Physical and Chemical properties of rainwater and its suitability for drinking and irrigating in Erbil city

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1. INTRODUCTION

The pollution of air comes from the unwanted substance of air that could have a negative effect on human health, animals and plants. Sulfur dioxide, Nitrogen Oxides and dust particles are the most frequent pollutant found in the air (kulshresta et al, 2003). Traffics such as Trains and Plans are considered as the main source of air pollutants. Some of this pollutant could react with other substances present in the air which in turn affect the quality of the air. Traffic is responsible for one-third of the greenhouse gas emissions. Greenhouse gases in the atmosphere are the primary causes for climate change.

The agriculture emits pollutants mainly in the form of nitrous dioxide (N₂O) and methane...
(CH₄) is considered as greenhouse gases as well. Many other chemical wastes are produced and emitted by Industrial such as carbon dioxide, sulfur dioxide, nitrogen dioxide small dust particles, Methane and ammonia.

Beside emission factor, the pollution of air comes from different factors such local and synoptic meteorological condition, topography and atmospheric chemical process (Hosseinibalam and Hejazi, 2012).

Rainwater is an important means of scavenging pollutants from the atmosphere, for both gases and the particulate phase. The composition of rainwater actually reflects the composition of the atmosphere through which it falls. Gromping et al. (2007) has reported that more than 90% of the total amount of pollutants present in the atmosphere is lixiviated by wet deposition, being the predominant cleansing mechanism to remove pollutants from the air. Thus, rainwater can be a way to reduce the atmospheric load of pollutants, as well as a source of contamination for soil, water and terrestrial vegetation (Flues et al., 2002).

In order to measure the degree of pollution of water rain samples, many chemical and physical properties should be tested including PH level, electrical conductivity (Ec), calcium (Ca²⁺), chloride (Cl⁻), total alkalinity, total hardness and turbidity, Total Dissolved Salt (TDS), nitrate (NO₃⁻)

PH value is an indication to the level of acid or alkaline condition of the solution (Patil, 2010) many factors could affect pH value including human activity, agriculture activity and use of fertilizers. Electrical conductivity is an indication to the concentration of ionized substance or other mineral contamination in water depending on temperature and type of present ions. Total hardness results from metallic cations of calcium and magnesium resent in water. Calcium and magnesium salts contribute to water hardness. Calcium is considered essential elements for plant and animal life. Chloride is widely spread in nature and comes from different chemical compounds such as NaCl, KCl, and CaCl₂.

Water is a prime natural resource and precious national asset, forms the chief constituent of ecosystem. Water sources may be mainly in the form of rivers, lakes, glaciers, rainwater, ground water etc. Beside the need of water for drinking, water resources play a vital role in various sectors of economy such as agriculture, livestock production, forestry, industrial activities, hydropower generation, fisheries and other creative activities (WHO, 2012). Rainwater is the purest form of naturally occurring water. It is considered therefore to be produced by a kind of natural distillation. However, it contains dissolved gases such as carbon dioxide, sulphur dioxide, nitrogen dioxide, ammonia, fine particulate materials or aerosols, etc from the atmosphere (Asthana, 2003; Nsi New., 2007). A huge variety of substances can be found in the air being the anthropogenic sources responsible for issuing most of the potentially polluting substances. Those sources of pollution are mainly characterized by the combustion of fossil fuels, the usage and production of biocides and pesticides, mining activities and the inappropriate treatment of industrial effluents, which are directly responsible for the increasing levels of particulate matter suspended in the atmosphere (Seinfeld., 2006). A water resource such as rain, river, groundwater and sea is one of the major components of environmental resources that are under serious threat from over exploitation or
pollution from anthropogenic activities (Efe S.T., 2005)

The formation of air pollutant can be happened in different ways such human activities. Weather parameter play important role in forming or removing air pollutants, for example, winds could carry the pollutions from one region to another, also, rain transport the pollutants from the atmosphere to the soil and water.

Generally air pollution can be divided into three categories:

- Biological air pollutant such as pollens, small insects
- Physical air pollutant such as sound, smell, thermal pollution and radioactive radiation.
- Chemical air pollution such as Ozone, aerosol and ammonia.

