Assessment of the quality of drinking water of Halabja City-Iraqi Kurdistan

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ABSTRACT

The quality of drinking water is a crucial factor for human health. The objective of this study was to assess the physico chemical and biological characteristics of the various sources of drinking water in the city of Halabja, Iraqi Kurdistan. Forty water samples were collected and analyzed for physico-chemical and biological characteristics. The study included 27 samples from municipality wells and 13 samples from household tap water. Analysis was done for physico-chemical parameters including pH, Electrical Conductivity (EC), total dissolved solids (TDS), total hardness (TH), Chloride (Cl⁻), Alkality M, Alkality P, Aluminum (Al), Copper (Cu), Calcium (Ca), Boron (B) and MPN. The results were compared with the standards prescribed by World Health Organization (WHO). All the physico-chemical parameters were found to be within allowable limits. It can, therefore, be concluded that the groundwater in the study area is suitable for drinking and other household purposes. But from the pH values it is clear that the ground water of the study area is alkaline in nature and the total hardness varies between 203-323 mg/l which indicate that water in the deep aquifer is hard hence suggested to Halabjah water director to soften the tube well water before consumption. There were no statistically significant differences between water samples from wells and households in terms of these parameters. Although the drinking water of the area is considered safe. Nevertheless biological surveillance is need especially in hot weather.
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Tقييم نوعية مياه الشرب في مدينة حلبجة – كوردستان العراق

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المملخص

نوعية مياه الشرب هي عاملاً حاسماً لصحة الإنسان. وكان الهدف من هذه الدراسة هو تقييم الخصائص الفيزيائية والكيميائية والبيولوجية لمصادر مختلفة من مياه الشرب في مدينة حلبجة في كوردستان العراق. حيث تم جمع أربعين عينة من مياه الشرب، وتم تحليلها لمعرفة الخصائص الفيزيائية والكيميائية والبيولوجية. وشملت الدراسة 27 عينة من مياه الآبار البلدية و13 عينة من مياه الحنفية المنزلية. وقد تم تحليل بارامترات الفيزيائية والكيميائية بما في ذلك درجة الحموضة، التوصيل الكيربيك (EC)، المواد الصمبة الذائبة (TDS)، العسر الكمي (TH)، كلوريد (الكلوريك)، الكربونات (الكربونات)، الكالسيوم (الماء)، النحاس (النيازك)، الألومنيوم (الألمنيوم)، المعدن الجاف، ومتبخرة النيازك. وتمت مقارنة النتائج مع المعايير الخاصة بالWHO. تم العثور على جميع بارامترات الكيميائية و الفيزيائية للكهربائي، (EC)، المواد الصلبة الذائبة (TDS)، العصر الكلي (TH)، كلويريد (الكلوريك). وتم العثور على جميع بارامترات الكيميائية و الفيزيائية للكهربائي، (EC)، المواد الصلبة الذائبة (TDS)، العصر الكلي (TH)، كلويريد (الكلوريك). وتم العثور على جميع بارامترات 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1. INTRODUCTION

