Evaluation of physical and chemical quality of well water in Zakho District, Kurdistan region, Iraq

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Abstract. This study evaluates the physical and chemical characteristics of well water in Zakho district, Duhok governorate. Standard field and laboratory methods were followed. In order to characterize ground water quality in Zakho district, eight wells were selected to represent their water quality. Monthly samples were collected from the wells for the period from October 2016 to April 2017. The samples were tested for electrical conductivity (EC), total alkalinity (TA), total dissolved solids (TDS), pH, Nitrate (NO₃⁻), total hardness (TH) and chlorides, according to the standard methods (American Public Health Association. The results of statistical analysis showed significant difference among the wells water quality in the measured parameters. Ground water of Zakho district have high dissolved ions due to the dissolved rocks of the study area. Total dissolved solids of more than 1000 mg/l made the wells Frawla, Kealk and Zarek need to be treated to made taste palatable. Additionally high electrical conductivity and TDS made Zakho ground water have a slight to moderate restriction to crop growth. The high alkalinity of Zakho ground water indicated stabilized PH. The water quality of all the wells were found excessively hard. The nitrate concentration of Zakho well water ranged between 0.19 to 42.4 mg/l below the guidelines for.

Keywords: well water, Water Quality, Physical and chemical parameters, Kurdistan region

1. Introduction
In Kurdistan region well water has a major role to satisfy the needs of agriculture and domestic uses. The ever growing demands for water resources coupled with the rate at which much of the earth’s fresh water being adversely affected by human activities demonstrate a developing crisis and horrible future if environmental water resources are not appropriately managed. The ground water quality depends on various chemical constituents and their concentration, which are mostly derived from the geological data of the particular region. Ground water occurs in weathered portion, along the joints and fractures of the rocks. In fact, industrial waste and the municipal solid waste have emerged as one of the leading causes of pollution of surface and ground water [3]. The objective of present work is1- to evaluate the water quality of the Zakho district aquifer, and 2- to find out whether the quality of well water in the study areas is suitable for domestic purpose or not, which has not been reported for a long time. Groundwater is a finite, renewable yet vulnerable natural resource catering to needs of multiple stakeholders for a range of purposes such as domestic water supply. People who are not researchers are most likely to intersect environmental science in the context of protecting or restoring a place or species about which they are concerned, or in the context of pollution trying to understand the sources and effects of contaminants, or trying to prevent or remediate environmental contamination. In Zakho district the most common source of the drinking water for the inhabitants is wells. This is because in the study area, there is lack of water sheds, dams, rivers or lakes. Hence, the wells are the main sources of water available to the village’s community settlement In Zakho district Northern Duhok government. These water supplies are important public health issue because they are
often vulnerable and may cause microbiological or chemical quality-associated health risks to the water consumers. Therefore, the quality control of natural well water is an area of interest [4]. Ground water quality is mostly affected by either natural geochemical such as mineral weathering dissolution/precipitation reactions, ion exchange, etc.; the quality of groundwater may vary from place to place. In addition to above rapid population growth, increasing living standards, untreated municipal and industrial wastewater fertilizer application of pesticides sewers and landfill areas are the potential sources of groundwater pollution. Therefore, basic concentration is needed to monitor the quality of water as well as to find out various sources which increased groundwater pollution [5].

2. Materials and Method
Well water samples were collected from eight stations from different region of the Zakho District. (Figure 1). Monthly samples were collected from the wells during the period from October 2016 to April 2017. The collected well water samples were carried to the laboratory for the analysis of major ions such as electrical conductivity (EC), total alkalinity (TA), total dissolved solids (TDS), pH, Nitrate (NO3-), total hardness (TH), Chlorides. The water quality variance analysis was done according to the procedures outlined in the standard methods for the examination of water and wastewater with three replications [6].

![Figure 1. Shows the sampling locations within the study areas.](image)

3. Results and Discussion
Table (1) shows significant variations in the electrical conductivity among the studied wells. The highest values were recorded in the wells Frawla, Kealk and Zarek with conductivity values of more than 1000 mos/cm. As conductivity is mostly naturally occurring according to the geological formation of the feeding area, these results indicate high concentration of dissolved chemical ions in these three wells, since the feeding water passing through more soluble rocks of calcite. This also indicated high total dissolved solids (TDS) as conductivity is an approximation measurements of the concentration of (TDS) [7].