The current study aim at carrying out the chemical analysis of rain water samples in Erbil city so that the environment of the city can be assessed. The present study allows us to understand the effect of dynamic weather on pollutant and determine the source of them whether it is locally or it comes from nearby area of our country.

2. MATERIALS AND METHODS

A. Study area

The current research were achieved in Erbil Governorate. Erbil region is located within south of Kurdistan region, Kurdistan region borders Syria to the west, Iran to the east and Turkey to the north, where fertile plains meet the Zagros Mountains. Which covers about 70Km2 between latitude 36° 09" to 36° 14" N and between longitude 43° 58" to 44° 03" E (Salash., 1966). It is the largest city in Iraqi Kurdistan Region and the state capital. It covers a surface area of 129 km², with a population of 885586 inhabitants (as at 2007). The climate most closely to Irano-Turanian type. The annual rainfall may exceed 1000mm. The annual average rainfall in Erbil city is around 440mm (Zohary, 1950).

b. Samples collection

During this study, rainwater samples were collected from four sites within Erbil city (Zhian Q, Karizan Q, Qartapa Q and Mamostian Q) during 1st and 22th November-2014 to 1st and 20th February-2015. The rain samples were collected in clean polyethylene plastic bottles. Analysis of rainwater samples were carried out immediately after storing the collection samples in a refrigerator at 4°C prior to analysis. Standard techniques were used (A.P.H.A.,1998) to analyze different physicochemical parameters: Turbidity was measured in situ by using (Turbidity meter, Hach company, UK), pH, EC and TDS were estimated by using (pH-ECTDS meter, HI9812, Hanna instrument), total hardness and calcium (EDTA titrimetric method), the Mohr method was used for determination of chloride content in the studied area.

C. Water Quality Index for drinking

Calculating of water quality index is to turn complex water quality data into information that is understandable and useable by the public. Therefore, water Quality Index (WQI) is a very useful and efficient method which can
provide a simple indicator of water quality and it is based on some important parameters. WQI provides information on a rating scale from zero to hundred. Nine parameters have been selected for developing the water quality index. In present study, the WQI were calculated in three steps. In the first step, each of the nine parameters (Turbidity, PH, EC, TDS, Total alkalinity, Total hardness, Calcium, Chloride, and Nitrate) were assigned a weight \( (w_i) \) according to its relative importance in the overall quality of water for drinking purposes in Table 1 Srinivasamoorthy et al (2008).

**Table 1. Details of chemical parameters with their relative weight and assigned weight with drinking water standards (WHO, 2014).**

| Parameters                  | Water Quality Standard | Weight \((w_i)\) | Relative weight \((W_i)\) |
|-----------------------------|------------------------|-----------------|--------------------------|
| Turbidity (NTU)             | 5                      | 3               | 0.12                     |
| pH                          | 6.5-8.5                | 4               | 0.16                     |
| EC (µs/cm)                  | 1000                   | 3               | 0.12                     |
| TDS (mg/L)                  | 500                    | 3               | 0.12                     |
| Alkalinity (mgCaCO3/L)      | 200                    | 1               | 0.04                     |
| Hardness (mgCaCO3/L)        | 200                    | 2               | 0.08                     |
| Calcium (mg/L)              | 100                    | 2               | 0.08                     |
| Chloride (mg/L)             | 250                    | 2               | 0.08                     |
| Nitrate (mg/L)              | 50                     | 5               | 0.2                      |

\[ \sum w_i = 25 \quad \sum W_i = 1 \]

The maximum weight of five has been assigned to the parameter nitrate due to its major importance in water quality assessment (Srinivasamoorthy, 2008). Alkalinity gives the minimum weight of 1 as it plays an insignificant role in the water quality assessment. Other parameters like calcium, pH, EC and TDS were assigned weight between 1 and 5 depending on their importance in water quality determination. In the second step, the relative weight \((W_i)\) is computed from the following equations

\[ W_i = w_i / \sum w_i \quad \text{(1)} \]

\( W_i \) and \( w_i \) is the relative weight and weight of each parameter, respectively, and \( n \) is the number of parameters.

