 | 242 |
| 4 | Chakdara | 334 | 126 | 340 | 120 |
| 5 | Badwan | 255 | 149 | 97 | 90 |
| 6 | Asbanr | 210 | 155 | 55 | 34 |
| 7 | Usakai | 139 | 29 | 239 | 131 |
| 8 | Talash | 128 | 109 | 193 | 133 |
| 9 | Talash Banda | 135 | 100 | 167 | 140 |
| 10 | Timargara | 200 | 68 | 312 | 189 |
| 11 | Samarbagh | 240 | 70 | 300 | 200 |
| 12 | Maidan | 241 | 90 | 278 | 170 |
| 13 | Gulabad | 250 | 98 | 213 | 123 |
| 14 | Sarai Bala | 300 | 112 | 113 | 140 |

Table 15
Analysis of Na, K, Ca and Mg in tap water samples collected from different areas of Dir Lower

| S# | Sample ID | Na: mg/l (WHO Standard: 200 mg/l) | K: mg/l (WHO Standard: 75 mg/l) | Ca: mg/l (WHO Standard: 250 mg/l) | Mg: mg/l (WHO Standard: 150 mg/l) |
|----|-----------|------|------|------|------|
| 1 | Ramora | 214 | 81 | 249 | 177 |
| 2 | Dara | 208 | 79 | 229 | 21 |
| 3 | Gulmuqam | 113 | 90 | 320 | 243 |
| 4 | Chakdara | 362 | 124 | 347 | 120 |
| 5 | Shawa | 250 | 144 | 96 | 90 |
| 6 | Tazagram | 200 | 146 | 55 | 33 |
| 7 | Kityari | 136 | 20 | 245 | 131 |
| 8 | Asbanr | 122 | 102 | 195 | 136 |
| 9 | Ouch | 234 | 80 | 200 | 213 |
| 10 | Usakai | 200 | 90 | 211 | 200 |
| 11 | Talash | 280 | 100 | 230 | 220 |
| 12 | Timargara | 300 | 123 | 231 | 224 |
| 13 | Samarbagh | 311 | 111 | 250 | 180 |
| 14 | Maidan | 310 | 130 | 245 | 160 |
| 15 | Gulabad | 223 | 134 | 200 | 170 |
| 16 | Sarai Bala | 243 | 140 | 260 | 165 |

Physicochemical parameters of tap water samples are listed in Table 20. The concentration of nitrate was 6.8 mg/l (maximum) in the sample collected from Samarbagh and Maidan followed by 6.2 mg/l in the sample collected from Gulabad. The highest concentration of sulphate was 21 mg/l in the samples collected from Samarbagh, whereas the least content, 1.1 mg/l was observed in the sample collected from Dara. Fluoride contents were 0.41 mg/l (highest) in the samples collected from Gulmuqam and Chakdara, while the least values observed were 0.10 mg/l in the samples collected from Talash, Ouch and Usakai. The highest concentration of Cl was 23.1 mg/l in the sample collected from Sarai Bala followed by 23.1 mg/l in the sample collected from Tazagram while in other samples the Cl concentrations were in the range of 21.1–7.12 mg/l.

The physicochemical parameters of hand pump water samples are given Table 21. The highest concentrations of nitrate were 6.9 mg/l in the sample collected from Talash, Ziarat and Timargara followed by 6.2 mg/l in the sample collected from Rabat and

Table 16
Analysis of Na, K, Ca and Mg in hand pump water samples collected from different areas of Dir Lower