Table (1) also shows that all the water of the studied wells have slight to moderate restriction to crop growth as the conductivity of the groundwater of the studied wells was over 700 mos/cm except for Shenava well water. In other words, the water of the studied wells except Shenava will cause a reduction in crop growth and yield loss as the plant will redirect the energy from growing to extracting pure water from the saline water in the root zone [8] Similar results reported by [9].
Additionally, the groundwater of the studied area have slight to moderate restriction to agricultural use. Kandawgye water with 1000mg/l or more need to be softened before use. These results was lower than those reported by [3].

Means with different letters vertically have significant difference at p≤0.05.

Total dissolved solids (TDS) is the best individual value representing the salinity of the water. Table (2) shows significant variation in TDS among the wells in the study area. It ranged between 632.3-1439.7 mg/l. Shenava well recorded the lowest TDS values ranging within the study period with a maximum TDS values of 733.0 mg/l, while Kealk well recorded the maximum TDS values ranging within the study period with 1243.7 to 1439.7 mg/l. Although TDS values of the studied wells were below the upper limit for drinking by [2] and [10] of less than 1500mg/l, but water with 1000mg/l or more usually yield poor taste and unpalatable. Therefore, the wells sited in Frawla, kealk and Zarek need to be softened when used for drinking. These results was lower than those reported by [3]. Additionally, the groundwater of the studied area have slight to moderate restriction to agricultural use as TDS values was higher than 450mg/l in all the studied wells according to [8].

### Table 1. Variation of EC mos/cm among the studied wells along the study period .

| sites   | Oct. Mean | Oct. SE | Nov. Mean | Nov. SE | Dec. Mean | Dec. SE | Jan. Mean | Jan. SE | Feb. Mean | Feb. SE | Mar. Mean | Mar. SE | Apr. Mean | Apr. SE |
|---------|-----------|---------|-----------|---------|-----------|---------|-----------|---------|-----------|---------|-----------|---------|-----------|---------|
| Zarek   | 123       | 11.9    | 127       | 21.7    | 127       | 6.94    | 131       | 29.8    | 132       | 19.2    | 126       | 23.5    | 121       | 4.00    |
| Ab      | 2.0       | 3.0     | 8         | 0.7     | 126       | 7.3     | 3         | 4.0     | 6         | 7.3     | 9         | 3.0     |           |         |
| Kealk   | 143       | 106.0   | 145       | 119.0   | 115.0     | 0.0     | 148       | 64.1    | 146       | 77.7    | 145       | 94.7    | 140       | 98.5    |
| A       | 43.0      | 7.3     | 2         | 0.0     | 0         | 0.0     | 3         | 2.3     | 7         | 6.3     | 5         | 6.0     | 7         |         |
| Pebaz   | 992.0     | 283.0   | 95.0      | 281.0   | 100.0     | 303.0   | 969.0     | 284.0   | 966.0     | 287.0   | 961.0     | 284.0   | 951.0     | 289.0   |
| Av      | 33        | 9       | 33        | 8       | 6.0       | 0       | 67        | 67      | 67        | 2       | 67        | 72      | 0         | 0       |
| Shena   | 650.0     | 16.0    | 616.0     | 45.5    | 714.0     | 5.17    | 691.0     | 8.33    | 679.0     | 5.69    | 669.0     | 2.0     | 649.0     | 10.4    |
| Pakhl   | 711.0     | 51.3    | 612.0     | 29.5    | 720.0     | 5.04    | 729.0     | 8.82    | 725.0     | 17.9    | 705.0     | 22.2    | 691.0     | 32.2    |
| Kanda   | 755.0     | 9.33    | 790.0     | 18.1    | 883.0     | 39.1    | 829.0     | 7.22    | 791.0     | 2.52    | 769.0     | 6.93    | 754.0     | 2.33    |
| Frawla  | 109       | 148.0   | 103.0     | 153.0   | 115.0     | 146.0   | 111.0     | 139.0   | 108.0     | 153.0   | 115.0     | 197.0   | 113.0     | 188.0   |

Means with different letters vertically have significant difference at p≤0.05.