Drinking water must be free from constituents hazardous to human health including some minerals, organic substances and pathogenic microorganisms. Large portions of the population in developing countries suffer from water-related health problems either due to shortage of safe drinking water or due to the presence of hazardous substances and microbial contamination of water [1]. Poor water quality is responsible for the death of an estimated 5 million children in the developing annually [2]. The Joint Monitoring Program (JMP) for Water Supply and Sanitation, implemented by the World Health Organization (WHO) and UNICEF, reports that 783 million people in the world (11% of the total population) have no access to safe water, 84% of whom live in rural areas [3]. Iraq has insufficient fresh water [4]. The global environment is changing continuously due to unfavorable alteration of surroundings, holly as a by-product of man’s actions, through direct or indirect effects of changes in energy pattern, radiation levels, chemical and physical constitution of organisms. These changes may affect man directly or through his supplies of water and of agricultural and other biological products, the most common types of pollution and pollutants discharged, encountered in domestic and industrial waste waters, along with their possible effects on the water resources are discussed. Chemicals are a major source of water Contamination [5], that introduced during water movement through geological materials, manufactured chemicals may cause problems. Fertilizers and pesticides are major contributors to water pollution; Nitrates from fertilizers are a common chemical pollutant of water. Heavy metals, sulphates, nitrates, chlorides, phosphates, carbonates, ammonia, pesticides, phenols, soaps and detergents are the common chemical pollutants. The WHO estimated that in developing countries about 80% of water pollution is a result of domestic waste. Water quality is used to describe the condition of the water, including its physical, chemical and biological characteristics,
usually with respect to its suitability for a particular purpose (i.e., drinking, swimming or fishing) [6]. The drinking water of Halabja city is supplied through two sources. Part of the city is supplied through Ahmadawa water project; a spring water source pumped to an elevated storage tank in Halabja where it is chlorinated and distributed through the water network. The other source includes 27 of deep wells pumped either directly to the network or pumped to elevated storage tanks after chlorination and then distributed to the water network. Suitability of water for various uses depends on type and concentration of dissolved minerals and groundwater has more mineral composition than surface water [7]. The quality of groundwater changes constantly in response to daily, seasonal and climatic factors. Continuous monitoring of water quality parameters is highly crucial because changes in the quality of water have far reaching consequences in terms of its effects on man and biota [7]. Moreover, the inadequate management of water systems can cause serious problems in the availability and quality of water [8]. The aim of this study was the assessment of physical, chemical and biological quality of the drinking water in the city of Halabja for determines its suitability for drinking purposes.

2. MATERIALS and METHODS

Halabjah is one of the district towns of Sulaimani governorate located 80 Km southeast of Sulaimani city at 35.1786° North and 45.9853° East with an elevation of 721 meters above the sea level Figure (1). The city’s main source of municipality drinking water is ground water provided by 27 of deep wells. These well are pumped to elevated storage tanks and then distributed to the households. In order to assess the quality of water, 40 sites were chosen for sample collection in the study area along the stretch of the stream. Samples of water were collected from 27 municipality wells including one sample from Ahmadawa source and 13 households during the period from January to March 2014. Water samples were collected in pre-cleaned, sterilized glass bottles of 500 ml capacity and transported to the chemical laboratory at medical laboratory technical the technical institute of Halabja and the biomedical research laboratory of Sulaimani Polytechnic University in ice-cooled containers.

Analysis was done for physico-chemical parameters including pH, Electrical Conductivity (EC), total dissolved solids (TDS), total hardness (TH), Chloride (Cl), Alkality M, Alkality P,
Aluminum (Al), Copper (Cu), Calcium (Ca), Boron (B), by determined alkalinity – m and alkalinity – p we classify the alkalinity as hydroxide, carbonate and hydrogen carbonate. We used multi-direct photometer for the analysis with standard reagents and deionizer water for experimental purposes (Photometer Multidirect Instruction, 2011). The bacteriological analysis was done using MPN method with MacConky broth multiple tube method for determining the most probable number of coliforms [9]. All the precautions were taken as given in APHA, AWWA, WPCF (2003), for sampling and analysis [10].

![Figure (1): Location of Halabja at Sulaimani governoate.](image)

### 3. RESULTS

Table (1) shows the results of samples from the municipality wells and Table (2) shows the same results for samples taken from households supplied by these wells. pH of all samples ranged from 6.3-8.08. Total dissolved solids (TDS) ranged from 209-705 and total hardness ranged from 203-323mg/l. The chloride content of water sample ranged from 0.6-24.5mg/l and calcium content was varied widely between 22-289 mg/l. The MPN index ranged from 1 to 6 per 100 ml. For values of other constituents please see Table (1) and (2). The mean values of physico-chemical parameters for all 40 samples are shown in Table (3). The mean TDS was 341(SD 129), the mean total hardness was 257(SD 32), the mean chloride content was 6.9 mg( SD 4.7) per
liter and the mean calcium was 107 mg (SD 59.8) per liter. The mean MPN index for contamination was 2.9 (SD 1.6) per 100 ml. We compared the mean values of these parameters between the wells and the household samples for any significant differences. Although there were some differences between the wells and household but none of these differences were statistically significant except temperature and alka-m. See Table (3). The mean values of alka-m for the well samples was 223(SD 104) compared to 166 (SD 14) for the household samples, a difference which was statistically significant at 0.05%. Although MPN was higher in household samples than well samples (3.3 vs. 2.6) but this difference was not statistically significant.