| S# | Sample ID | Na: mg/l (WHO Standard: 200 mg/l) | K: mg/l (WHO Standard: 75 mg/l) | Ca: mg/l (WHO Standard: 250 mg/l) | Mg: mg/l (WHO Standard: 150 mg/l) |
|---|---|---|---|---|---|
| 1 | Ramora | 211 | 86 | 230 | 183 |
| 2 | Dara | 209 | 79 | 229 | 20 |
| 3 | Gulmuqam | 118 | 98 | 320 | 242 |
| 4 | Chakdara | 368 | 127 | 341 | 126 |
| 5 | Badwan Kuz | 263 | 147 | 99 | 98 |
| 6 | Badwan Bar | 210 | 146 | 56 | 39 |
| 7 | Shawa | 136 | 20 | 240 | 123 |
| 8 | Kityari | 128 | 103 | 199 | 131 |
| 9 | Asbanr | 124 | 102 | 150 | 130 |
| 10 | Ouch | 134 | 104 | 151 | 120 |
| 11 | Usakai | 150 | 106 | 212 | 100 |
| 12 | Talash | 160 | 125 | 236 | 80 |
| 13 | Talash Ziarat | 167 | 126 | 238 | 83 |
| 14 | Timargara | 260 | 130 | 300 | 216 |
| 15 | Rabat | 200 | 127 | 230 | 150 |
| 16 | Samarbagh | 230 | 134 | 290 | 209 |
| 17 | Maidan | 231 | 130 | 260 | 210 |
| 18 | Gulabad | 180 | 134 | 201 | 176 |
| 19 | Gulabad Barorai | 170 | 120 | 170 | 170 |

Table 17
Analysis of Na, K, Ca and Mg in spring water samples collected from different areas of Dir Lower

| S# | Sample ID | Na: mg/l (WHO Standard: 200 mg/l) | K: mg/l (WHO Standard: 75 mg/l) | Ca: mg/l (WHO Standard: 250 mg/l) | Mg: mg/l (WHO Standard: 150 mg/l) |
|---|---|---|---|---|---|
| 1 | Ramora | 211 | 84 | 251 | 186 |
| 2 | Dara Faqirabad | 207 | 79 | 229 | 20 |
| 3 | Dara Spinakhawra | 120 | 97 | 320 | 243 |
| 4 | Dara Sharab Kowi | 364 | 127 | 344 | 125 |
| 5 | Gulmuqam | 256 | 146 | 99 | 99 |
| 6 | Chakdara | 209 | 147 | 55 | 39 |
| 7 | Badwan | 138 | 23 | 245 | 134 |
| 8 | Shawa | 125 | 105 | 198 | 143 |
| 9 | Shawa Tandodag | 122 | 107 | 158 | 137 |
| 10 | Tazagram | 135 | 108 | 156 | 128 |
| 11 | Tazagram Jango | 145 | 105 | 153 | 115 |
| 12 | Kityari | 151 | 99 | 109 | 69 |
| 13 | Kityari Batan | 153 | 98 | 79 | 78 |
| 14 | Khanpur | 143 | 100 | 85 | 107 |
| 15 | Asbanr | 146 | 103 | 86 | 135 |
| 16 | Ouch | 209 | 115 | 207 | 215 |
| 17 | Khairabad | 185 | 116 | 216 | 244 |
| 18 | Khairabad Dari | 173 | 87 | 201 | 240 |
| 19 | Usakai | 163 | 109 | 225 | 204 |
| 20 | Talash | 210 | 111 | 253 | 215 |
| 21 | Timargara | 251 | 123 | 295 | 217 |
| 22 | Rabat | 208 | 102 | 245 | 119 |
| 23 | Samarbagh | 252 | 105 | 323 | 210 |
| 24 | Maidan | 184 | 113 | 303 | 210 |
| 25 | Sarai Bala | 219 | 75 | 325 | 119 |

Table 18
Physicochemical parameters of tube well water samples collected from different areas of Dir Lower