In the third step, a quality rating scale \((Q_i)\) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the (WHO, 2004) and the result for the same is multiplied by 100 (Equation 2).

\[ Q_i = C_i / S_i * 100 \quad \text{(2)} \]

Where, \( Q_i \) is the quality rating, \( C_i \) is the concentration of each chemical parameter in each water sample in mg/L. Also \( S_i \) is the Indian drinking water standard for each chemical parameter in mg/L according to the guidelines of the WHO.

For computing the WQI, the \( S_i \) is first determined for each chemical parameter, which is then used to determine the WQI as per the following Equations (3 and 4)

\[ S_{li} = W_i \times Q_i \quad \text{(3)} \]

\[ \text{WQI} = \sum^n S_{li} \quad \text{(4)} \]
where, $S_{li}$ is the sub index of $i^{th}$ parameter, $Q_{i}$ is the rating based on concentration of $i^{th}$ parameter, $n$ is the number of parameters.

The computed WQI values are categorized into five types as “excellent water” to “water, unsuitable for drinking”. The range for WQI for drinking purpose is tabulated in (Table 2) according to Ramakrishnaiah et al.,(2009)

Table 2. Range of water quality index specified for drinking water

| WQI range | Water quality       |
|-----------|---------------------|
| <50       | Excellent water     |
| 50-100    | Good water          |
| 100-200   | Poor water          |
| 200-300   | Very poor water     |
| >300      | Water unsuitable for drinking purpose |

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| EC (µs/cm) | 1000 | 3 | 0.12 |
| TDS (mg/L) | 500 | 3 | 0.12 |
| Alkalinity (mgCaCO3) | 200 | 1 | 0.04 |
| Hardness (mgCaCO3) | 200 | 2 | 0.08 |
| Calcium (mg/L) | 100 | 2 | 0.08 |
| Chloride (mg/L) | 250 | 2 | 0.08 |
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The maximum weight of five has been assigned to the parameter nitrate due to its major importance in water quality assessment (Srinivasamoorthy., 2008). Alkalinity gives the minimum weight of 1 as it plays an insignificant role in the water quality assessment. Other parameters like calcium, pH, EC and TDS were assigned weight between 1 and 5 depending on their importance in water quality determination. In the second step, the relative weight ($W_i$) is computed from the following equations

\[ W_i = \frac{w_i}{\sum^n w_i} \]
Wi and wi is the relative weight and weight of each parameter, respectively, and n is the number of parameters.

In the third step, a quality rating scale (Qi) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the (WHO., 2004) and the result for the same is multiplied by 100 (Equation 2).

\[ Qi = \frac{Ci}{Si} \times 100 \]  \hspace{1cm} (2)

Where, Qi is the quality rating, Ci is the concentration of each chemical parameter in each water sample in mg/L. Also Si is the Indian drinking water standard for each chemical parameter in mg/L according to the guidelines of the WHO.

For computing the WQI, the SI is first determined for each chemical parameter, which is then used to determine the WQI as per the following Equations (3 and 4)

\[ SIi = Wi \times Qi \]  \hspace{1cm} (3)

\[ WQI = \sum^n_{i=1} SIi \]  \hspace{1cm} (4)

where, SIi is the sub index of ith parameter, Qi is the rating based on concentration of ith parameter, n is the number of parameters.

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d. Water Quality Index for irrigation

For irrigated agriculture, numerous classifications for water use have been developed, each with a certain suitability, although none has proved entirely satisfactory. The irrigation water quality index is an a dimensional number generated from the aggregation of certain data by means of specific methods that indicates water quality for diverse purposes (Maia and da paz Rodriguez., 2012).

According to Ayers and Westcot.,(1991), the samples in this EC range may be used without any restriction degree with regard to salinity. In the reference samples, the mean values and respective standard deviation were calculated for each characteristic evaluated for the three water sources. For all characteristics evaluated, data normality was confirmed by Lilliefors test. To calculate the deviation from the reference values for each characteristic, considering normal data distribution, the data were standardized according to equation 1.

\[ Zi = \frac{X_i - \mu}{\sigma} \]  \hspace{1cm} (1)

in which Zi = standardized value of the characteristic analyzed; \( x \) = value of the characteristic evaluated at the water source; \( \mu \) = mean value of the characteristic evaluated in the reference population; \( \sigma \) = standard deviation.
of the characteristic evaluated in the reference population.