**Table (1):** Physico-chemical analysis of water samples from Halabja municipality wells.

| Sample No. | Hardness | Chloride | PH | TDS mg/l | Conductivity ms/cm | Al mg/l | Cu mg/l | Ca mg/l | Boron mg/l | Alka-m | Alka-p | Hydrousalkalinity | Carbonatealkalinity | Bicarbonatealkalinity | Temp | MPN index |
|------------|----------|----------|----|----------|-------------------|--------|--------|--------|------------|--------|--------|------------------|----------------------|---------------------|------|-----------|
| Well 1     | 230      | 9.1      | 6.4 | 458      | 0.716             | 0.01   | 0.14   | 153    | 0.1        | 180    | 18     | 36               | 144                  | 19.3                |      | 2         |
| Well 2     | 296      | 9.9      | 7.3 | 388      | 0.606             | 0.01   | 0.05   | 289    | 0.3        | 152    | 10     | 0                | 20                   | 132                 | 19.8 | 3         |
| Well 3     | 203      | 2.9      | 7.6 | 529.5     | 0.827             | 0.1    | 0.05   | 22     | 0.1        | 172    | 18     | 0                | 36                   | 136                 | 19.4 | 4         |
| Well 4     | 274      | 3.1      | 6.5 | 304.6     | 0.476             | 0.01   | 1.4    | 188    | 0.1        | 169    | 20     | 0                | 40                   | 129                 | 19.4 | 2         |
| Well 5     | 283      | 6.8      | 6.8 | 379       | 0.592             | 0.01   | 0.05   | 202    | 0.1        | 230    | 18     | 0                | 36                   | 194                 | 19.2 | 6         |
| Well 6     | 310      | 5.1      | 6.4 | 667.3     | 1.043             | 0.01   | 0.15   | 284    | 0.1        | 241    | 15     | 0                | 30                   | 211                 | 19.4 | 6         |
| Well 7     | 322      | 24.5     | 6.6 | 681.8     | 1.065             | 0.01   | 0.58   | 229    | 0.1        | 211    | 29     | 0                | 58                   | 153                 | 19.4 | 3         |
| Well | 8    | 9    | 10   | 11   | 12   | 13   | 14   | 15   | 16   | 17   | 18   | 19   | 20   | 21   | 22   |
|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|      | 257  | 230  | 210  | 260  | 258  | 260  | 281  | 258  | 266  | 258  | 259  | 239  | 323  | 253  | 216  |
| Depth| 5    | 12.3 | 8.3  | 3.3  | 7.7  | 5.1  | 5.2  | 8.5  | 0.7  | 3.3  | 3.3  | 4.2  | 4.8  | 16   | 7.9  |
| Water| 6.3  | 8.08 | 7.75 | 7.81 | 7.85 | 7.89 | 7.9  | 7.98 | 7.93 | 7.87 | 7.68 | 7.6  | 7.43 | 7.85 | 7.47 |
| Temperature| 705.2 | 208.9 | 219.8 | 230.8 | 243  | 258  | 272  | 240.4 | 316.2 | 307.5 | 288  | 243  | 330  | 398.9 | 272.1 |
| Gas| 1.102 | 0.326 | 0.343 | 0.361 | 0.38  | 0.403 | 0.425 | 0.376 | 0.494 | 0.481 | 0.45  | 0.38  | 0.516 | 0.623 | 0.425 |
| Oil| 0.05  | 0.01  | 0.01  | 0.01  | 0.05  | 0.01  | 0.16  | 0.01  | 0.05  | 0.1   | 0.15  | 0.53  | 0.05  | 0.05  | 0.05  |
| Water| 115  | 72   | 73   | 72   | 73   | 76   | 76   | 73   | 81   | 83   | 72   | 70   | 73   | 85   | 75   |
| Gas| 0.1  | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  |
| Oil| 217  | 168  | 170  | 157  | 189  | 193  | 481.5 | 155  | 470  | 438.5 | 471.4 | 169  | 244  | 344.5 | 172  |
| Water| 19   | 13   | 18   | 9    | 5    | 9    | 5    | 9    | 14   | 6    | 8    | 10   | 11   | 9    | 11   |
| Gas| 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Oil| 38   | 26   | 36   | 18   | 0    | 18   | 0    | 18   | 28   | 12   | 16   | 20   | 22   | 18   | 22   |
| Water| 179  | 142  | 134  | 139  | 189  | 175  | 481.5 | 137  | 442  | 426.5 | 455.4 | 149  | 222  | 222  | 150  |
| Gas| 19.3 | 19.4 | 19.4 | 19.5 | 19.4 | 19.2 | 19.4 | 19.6 | 19.4 | 19.2 | 19.6 | 19.9 | 19.4 | 22   | 19.5 |
### Table (2): Physico-chemical analysis of water samples from Halabja households.