| S# | Sample ID | PH | EC (µS/ml) | TDS (mg/l) PS (dw) Standard: 1,000–1,500 | Turbidity (NTU) PS (dw) Standard: 1 | Alkalinity | Hardness (mg/l) PS (dw) Standard: 20–500 | $NO_3^{1-}$ (mg/l) PS (dw) Standard: 45 | $SO_4^{2-}$ (mg/l) PS (dw) Standard: 200–400 | $F^{1}$ (mg/l) PS (dw) Standard: 1.5 | $Cl^{1}$ (mg/l) PS (dw) Standard: 200–600 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ramora | 7.40 | 486 | 446 | 1.3 | 6.5 | 175 | 1.3 | 11.0 | 0.14 | 10.4 |
| 2 | Dara Faqirabad | 7.36 | 480 | 408 | 0.00 | 5.8 | 180 | 1.4 | 1.0 | 0.15 | 10.6 |
| 3 | Dara Spinakhawra | 7.42 | 480 | 370 | 0.50 | 5.8 | 334 | 4.6 | 14 | 0.42 | 11.2 |
| 4 | Dara Sharab Kowi | 7.2 | 450 | 350 | 0.40 | 5.8 | 330 | 4.6 | 14 | 0.41 | 11.7 |
| 5 | Gulmuqam | 7.2 | 642 | 360 | 0.00 | 6.0 | 330 | 0.4 | 8.0 | 0.31 | 21.2 |
| 6 | Chakdara | 7.3 | 645 | 317 | 0.00 | 6.0 | 230 | 0.4 | 8.0 | 0.20 | 23.2 |
| 7 | Badwan | 7.4 | 780 | 400 | 0.40 | 4.6 | 240 | 1.5 | 8.3 | o.22 | 11.2 |
| 8 | Shawa | 7.3 | 780 | 416 | 0.70 | 4.6 | 250 | 0.3 | 11.1 | 023 | 13.6 |
| 9 | Shawa Tandodag | 7.4 | 814 | 445 | 0.80 | 6.0 | 250 | 0.3 | 11.3 | 0.10 | 7.12 |
| 10 | Tazagram | 7.4 | 835 | 434 | 0.80 | 6.0 | 250 | 1.2 | 19 | 0.10 | 7.12 |
| 11 | Tazagram Jango | 7.4 | 834 | 447 | 0.00 | 5.4 | 260 | 1.2 | 19 | 0.11 | 7.3 |
| 12 | Kityari | 7.4 | 684 | 432 | 0.00 | 5.4 | 260 | 6.8 | 20 | 0.13 | 8.1 |
| 13 | Kityari Batan | 7.4 | 684 | 431 | 0.00 | 6.4 | 270 | 6.8 | 20 | 0.14 | 8.1 |
| 14 | Khanpur | 7.3 | 620 | 421 | 0.80 | 6.4 | 270 | 6.9 | 4.6 | 0.14 | 7.1 |
| 15 | Asbanr | 7.3 | 630 | 432 | 0.30 | 6.4 | 190 | 6.1 | 5.0 | 0.15 | 11.0 |
| 16 | Ouch | 7.1 | 813 | 480 | 0.30 | 4 | 180 | 6.1 | 4.6 | 0.15 | 30.2 |
| 17 | Khairabad | 7.2 | 640 | 470 | 0.00 | 4 | 250 | 6.2 | 1.3 | 0.12 | 22.1 |
| 18 | Khairabad Dari | 7.2 | 640 | 470 | 0.00 | 5 | 250 | 5.0 | 1.3 | 0.22 | 23.1 |
| 19 | Usakai | 7.3 | 820 | 436 | 0.00 | 5 | 270 | 0.9 | 9.2 | 0.12 | 50.1 |
| 20 | Talash | 7.4 | 820 | 380 | 0.70 | 5.8 | 270 | 0.9 | 9.1 | 0.16 | 45.0 |
| 21 | Timargara | 7.5 | 810 | 450 | 0.80 | 5.8 | 290 | 0.3 | 11.3 | 0.44 | 90.2 |
| 22 | Rabat | 7.4 | 811 | 337 | 0.00 | 5.0 | 260 | 0.4 | 10 | 0.11 | 70.3 |
| 23 | Samarbagh | 7.4 | 1,021 | 360 | 0.70 | 5.0 | 320 | 1.2 | 6.3 | 0.13 | 95.0 |
| 24 | Maidan | 7.3 | 686 | 364 | 0.80 | 5.0 | 320 | 1.2 | 6.5 | 0.14 | 99.1 |
| 25 | Gulabad | 7.3 | 687 | 337 | 0.00 | 4.0 | 300 | 0.9 | 3.4 | 0.20 | 23.2 |
| 26 | Sarai Bala | 7.3 | 340 | 336 | 0.00 | 4.1 | 312 | 0.9 | 3.5 | 0.22 | 21.2 |