The Quality Index was calculated for each characteristic (WQli) in the sample, for which WQli was determined for Ca, Mg, Na, K, Cl, HCO3+CO3, SO4, and the SAR (equation 2) and the Irrigation Water Quality Index (IWQI) by equation 3.

\[
WQli = \sqrt{Zi^2} \hspace{1cm} (2)
\]

\[
IWQI = \frac{1}{N} \sum_{i=1}^{N} WQi \hspace{1cm} (3)
\]

in which WQli = Water Quality Index for the characteristic; IWQI = Irrigation Water Quality Index; Zi = standardized value of the variable; N = number of characteristics evaluated.

For WQli and IWQI, four irrigation water quality classes (I, II, III and IV) were created (Table 3). The classification was determined based on the range of values from -1.96 to 1.96 for class I. This indicates a 95% probability that the WQli value is statistically equal to the reference population; in other words, the values of the indices contained in the determined interval do not present any degree of restriction. The other classes were obtained according to table 3.

Table 3. Condition for classification of the Water Quality Index for the characteristic evaluated (WQli) and for the Irrigation Water Quality Index (IWQI)

| Class       | Condition                        |
|-------------|----------------------------------|
| I (Excellent)| $WQli \text{ or } IWQI \leq 1.96$|
| II (Good)   | $1.96 < WQli \text{ or } IWQI \leq 5.88$|
| III (Average)| $5.88 < WQli \text{ or } IWQI \leq 9.80$|
| IV (Poor)   | $WQli \text{ or } IWQI > 9.80$    |

3. RESULTS AND DISCUSSION

Rain water physical and chemical composition (Tables 4, 5, 6 and 7) shows the average and values for turbidity, pH, electrical conductivity, total dissolved solids, total alkalinity, total hardness, chloride and nitrate concentrations of the 20 samples (three replication with each sample) of atmospheric precipitation.

Rainwater turbidity varied between (2.0-11.1NTU), the lower value recorded in February-2015 while, the higher values calculated in February-2014. The value of turbidity in rainwater in 2015 exceeded while in 2014 was within the recommendation of World Health Organization [14]. This may also be due to particulate matters produced during gas flaring, air pollution through different resources that may contribute to total suspended solid present in rainwater (WHO, 2004). Their concentration of turbidity specifically increases in rain events that follow long dry periods, as well as due to small rain events. In general, the sampling locations, within pure urban rainwater points, that present the highest concentration of solids are those that are closest to industrial area. pH of rainwater samples at four zones, representing different surroundings, varied from 6.9 to 8.5. The relatively higher pH values have been attributed to the dominance of crustal components particularly carbonates and bicarbonates of Ca2+ which buffer the acidity.
of sulphate and nitrate (Kulshrestha, 2003). However, few samples of wet precipitation showed lower pH during rain events indicating the reduction of buffering action of rainwater to a minimum level by washing out the dust particles from the atmosphere (Kulshrestha, 1996). The electric conductivity (EC) and total dissolved solids of rainwater during the sampling period ranged from 24.4-435 µs/cm and 12.2-217.5 mg/L respectively. These values are somewhat smaller than the standard value (1000 µs/cm and 1000 mg/L) for potable water as requested by the World Health Organization (WHO, 2004). In regard to alkalinity, Hardness, Calcium, Chloride, and NO3 parameters, all samples comply with World Health Organization (WHO) for Drinking Water Standards except hardness samples exceeded the WHO [14]. Alkalinity values ranged between 30-140 mg CaCO3/L during the studied period, these data are within recommendation of WHO for drinking purposes (WHO, 2004). The range of hardness and calcium varies from (120-400 mg CaCO3/L) and (32-176 mg/L), this variation may be due to effect of both industrial and municipal effluents, flaring of gases and runoffs from surrounding areas and anthropogenic activities (Efe, 2005). A huge variety of substances can be found in the air being the anthropogenic sources responsible for issuing most of the potentially polluting substances. Those sources of pollution are mainly characterized by the combustion of fossil fuels, the usage and production of biocides and pesticides, mining activities and the inappropriate treatment of industrial effluents, which are directly responsible for the increasing levels of particulate matter suspended in the atmosphere (Seinfeld, 2006). Based on taste threshold, WHO has prescribed 250 mg/l as the acceptable limit and 1000 mg/l as the permissible limit for chloride. The concentrated of chloride in the collected samples were in the range of 18.4–70.0 mg/l. Chloride level in all rainwater samples was within the acceptable limit for drinking purposes according to (WHO, 2004). The presence of nitrate in drinking water is a potential health hazard when present in large quantities. The combination of nitrates with amines, amides, or other nitrogenous compounds through the action of bacteria in the digestive tract results in the formation of nitrosamines, which are potentially carcinogenic (Singh, 2016). The maximum allowable nitrate concentration as per WHO for drinking water is 50 mg/L as NO3. The concentration of nitrate in rainwater samples of the study area ranges between 0.3 and 3.2 mg/l (Figure 13) and is found to be well within the desirable limit prescribed by (WHO, 2004). Those particulate materials, such as Cl and NO3 generally remain in the atmosphere until they are scavenged by precipitation, through dissolution, by falling rain droplets (Baron, 1993). Rainwater composition is directly related to the level of local emissions, pollutant transport, climate conditions and drop size, which influences the rainout (in–cloud scavenging) and the washout (below–cloud scavenging) of pollutants.