| Sample  | Hardness mg/l | Chloride mg/l | pH | TDS mg/l | EC ms/cm | Al mg/l | Ca mg/l | Boron | Alka-m | Alka-p | Hydroxidealkalinity | Carbonatealkalinity | Bicarbonatealkalinity | Temp | MPN index |
|---------|---------------|---------------|----|----------|-----------|--------|---------|-------|--------|--------|---------------------|---------------------|----------------------|------|-----------|
| House 1 | 211           | 5.7           | 7.1 | 239.3    | 0.374     | 0.01   | 0.05   | 176   | 0.1    | 164    | 5                   | 0       | 0                   | 164  | 19.4      | 2     |
| House 2 | 275           | 2.7           | 6.8 | 376.3    | 0.588     | 0.01   | 0.05   | 152   | 0.1    | 149    | 13                  | 0       | 26                  | 123  | 19.5      | 2     |
| House 3 | 208           | 11.7          | 7.92| 212.1    | 0.331     | 0.01   | 0.05   | 73    | 0.1    | 151    | 17                  | 0       | 34                  | 117  | 19.2      | 1     |
| House 4 | 269           | 6.4           | 7.83| 253.9    | 0.397     | 0.01   | 0.31   | 76    | 0.1    | 196    | 8                   | 0       | 16                  | 180  | 20        | 3     |
| House 5 | 311           | 3.7           | 8.06| 231.3    | 0.361     | 0.01   | 0.05   | 81    | 0.1    | 162    | 5                   | 0       | 0                   | 162  | 19.8      | 3     |
| House 6 | 211           | 4.5           | 7.41| 372.4    | 0.582     | 0.01   | 0.09   | 72    | 0.1    | 153    | 11                  | 0       | 22                  | 131  | 15.6      | 6     |

*Shaded cells indicate minimum and maximum values*
Table (3): Comparison of physic-chemical properties of water samples from municipality wells and corresponding households in Halabja

| House | n=11 | Mean (SD) | Mean (SD) | P value (t-test) |
|-------|------|-----------|-----------|-----------------|
| Characteristic | All samples | Well sample | Household samples | |
| Hardness mg/l | 256.6(32.2) | 262.2(6.1) | 246.5(36.7) | 0.19 |
| TDS | 340.7(129.3) | 359.1(141.4) | 294.0(58.7) | 0.15 |
| PH | 7.44(0.54) | 7.42(0.55) | 7.53(0.47) | 0.55 |
| Chloride mg/l | 6.88(4.65) | 7.62(5.0) | 6.39(3.57) | 0.46 |
| Conductivity EC ms/cm | 0.47(0.18) | 0.50(0.19) | 0.39(0.08) | 0.1 |
| Al mg/l | 0.01(0.015) | 0.01(0.02) | 0.01(0.02) | 0.40 |
| Cu mg/l | 0.18(0.25) | 0.23(0.3) | 0.11(0.09) | 0.2 |
| Ca mg/l | 106.6 (59.8) | 110.2 (69.6) | 101.3 (39.6) | 0.7 |
| Boron mg/l | 0.11(0.03) | 0.11(0.04) | 0.11(0.03) | 0.52 |
|-----------|------------|------------|------------|------|
| Alka-m    | 216.5(97.8) | 223.2(104.5) | 165.6(13.5) | 0.04 |
| Alka-P    | 11.8(8.2)   | 12.5(5.7)   | 10.7(4.2)   | 0.35 |
| Carbonate alkalinity | 22.4(12.5) | 24.2(12.7) | 19.6(11.6) | 0.3 |
| Bicarbonate alkalinity | 194.1(100.6) | 209.0(109.1) | 146.0(19.9) | 0.07 |
| Temperature | 19.3(1.2)   | 19.6(0.6)   | 18.2(1.7)   | <0.001 |
| MPN       | 2.85(1.62)  | 2.62(1.47)  | 3.27(1.79)  | 0.25 |