Table 19
Evaluation of physical parameters of the open well water of different areas of District Dir Lower

| S# | Sample ID | PH | EC (μS/ml) | TDS (mg/l) PS (dw) Standard: 1,000–1,500 | Turbidity (NTU) PS (dw) Standard: 1 | Alkalinity | Hardness (mg/l) PS (dw) Standard: 20–500 | $NO_3^{1-}$ (mg/l) PS (dw) Standard: 45 | $SO_4^{2-}$ (mg/l) PS (dw) Standard: 200–400 | $F^{-1}$ (mg/l) PS (dw) Standard: 1.5 | $Cl^{-1}$ (mg/l) PS (dw) Standard: 200–600 |
|----|-----------|------|-----|-----|------|-----|-----|-----|-------|------|------|
| 1 | Ramora | 7.40 | 487 | 445 | 1.2 | 6.6 | 175 | 1.2 | 11.0 | 0.15 | 10.5 |
| 2 | Dara | 7.3 | 482 | 409 | 0.00 | 5.9 | 181 | 1.5 | 1.0 | 0.16 | 10.7 |
| 3 | Gulmuqam | 7.4 | 481 | 375 | 0.50 | 5.8 | 337 | 4.5 | 15 | 0.41 | 11.4 |
| 4 | Chakdara | 7.2 | 452 | 355 | 0.40 | 5.8 | 333 | 4.5 | 15 | 0.41 | 11.8 |
| 5 | Badwan | 7.2 | 643 | 363 | 0.00 | 6.1 | 331 | 0.4 | 8.4 | 0.31 | 21.4 |
| 6 | Asbanr | 7.2 | 645 | 318 | 0.00 | 6.1 | 230 | 0.4 | 8.4 | 0.21 | 23.3 |
| 7 | Usakai | 7.5 | 784 | 401 | 0.41 | 4.8 | 243 | 1.6 | 8.5 | 0.23 | 11.4 |
| 8 | Talash | 7.2 | 786 | 418 | 0.72 | 4.8 | 254 | 0.4 | 11.31 | 0.24 | 13.5 |
| 9 | Talash Banda | 7.3 | 817 | 447 | 0.80 | 6.3 | 254 | 0.4 | 11.2 | 0.10 | 7.13 |
| 10 | Timargara | 7.5 | 836 | 436 | 0.80 | 6.3 | 256 | 1.3 | 20 | 0.10 | 7.12 |
| 11 | Samarbagh | 7.4 | 837 | 448 | 0.00 | 5.5 | 266 | 1.3 | 19 | 0.12 | 7.3 |
| 12 | Maidan | 7.4 | 685 | 432 | 0.00 | 5.5 | 265 | 6.8 | 21 | 0.13 | 8.2 |
| 13 | Gulabad | 7.3 | 687 | 434 | 0.00 | 6.6 | 274 | 6.8 | 21 | 0.15 | 8.2 |
| 14 | Sarai Bala | 7.3 | 689 | 442 | 0.00 | 6.0 | 263 | 6.9 | 11.1 | 0.13 | 7.3 |