### Table 2. Variation of total dissolved solids among the studied wells along the study period .

| Sites   | Oct. Mean | Oct. SE | Nov. Mean | Nov. SE | Dec. Mean | Dec. SE | Jan. Mean | Jan. SE | Feb. Mean | Feb. SE | Mar. Mean | Mar. SE | Apr. Mean | Apr. SE |
|---------|-----------|---------|-----------|---------|-----------|---------|-----------|---------|-----------|---------|-----------|---------|-----------|---------|
| Zarek   | 1204.7    | 7.51    | 1250.0    | 38.1    | 1219.7    | 4.37    | 1274.0    | 60.1    | 1145.7    | .3      | 1458.0    | 19.4    | 1108.0    | 7.3    |
| Kealk   | 1439.7    | 122.0   | 1429.7    | 109.0   | 1407.0    | 84.1    | 1436.3    | 51.7    | 1289.3    | 58.0    | 1424.0    | 58.0    | 1242.0    | 61.8    |
| Pehazne | 989.0     | 287.0   | 981.33    | 274.0   | 911.33    | 286.0   | 970.67    | 260.0   | 929.33    | 21.0    | 903.0     | 215.0   | 868.3     | 217.0   |
| Shenava | 658.33    | 29.4    | 733.0     | 11.7    | 684.33    | 32.4    | 686.67    | 4.67    | 679.0     | 10.0    | 652.0     | 12.1    | 632.3     | 15.5    |
| Pakhloja | 643.33   | 3.28    | 677.0     | 43.5    | 671.33    | 16.0    | 657.33    | 9.49    | 634.6     | 16.0    | 621.0     | 14.3    | 605.7     | 2.96    |
| Dera    | 732.0     | 50.5    | 739.33    | 56.6    | 862.0     | 97.5    | 822.67    | 78.8    | 796.67    | 83.0    | 695.0     | 46.3    | 697.0     | 43.0    |
| Kanda   | 759.67    | 7.51    | 758.67    | 13.3    | 885.0     | 30.0    | 868.0     | 9.71    | 860.33    | 7.0     | 759.0     | 3.28    | 737.3     | 3.93    | 67.0     | 3.0     |
| Av      | 2.0       | 3.0     | 8         | 0.7     | 126       | 7.3     | 3         | 4.0     | 6         | 7.3     | 9         | 3.0     |           |         | 0         | 0       | 0         | 0       |
Means with different letters vertically have significant difference at p≤0.05.

Table (3) shows a significant variation in PH values among the studied wells included in the study with a range from 7.40 to 8.95. For wells Frawla, Kandaw, Kealk and Zarek, PH was higher than 8.0 along the study period. While the other wells ranged between 7.4 to 8.16. These PH values were alkaline and did not depress chlorine and corrode the metals. Also no effect on taste well be observed. For agricultural use most of the observed values were within the normal range from 6.5-8.4 according to [8]. Guidelines. In this study are significantly higher than those reported by [11].

Table 3. Variation of pH among the studied wells along the study period.

| sites    | Oct. Mean | Nov. Mean | Dec. Mean | Jan. Mean | Feb. Mean | Mar. Mean | Apr. Mean |
|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Zarek    | 8.37      | 8.42      | 8.56      | 8.33      | 8.37      | 8.09      | 8.23      |
|          | Ab        | Ab        | Ab        | Ab        | Ab        | Ab        | Ab        |
| Kealk    | 8.73      | 8.69      | 8.69      | 8.66      | 8.08      | 8.41      | 8.32      |
|          | Ab        | Ab        | Ab        | a         | Ab        | ab        | A         |
| Pehazne  | 7.66      | 8.48      | 7.86      | 7.61      | 7.61      | 7.49      | 7.40      |
|          | Bc        | bcd       | bcd       | b         | Ab        | c         | B         |
| Shenava  | 7.97      | 7.86      | 7.70      | 8.03      | 7.56      | 7.48      | 7.43      |
|          | Bcd       | bcd       | ab        | Ab        | Ab        | c         | B         |
| Pakhloja | 8.1       | 7.97      | 7.58      | 8.16      | 7.68      | 7.55      | 7.49      |
|          | Ab        | cd        | Ab        | Ab        | Ab        | bc        | B         |
| Derabon  | 8.09      | 7.5       | 7.32      | 7.59      | 7.52      | 7.48      | 7.35      |
|          | ab        | D         | d         | B         | B         | B         | B         |
| Kandaw   | 8.22      | 8.24      | 8.39      | 8.42      | 8.01      | 8.12      | 8.01      |
|          | ab        | Ab        | Ab        | Ab        | Ab        | Ab        | Ab        |
| Frawla   | 8.61      | 8.87      | 8.95      | 8.54      | 8.61      | 8.52      | 8.33      |
|          | a          | a         | Ab        | Ab        | Ab        | A         | A         |

Means with different letters vertically have significant difference at p≤0.05.