* two household samples are excluded because they come from same wells

**Table (4): Classification of groundwater on the basis of salinity values [11]**

| TDS ( ppm ) | Description     | No. of Samples |
|-------------|-----------------|----------------|
| Less than 1000 | Non-Saline     | 40             |
| 1000-3000   | Slightly saline | 0              |
| 3000-10000  | Moderately saline | 0          |
| More than 10000 | Very Saline   | 0              |
| Total       |                 | 40             |

**Table (5): Classification of water on the basis of total hardness [12]**

| Total Hardness (mg/l) | Nature of water | No. of Samples |
|-----------------------|-----------------|----------------|
| 0-60                  | Soft            | 0              |
| 61-120                | Moderate        | 0              |
| 121-180               | Hard            | 0              |
| More than 180         | Very Hard       | 40             |
| Total                 |                 | 40             |
4. DISCUSSION

In this study 27 samples from municipality wells and 13 samples from household tap water were collected and analyzed for physic-chemical and biological characteristics. One limitation of this study is that it was performed in one season however; the season of the study was in winter. There were no statistically significant differences between water samples from wells and households in terms of these parameters. pH indicates the intensity of acidic or basic character at a given temperature. pH is an important factor that determines the suitability of water for various purposes [13] and it is one of the most important operational water quality parameters. PH values higher than 8.5 are not suitable for effective disinfection while values less than 6.5 enhance corrosion in water mains and household. Therefore, the pH values for all well and house within WHO limit except well 1 and 23 were (6.4), well 8 was (6.3). The low pH does not cause any harmful effect [14]. In groundwater hardness is mainly contributed by bicarbonates, carbonates, sulphates and chlorides of calcium and magnesium. The principal hardness causing ions are calcium and magnesium. The acceptable limit of total hardness is 100 mg/l and maximum limit 500 mg/l was less than the WHO guideline value of 500 mg/L as CaCO3 [15]. Durfor and Becker have classified water as given in Table (5) [11]. As per this classification 100% samples are very hard in nature. The level of hardness in present study was less than previous study in Halabja [16] range (178.84 – 638.46 mg/l). The acceptable limit of carbonate and bicarbonate is 75 mg/l and 150 mg/l respectively. The maximum permissible limit of chloride in potable water is 200 mg/l. All the samples found chloride concentration within the permissible limit. No health-based guideline is proposed by WHO for TDS. Since TDS higher than 500 mg/L impart taste to the water, therefore, a desirable value of 500 mg/L is proposed by (WHO). Furthermore, a value higher than 500 mg/L results in excessive scales in water pipes, heaters, boilers and household appliances [15]. TDS for well and house 3, 6, 7, 8 and 12 were 529.5, 667.3, 681.8, 705.2 and 588.9 respectively and all the water samples are non-saline as per the salinity classification Table (4) suggested by Robinove [11]. Electrical conductivity is a measure of cations in water which can greatly affect its taste and thus has significant impact on the acceptability of water for drinking [17] and its suitability for irrigation. Higher value of conductivity shows higher concentration of dissolved ions. Electronic conductivity is a useful tool to assess the purity of...
water. The acceptable limits of Ca\(^{2+}\) 75 mg/l. 100% of water samples showed Ca\(^{2+}\) concentration above the acceptable limit.

5. CONCLUSION

In this study characterization of physicochemical parameters and biological test of twenty seven wells of groundwater and thirty house samples at Halabjacity area was carried out. To assess the quality of ground water and end point user each parameter was compared with the standard desirable limits prescribed by World health organization (WHO). From the study it can be concluded that groundwater is safe for drinking purposes from the point of view of level of pH, Hardness, TDS, Ca, Boron, Alka-p, Alka-m, Al, Cu, Cl, conductivity and MPN. However biological surveillance is need especially in hot weather. But from the total hardness varies between 203-323 mg/l, which indicates that water in the deep aquifer is hard. Hence it is recommended that Halabjah water directorate take actions to soften the well water before consumption. Further research to carry out chemical and biological studies for existing water sources.

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