Table 20
Evaluation of physical parameters of the tap water of different areas of District Dir Lower

| S# | Sample ID | PH | EC (μS/ml) | TDS (mg/l) PS (dw) Standard: 1,000–1,500 | Turbidity (NTU) PS (dw) Standard: 1 | Alkalinity | Hardness (mg/l) PS (dw) Standard: 20–500 | $NO_3^{1-}$ (mg/l) PS (dw) Standard: 45 | $SO_4^{2-}$ (mg/l) PS (dw) Standard: 200–400 | $F^{-1}$ (mg/l) PS (dw) Standard: 1.5 | $Cl^{-1}$ (mg/l) (dw) Standard: 200–600 |
|----|-----------|------|-----|-----|------|-----|-----|-----|------|------|------|
| 1 | Ramora | 7.31 | 482 | 444 | 1.2 | 6.4 | 173 | 1.2 | 11.0 | 0.14 | 10.3 |
| 2 | Dara | 7.35 | 480 | 404 | 0.00 | 5.8 | 180 | 1.4 | 1.1 | 0.16 | 10.5 |
| 3 | Gulmuqam | 7.41 | 476 | 366 | 0.50 | 5.8 | 331 | 4.6 | 14 | 0.41 | 11.1 |
| 4 | Chakdara | 7.1 | 446 | 349 | 0.40 | 5.8 | 329 | 4.6 | 15 | 0.41 | 11.4 |
| 5 | Shawa | 7.2 | 641 | 359 | 0.00 | 6.1 | 330 | 0.3 | 8.0 | 0.30 | 21.1 |
| 6 | Tazagram | 7.3 | 643 | 316 | 0.00 | 6.0 | 228 | 0.3 | 8.0 | 0.19 | 23.1 |
| 7 | Kityari | 7.2 | 780 | 390 | 0.39 | 4.4 | 238 | 1.6 | 8.1 | 0.21 | 11.1 |
| 8 | Asbanr | 7.1 | 778 | 414 | 0.66 | 4.4 | 250 | 0.4 | 11.1 | 0.22 | 13.3 |
| 9 | Ouch | 7.4 | 812 | 443 | 0.80 | 6.1 | 249 | 0.4 | 11.1 | 0.10 | 7.12 |
| 10 | Usakai | 7.4 | 834 | 431 | 0.80 | 6.1 | 250 | 1.1 | 18 | 0.10 | 7.12 |
| 11 | Talash | 7.5 | 832 | 443 | 0.00 | 5.3 | 259 | 1.2 | 18 | 0.10 | 7.2 |
| 12 | Timargara | 7.4 | 682 | 431 | 0.00 | 5.2 | 260 | 6.0 | 20 | 0.12 | 8.0 |
| 13 | Samarbagh | 7.5 | 683 | 431 | 0.00 | 6.2 | 266 | 6.8 | 21 | 0.13 | 8.0 |
| 14 | Maidan | 7.2 | 619 | 421 | 0.80 | 6.2 | 266 | 6.8 | 4.6 | 0.12 | 7.1 |
| 15 | Gulabad | 7.2 | 632 | 434 | 0.21 | 6.2 | 190 | 6.2 | 5.0 | 0.14 | 11.0 |
| 16 | Sarai Bala | 7.1 | 812 | 478 | 0.30 | 4.1 | 180 | 6.0 | 4.7 | 0.14 | 30.1 |

Table 21
Evaluation of physical parameters of the hand pump water of different areas of District Dir Lower