Table (4) shows significant differences in alkalinity of groundwater among the studied wells. The highest values were recorded in Zarek well above 600 mg/l, while the lowest values were recorded in Kandaw well at some months and at Derabon at the other months. As alkalinity is naturally occurring in water, its variation can be related to the geological formation of the sites of the wells. The values of alkalinity of 100-200 mg/l as CaCO3 indicated a stabilized PH values of water, but higher values may cause scale problems and corrosion. Water with high alkalinity always has PH values of 7or more, but water with high PH does not always has high alkalinity. This is important because of high alkalinity exerts the most significant effect on growing plants, fertility and plant nutrition. These results were higher than those reported by [12].

Table 4. Variation of total alkalinity among the studied wells along the study period.

| sites    | Oct. Mean | Nov. Mean | Dec. Mean | Jan. Mean | Feb. Mean | Mar. Mean | Apr. Mean |
|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Zarek    | 611.67    | 41.33     | 661.33    | 27.45     | 602.67    | 50.22     | 638.67    |
|          | a         | a         | a         | A         | A         | a         | a         |
| Kealk    | 432.0     | 97.37     | 450.67    | 124.79    | 461.67    | 84.67     | 459.0     |
|          | abc       | ab        | ab        | Ab        | Ab        | Ab        | Ab        |
| Pehazne  | 547.67    | 71.67     | 455.33    | 84.46     | 507.67    | 53.44     | 490.67    |
|          | ab        | ab        | ab        | Ab        | Ab        | Ab        | Ab        |
| Shenava  | 389.33    | 72.47     | 460.33    | 78.64     | 405.33    | 68.76     | 481.33    |
|          | abc       | abc       | abc       | Ab        | Ab        | Ab        | Ab        |
| Pakhloja | 327.0     | 37.24     | 303.33    | 13.54     | 335.33    | 31.05     | 304.67    |
|          | b         | b         | b         | Ab        | Ab        | Ab        | Ab        |
| Derabon  | 283.0     | 33.5      | 292.33    | 29.87     | 321.67    | 11.7      | 288.0     |
|          | c         | b         | Cd        | Cd        | b         | b         | b         |
| Kandaw   | 320.33    | 33.6      | 294.0     | 47.65     | 265.33    | 19.19     | 303.0     |
|          | bc        | b         | C         | B         | C         | b         | b         |
| Frawla   | 428       | 110.7     | 477.67    | 122.79    | 478.33    | 123.4     | 490.33    |
|          | 414.0     | 106.3     | 448.67    | 64.48     | 469.0     | 77.6      | 478.33    |
Hard water is a common problem associated with groundwater, generally related to the abundance of calcium and/or magnesium. Table (5) shows the mean hardness of groundwater of the studied wells along the study period. It ranged from 385.33 to 1160.0 mg/l as CaCO₃. The lowest hardness altered between Kandaw and Shenava wells along the study period with a values from 385.33 to 578.0 mg/l as CaCO₃. On the other hand, Kealk wells water recorded the highest hardness among the other wells with values of more than 1000mg/l as CaCO₃. These results were higher than those reported by [13]. Generally, groundwater in the studied area can be considered as excessively hard as hardness was more than 250mg/l as CaCO₃ in all the studied wells according to various textbook classifications. These results reflects the characteristics of the geological formations rich with calcium and magnesium in contact with water. Also Erbil groundwater [14]and Mosul ground water [15] were very hard water. Also These results were higher than those reported by [5].