Applying the former equations on the results of water analysis data of rainwater, have been plotted in (Table 8). The results showed that, for rain water, of the samples are coming under “Excellent” (range 0-50) in most of sites during 1st 22th November-2014 and “Good” (range 50-100) water quality in all sites during 1st 20th-February-2015. This may evident that the rainwater in 2014 is more clear or less pollutant than 2015. This may be due to sources of pollution are mainly characterized by the combustion of fossil fuels, the usage and production of biocides and pesticides, mining
activities and the inappropriate treatment of industrial effluents, which are directly responsible for the increasing levels of particulate matter suspended in the atmosphere [20]. Those particulate materials, such as SO2 and NOX, salts and trace metals, generally remain in the atmosphere until they are scavenged by precipitation, through dissolution, by falling rain droplets. (Baron and Denning., 1993) Rainwater composition is directly related to the level of local emissions, pollutant transport, climate conditions and drop size, which influences the rainout (in–cloud scavenging) and the washout (below–cloud scavenging) of pollutants (Baron and Denning., 1993). Thus, based on EC, the IWQI may classify the waters as excellent, good, average and poor for IWQI I, II, III, and IV respectively, and this classification varied with the EC, according to the source evaluated. According to (Table3), IWQI values for all sites during the studied period varied from site to others but all sites was put in class I which means were excellent quality for irrigation purposes(Table 9).

![Table (4):-Physical and chemical properties of rainwater samples from during 1stNovember-2014](image)

| Sites     | Zhanan Q | Qarta Q | Karizan Q | Mamostian Q |
|-----------|----------|---------|-----------|-------------|
| Factors   | Turbidity (NTU) | Turbidity (NTU) | Turbidity (NTU) | Turbidity (NTU) |
| pH        | 6.9      | 7.0     | 8.0       | 8.0         |
| EC (µs/cm)| 119      | 37.9    | 435       | 93.9        |
| TDS (mg/L)| 69.5     | 18.9    | 217.5     | 46.9        |
| Alkalinity (mgCaCO3/L)| 42      | 30      | 140       | 80          |

| Factors | Hardness (mgCaCO3/L) | Calcium(mg/L) | Chloride (mg/L) | Nitrate (mg/L) |
|---------|---------------------|---------------|----------------|----------------|
| Zhanan Q | 188                 | 48            | 33.1           | 0.7            |
| Qarta Q | 300                 | 176           | 34.9           | 1.0            |
| Karizan Q | 250                 | 96            | 20.2           | 0.9            |
| Mamostian Q | 220               | 94            | 18.4           | 0.3            |