| S# | Sample ID | PH | EC (µS/ml) | TDS (mg/l) PS (dw) Standard: 1,000–1,500 | Turbidity (NTU) PS (dw) Standard: 1 | Alkalinity | Hardness (mg/l) PS (dw) Standard: 20–500 | $NO_3^{1-}$ (mg/l) PS (dw) Standard: 45 | $SO_4^{2-}$ (mg/l) PS (dw) Standard: 200–400 | $F^{-1}$ (mg/l) PS (dw) Standard: 1.5 | $Cl^{-1}$ (mg/l) PS (dw) Standard: 200–600 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ramora | 7.4 | 488 | 447 | 1.5 | 6.6 | 176 | 1.4 | 11.0 | 0.14 | 10.5 |
| 2 | Dara | 7.3 | 483 | 409 | 0.00 | 5.9 | 182 | 1.4 | 1.0 | 0.16 | 10.7 |
| 3 | Gulmuqam | 7.4 | 480 | 376 | 0.50 | 5.8 | 334 | 4.4 | 14 | 0.42 | 11.5 |
| 4 | Chakdara | 7.2 | 450 | 350 | 0.41 | 5.8 | 330 | 4.7 | 14 | 0.44 | 11.8 |
| 5 | Badwan Kuz | 7.1 | 646 | 363 | 0.00 | 6.1 | 333 | 0.5 | 8.3 | 0.31 | 21.5 |
| 6 | Badwan Bar | 7.2 | 647 | 318 | 0.00 | 6.0 | 230 | 0.3 | 8.0 | 0.21 | 23.4 |
| 7 | Shawa | 7.2 | 782 | 408 | 0.41 | 4.7 | 245 | 1.6 | 8.4 | 0.24 | 11.2 |
| 8 | Kityari | 7.3 | 780 | 418 | 0.70 | 4.8 | 253 | 0.4 | 11.1 | 024 | 13.5 |
| 9 | Asbanr | 7.6 | 815 | 447 | 0.80 | 6.1 | 252 | 0.4 | 11.3 | 0.14 | 7.13 |
| 10 | Ouch | 7.4 | 836 | 438 | 0.80 | 6.2 | 253 | 1.5 | 19 | 0.14 | 7.12 |
| 11 | Usakai | 7.5 | 835 | 448 | 0.00 | 5.4 | 263 | 1.4 | 20 | 0.11 | 7.1 |
| 12 | Talash | 7.4 | 684 | 432 | 0.00 | 5.4 | 262 | 6.9 | 20 | 0.13 | 8.1 |
| 13 | Talash Ziarat | 7.4 | 685 | 434 | 0.00 | 6.5 | 274 | 6.9 | 21 | 0.16 | 8.1 |
| 14 | Timargara | 7.6 | 625 | 421 | 0.80 | 6.4 | 275 | 6.9 | 4.7 | 0.14 | 7.3 |
| 15 | Rabat | 7.3 | 631 | 434 | 0.32 | 6.6 | 195 | 6.2 | 5.0 | 0.16 | 11.2 |
| 16 | Samarbagh | 7.5 | 814 | 482 | 0.33 | 4.0 | 183 | 6.1 | 4.7 | 0.15 | 30.4 |
| 17 | Maidan | 7.2 | 643 | 476 | 0.00 | 4.5 | 253 | 6.2 | 1.4 | 0.12 | 22.3 |
| 18 | Gulabad | 7.2 | 645 | 476 | 0.00 | 5.4 | 253 | 5.1 | 1.3 | 0.24 | 23.2 |
| 19 | Barorai | 7.3 | 823 | 437 | 0.00 | 5.4 | 272 | 0.8 | 9.5 | 0.13 | 50.5 |

Table 22
Evaluation of physical parameters of spring water sample collected from different areas of District Dir Lower