**Table 5. Variation of total hardness among the studied wells along the study period.**

| sites   | Oct. Mean (SE) | Nov. Mean (SE) | Dec. Mean (SE) | Jan. Mean (SE) | Feb. Mean (SE) | Mar. Mean (SE) | Apr. Mean (SE) |
|---------|---------------|----------------|---------------|---------------|---------------|---------------|---------------|
| Zarek   | 1093.3 (130.0) | 1034.7 (160.98) | 1026.7 (179.4) | 963.67 (125.87) | 1031.7 (81.52) | 938.0 (128.8) | 1027.0 (118.1) |
| Kealk   | 1160.0 (81.69) | 1150.7 (77.17) | 1139.7 (82.63) | 1116.7 (47.98) | 1120.0 (39.7) | 1088.7 (53.38) | 1072.0 (45.32) |
| Pebazne | 609.0 (190.4)  | 603.67 (190.07) | 623.33 (176.0) | 630.0 (169.58) | 635.0 (176.7) | 622.0 (213.8) | 582.7 (190.4) |
| Shenava | 557.33 (29.46) | 469.0 (20.52)  | 532.67 (13.53) | 578.0 (19.01)  | 538.67 (25.87) | 436.33 (31.47) | 478.0 (22.5)  |
| Pakhojo | 483.0 (21.17)  | 457.33 (46.77) | 533.53 (53.55) | 554.0 (45.36)  | 549.67 (74.14) | 562.67 (38.2) | 520.3 (69.85) |
| Derabon | 509.67 (33.27) | 510.67 (35.82) | 655.33 (19.88) | 688.67 (23.33) | 692.67 (18.84) | 688.67 (33.21) | 640.7 (41.38) |
| Kandaw  | 385.33 (25.41) | 412.67 (30.64) | 542.67 (14.67) | 529.33 (40.25) | 525.67 (47.74) | 509.67 (35.79) | 452.7 (28.75) |
| Frawla  | 777.33 (139.6) | 790.0 (125.83) | 754.0 (52.7)  | 723.0 (57.33)  | 729.33 (71.79) | 799.33 (40.18) | 704.3 (67.11) |

Means with different letters vertically have significant difference at p≤0.05.

For chlorides (table 6) the lowest concentration were recorded in Pebazne and Shenava wells along the study period between 14.67-22.27 mg/l, while Frawla well water had the highest concentration among the studied wells from 42.37 to 56.3 mg/l. All the values are within the recommended levels of [2] of 250mg/l. Chloride concentration can be used as an indication of sewage, agricultural and industrial pollution since chloride are soluble and pass through pervious soils and rocks for great distances without diminution in concentration. Also chloride concentration decreased in area of impervious formation. These concentration were lower than those reported by [16].

**Table 6. Variation of chlorides among the studied wells along the study period.**

| sites   | Oct. Mean (SE) | Nov. Mean (SE) | Dec. Mean (SE) | Jan. Mean (SE) | Feb. Mean (SE) | Mar. Mean (SE) | Apr. Mean (SE) |
|---------|---------------|----------------|---------------|---------------|---------------|---------------|---------------|
| Zarek   | 25.07 (14.47) | 31.73 (20.64)  | 25.73 (14.39) | 26.3 (14.65)  | 24.83 (12.89) | 21.33 (11.3)  | 26.63 (17.4)  |
| Kealk   | 22.37 (7.19)  | 18.8 (5.1)     | 19.27 (4.41)  | 19.77 (4.78)  | 20.97 (5.2)   | 19.13 (2.26)  | 16.6 (3.87)   |
| Pebazne | 19.87 (4.95)  | 17.7 (4.11)    | 19.83 (2.83)  | 18.83 (3.58)  | 18.8 (3.97)   | 14.67 (1.48)  | 15.83 (3.25)  |
| Shenava | 18.57 (2.68)  | 17.2 (2.72)    | 19.23 (1.71)  | 17.73 (2.05)  | 19.37 (2.59)  | 22.27 (1.07)  | 17.97 (3.57)  |
| Pakhojo | 29.62 (3.79)  | 29.3 (2.95)    | 27.7 (2.8)    | 28.23 (3.13)  | 27.53 (2.56)  | 25.67 (2.97)  | 26.23 (1.41)  |
| Derabon | 28.73 (1.73)  | 31.17 (1.17)   | 31.3 (1.74)   | 32.13 (2.05)  | 31.73 (1.99)  | 32.5 (1.07)   | 29.17 (1.96)  |
| Kandaw  | 27.77 (1.73)  | 28.77 (1.73)   | 31.33 (1.39)  | 26.2 (4.99)   | 31.33 (1.96)  | 31.77 (2.23)  | 27.07 (0.92)  |