![Table (5):-Physical and chemical properties of rainwater samples from during 20th- November-2014](image)

| Sites     | Zhanan Q | Qarta Q | Karizan Q | Mamostian Q |
|-----------|----------|---------|-----------|-------------|
| Factors   | Turbidity (NTU) | Turbidity (NTU) | Turbidity (NTU) | Turbidity (NTU) |
| pH        | 7.5      | 8.5     | 7.2       | 7.6         |
| EC (µs/cm)| 24.4     | 88.6    | 41.6      | 65.8        |
| TDS (mg/L)| 12.2     | 44.3    | 21.5      | 32.9        |
| Alkalinity (mgCaCO3/L)| 60      | 50      | 40        | 44          |
| Hardness (mgCaCO3/L)| 400     | 300     | 240       | 320         |
| Calcium(mg/L) | 80       | 112     | 80        | 72          |
| Chloride (mg/L) | 46.0  | 55.2    | 55.3      | 46.1        |
| Nitrate (mg/L)  | 1.9     | 0.36    | 2.8       | 3.2         |

![Table (6):- Physical and chemical properties of rainwater samples from during 1st- February-2015](image)
### Table (7): Physical and chemical properties of rainwater samples from during 20th-February-2015

| Sites               | Zhi an Q | Qarta pa Q | Kariz an Q | Mamost ian Q |
|---------------------|----------|------------|------------|--------------|
| Factors             |          |            |            |              |
| Turbidity (NTU)     | 9.6      | 8.2        | 9.2        | 10.7         |
| pH                  | 8        | 8          | 7.8        | 8            |
| EC (µs/cm)          | 126.5    | 93.0       | 95.0       | 104.0        |
| TDS (mg/L)          | 5        | 5          | 6          | 4            |
| Alkalinity (mgCaCO3/L) | 50      | 50         | 60         | 46           |
| Hardness (mgCaCO3/L) | 160     | 365        | 365        | 120          |
| Calcium (mg/L)      | 48       | 40         | 56         | 64           |
| Chloride (mg/L)     | 75.5     | 64.47      | 62.63      | 70           |
| Nitrate (mg/L)      | 1.19     | 1.18       | 1.32       | 1.39         |

### Table (8): Water Quality Index for Rainwater during the studied period

| Date       | 1st Nov-2014 | 20th Nov-2014 | 1st Feb-2015 | 20th Feb-2015 |
|------------|--------------|---------------|--------------|---------------|
| Sites      |              |               |              |               |
| Zhian Q    | 36.498       | 48.419        | 59.156       | 57.362        |
| Qaratapa Q | 39.022       | 49.852        | 61.131       | 56.672        |
| Karizan Q  | 42.096       | 41.989        | 64.515       | 56.495        |
| Mamostian Q| 39.885       | 45.618        | 60.093       | 55.542        |

### Table (9): Irrigation Water Quality Index for rainwater during the studied period

| Date       | 1st Nov-2014 | 20th Nov-2014 | 1st Feb-2015 | 20th Feb-2015 |
|------------|--------------|---------------|--------------|---------------|
| Sites      |              |               |              |               |

| Factors             |          |            |            |              |
| Hardness (mgCaCO3/L) | 140      | 240         | 136         | 160           |
| Calcium (mg/L)      | 32        | 32          | 32          | 36            |
| Chloride (mg/L)     | 1.8       | 2.8         | 1.8         | 1.7           |
| Nitrate (mg/L)      | 64.6      | 92.1        | 73.6        | 64.4          |
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|               | Zhian Q |  | Qaratapa Q |  | Karizan Q |  | Mamostian G |
|---------------|---------|---|------------|---|-----------|---|-------------|
|               | 0.831   | 0 | 1.125      | 1.194 | 0         | 1.648 | 0          | 0         | 0         | 0         | 0         | 1.227 | 0.907 | 1.586 | 1.841 |

### Conclusions

1. Water quality index for rain water varied from excellent to good quality in 2014 and 2015 respectively, this means quality of rainwater is better in year 2014 than 2015 for drinking purposes.

2. Variation was observed in the ionic composition of the four sampling sites. Although different water qualities were observed, water with excellent quality was observed for irrigation during the period of this survey as classified as IWQI class I.

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