| S# | Sample ID | PH | EC (µS/ml) | TDS (mg/l) PS (dw) Standard: 1,000–1,500 | Turbidity (NTU) PS (dw) Standard: 1 NTU | Alkalinity | Hardness (mg/l) PS (dw) Standard: 20–500 | NO$_3^{1-}$ (mg/l) PS (dw) Standard: 45 | SO$_4^{2-}$ (mg/l) PS (dw) Standard: 200–400 | F$^{-1}$ (mg/l) PS (dw) Standard: 1.5 | Cl$^{-1}$ (mg/l) PS (dw) Standard: 200–600 |
|----|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1 | Ramora | 7.40 | 485 | 445 | 1.2 | 6.5 | 177 | 1.2 | 11.0 | 0.14 | 10.1 |
| 2 | Dara Faqirabad | 7.36 | 480 | 408 | 0.00 | 5.7 | 180 | 1.4 | 1.0 | 0.15 | 10.6 |
| 3 | Spinakhawra Dara | 7.41 | 481 | 370 | 0.50 | 5.7 | 331 | 4.6 | 14 | 0.40 | 11.2 |
| 4 | Dara Sharab Kowi | 7.3 | 451 | 350 | 0.40 | 5.7 | 330 | 4.6 | 12 | 0.40 | 11.8 |
| 5 | Gulmuqam | 7.2 | 644 | 361 | 0.00 | 6.0 | 330 | 0.4 | 8.0 | 0.30 | 21.2 |
| 6 | Chakdara | 7.3 | 642 | 314 | 0.00 | 6.0 | 225 | 0.3 | 8.0 | 0.20 | 23.1 |
| 7 | Badwan | 7.5 | 779 | 400 | 0.39 | 4.5 | 238 | 1.4 | 8.0 | 0.21 | 11.0 |
| 8 | Shawa | 7.3 | 778 | 413 | 0.67 | 4.6 | 250 | 0.3 | 11.0 | 0.23 | 13.6 |
| 9 | Shawa Tandodag | 7.4 | 812 | 444 | 0.80 | 6.0 | 245 | 0.2 | 11.1 | 0.10 | 7.13 |
| 10 | Tazagram | 7.4 | 836 | 432 | 0.80 | 5.9 | 250 | 1.1 | 19 | 0.10 | 7.13 |
| 11 | Tazagram Jango | 7.3 | 833 | 444 | 0.00 | 5.1 | 256 | 1.1 | 19 | 0.10 | 7.3 |
| 12 | Kityari | 7.4 | 683 | 431 | 0.00 | 5.4 | 260 | 6.7 | 18 | 0.11 | 8.3 |
| 13 | Kityari Batan | 7.4 | 682 | 430 | 0.00 | 6.2 | 267 | 6.7 | 18 | 0.14 | 8.1 |
| 14 | Khanpur | 7.1 | 620 | 420 | 0.80 | 6.2 | 267 | 6.5 | 4.3 | 0.13 | 7.4 |
| 15 | Asbanr | 7.3 | 628 | 430 | 0.28 | 6.1 | 187 | 6.2 | 5.0 | 0.14 | 11.0 |
| 16 | Ouch | 7.1 | 811 | 478 | 0.30 | 4.1 | 176 | 6.1 | 4.4 | 0.12 | 30.3 |
| 17 | Khairabad | 7.3 | 640 | 466 | 0.00 | 4.0 | 250 | 6.0 | 1.3 | 0.12 | 22.2 |
| 18 | Khairabad Dari | 7.2 | 639 | 466 | 0.00 | 5.1 | 250 | 5.0 | 1.3 | 0.21 | 23.0 |
| 19 | Usakai | 7.5 | 818 | 432 | 0.00 | 5.1 | 267 | 0.9 | 9.0 | 0.11 | 50.0 |
| 20 | Talash | 7.4 | 821 | 345 | 0.64 | 5.7 | 268 | 1.0 | 9.0 | 0.15 | 45.0 |
| 21 | Timargara | 7.5 | 810 | 450 | 0.80 | 5.8 | 288 | 0.1 | 11.1 | 0.42 | 90.1 |
| 22 | Rabat | 7.1 | 810 | 334 | 0.00 | 5.0 | 260 | 0.2 | 10 | 0.11 | 70.2 |
| 23 | Samarbagh | 7.4 | 1,021 | 357 | 0.60 | 5.1 | 319 | 1.1 | 6.1 | 0.13 | 95.0 |
| 24 | Maidan | 7.2 | 688 | 362 | 0.60 | 5.2 | 320 | 1.2 | 6.2 | 0.11 | 99.0 |
| 25 | Sarai Bala | 7.3 | 684 | 336 | 0.00 | 4.1 | 279 | 0.9 | 3.2 | 0.21 | 23.1 |

Table 23
The samples found having impermissible values of water quality parameters collected from different areas of Dir Lower during the year 2012

| S# | Parameters | No. of unfit samples out of 100 | Percentage | Overall percentage |
|---|---|---|---|---|
| 1 | Bacteria | 100 | 100 | 100 |
| 2 | Na | 53 | 53 | 53 |
| 3 | K | 92 | 92 | 92 |
| 4 | Ca | 32 | 32 | 32 |
| 5 | Mg | 44 | 44 | 44 |
| 6 | Cr | 86 | 86 | 86 |
| 7 | Ni | 92 | 92 | 92 |
| 8 | Fe | 73 | 73 | 73 |
| 9 | Pb | 48 | 48 | 48 |