Means with different letters vertically have significant difference at p≤0.05.
Well water needs to be treated to make it palatable. Growth area ground water quality of restriction mg/l nitrate for guidelines of runoff transport nitrate from sewage and fertilizers to ground water. Water with high nitrate concentration is harmful to infants. The nitrate concentration in the wells of the study area were the guidelines of [2] of 50 mg/l, for agricultural use, slight to moderate restriction appear on water of 5-30 mg/l nitrate for the wells Derabon, Kandaw, Frawla and Zakhe while Kealk well water has severe restriction. Similar results reported by, [17].

(Table 7) shows mean nitrate concentration in the studied wells along the study period. It ranged between 0.19 to 42.4 mg/l, with significant difference among the wells in the studied area. The lowest concentration was recorded in Pakholja ground water, while the highest nitrate concentration was observed in Kealk groundwater well. Nitrate are very soluble and do not bind with soil therefore, it has high potential to migrate to groundwater, especially when the wells near agricultural areas and runoff transport nitrate from sewage and fertilizers to ground water. Water with high nitrate concentration are harmful to infants. The nitrate concentration in the wells of the study area were the guidelines of [2] of 50 mg/l, for agricultural use, slight to moderate restriction appear on water of 5-30 mg/l nitrate for the wells Derabon, Kandaw, Frawla and Zakhe while Kealk well water has severe restriction. Similar results reported by, [17].

Table 7. Variation of nitrate among the studied wells along the study period.

| sites    | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. |
|----------|------|------|------|------|------|------|------|
|          | Mean | SE   | Mean | SE   | Mean | SE   | Mean |
| Zarek    | 30.51| 0.4  | 32.8 | 1.9  | 31.27| 0.2  | 34.02| 3.0  | 27.02| 1.0  | 27.13| 2.5  | 26.3 | 0.4  |
| Kealk    | 42.4 | 6.2  | 41.9 | 5.5  | 40.75| 4.3  | 42.23| 2.6  | 34.79| 3.0  | 33.75| 2.9  | 32.4 | 3.1  |
| Pebazne  | 19.59| 14.6 | 19.21| 13.9 | 15.66| 14.5 | 18.67| 13.2 | 16.57| 10.9 | 15.24| 10.9 | 13.5 | 11.0 |
| Shenava  | 2.86 | 1.5  | 6.64 | 0.6  | 4.17 | 1.6  | 4.29 | 0.2  | 3.9  | 3.5  | 2.54 | 0.6  | 1.54 | 0.8  |
| Pakholja | 2.1  | 0.2  | 3.8  | 0.2  | 2.32 | 0.8  | 2.81 | 0.5  | 1.63 | 0.8  | 1.0  | 0.7  | 0.19 | 0.1  |
| Derabon  | 6.59 | 2.6  | 6.96 | 2.9  | 13.17| 4.9  | 11.18| 4.0  | 9.86 | 4.2  | 4.75 | 2.4  | 4.82 | 2.2  |
| Kandaw   | 7.99 | 0.4  | 7.94 | 0.7  | 14.33| 1.5  | 13.47| 0.5  | 13.08| 0.4  | 7.99 | 0.2  | 6.86 | 0.2  |
| Frawla   | 20.96| 6.7  | 22.36| 7.8  | 28.05| 7.7  | 25.8 | 6.5  | 22.58| 5.2  | 20.27| 5.8  | 15.9 | 4.7  |

Means with different letters vertically have significant difference at p≤0.05.

4 Conclusion
Ground water quality of Zakho district have high dissolved ions due to the dissolved rocks of study area, High electrical conductivity of Zakho ground water have a slight to moderate restriction to crop growth, High total dissolved solids of more than 1000 mg/l made the wells Frawla, Kealk and Zakhe need to be treated to make taste palatable, The high alkalinity of Zakho ground water indicated to made taste palatable, The water quality of all the wells excessively hard, The nitrate concentration of Zakho well water were below the guidelines for WHO.

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