Maidan. The concentration of sulphate was 21 mg/l (maximum) in the samples collected from Talash Ziarat whereas the minimum concentration was 1.0 mg/l in the sample collected from Dara. Fluoride content was 0.44 mg/l (highest) in the sample collected from Chakdara, while the least value was 0.11 mg/l) in the sample collected from Usakai. The concentration of Cl was 50.5 mg/l (maximum) in the sample collected from Barorai followed by 30.4 mg/l in the sample collected from Samarbagh. The other samples Cl contents were in the range of 23.2–7.1 mg/l.

The physicochemical parameters of spring water samples are shown in Table 22. The concentrations of nitrate were 6.7 mg/l (maximum) in the samples collected from Kityari and Kityari Batan followed by 6.5 mg/l in the sample collected from Khanpur. The highest concentrations of sulphate were 19 mg/l in the samples collected from Tazagram and Jango, whereas the minimum value 1.0 mg/l was observed in the sample collected from Dara Faqirabad. Fluoride content was 0.42 mg/l in the sample collected from Timargara while the least values were 0.10 mg/l in samples collected from Shawa Tindodag, Tazagram and Jango. The concentration of Cl was highest (99.0 mg/l) in the sample collected from Maidan followed by 95.0 mg/l in the sample collected from Samarbagh. The values for other samples were in the range of 90.1–7.3 mg/l.

Bicarbonate has a key role in the protection of central nervous system of the body and plays an important role in regulating heart beat [14]. It also plays a very important role in the digestion process. The major amount of bicarbonate in human body comes from drinking water sources [15,16]. The normal blood level of chloride for adults is in the range of 95–105 Meq/l [17]. The high concentration of chloride ions can damage the metallic pipes and other structures. The maximum permissible value of chloride ion

set by WHO is 250 mg/l [18]. Drinking water is the key contributor of daily fluoride intake into human body. In some cases, the amount of fluoride is more than the optimum level (1 mg/l) and reaches the concentration of 1.5 mg/l. Fluoride is related with dental fluorosis and in severe case skeleton fluorosis. According to some reports, fluoride overdoses causes cancer [19]. Trace amount of fluoride in drinking water gives protection against the tooth decay in children and adults [20]. In 1980, Fingl reported that high intake of sodium and magnesium sulphate can cause dehydration as a side effect. The guideline level set by WHO for sulphates in drinking water is 250 mg/l [21].

The population of Lower Dir is not concentrated to one place, but dispersed in a large area. 71% area is cultivated from the total area of about $0.16 \times 10^6$ hectares. Water table has accessible depth and there are more chances for the exploitation of groundwater. Fertilizers are a great source of nitrate and especially bacteria. The flood of 2010 made the situation much deteriorating because it brought a great faecal contamination to water resources. The hygienic conditions of the area are very poor and there are no arrangements for the disposal of the waste materials of different sources. There is no system for the recycling of wastes and are discharged directly into water sources causing contamination of ground and surface water [22]. The water sources of the selected areas unfit for drinking are shown in Table 23.

## 4. Conclusion

The physical parameters were in the allowable range. Most of the chemical parameters were within the WHO range with few exceptions. The pathogenic bacteria were observed in most of the collected samples. Nutritional elements (Na, K, Ca, Mg) were also present in high amount. The presence of heavy metals

(Cr, Ni, Fe and Pb) is of great concern as the major sink of heavy metals is soil from where they enter into food chain by the process of leaching into groundwater. Keeping in view the hazardous effects of these contaminants, there is need of legislation and good governance for the implementation of stringent laws in order to protect water resources from contamination in the affected areas. The responsible agencies must be properly trained for this purpose.

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