How to Cite:
Mohit, M., & Suprita, S. (2022). A review on correlation between the total dissolved salts (TDS) and electrical conductivity (EC) of water samples collected from different area of Bhiwani city, Haryana, India. *International Journal of Health Sciences*, *6*(S6), 5431–5438. https://doi.org/10.53730/ijhs.v6nS6.10821

A review on correlation between the total dissolved salts (TDS) and electrical conductivity (EC) of water samples collected from different area of Bhiwani city, Haryana, India

Mohit
Chemistry Department, Shri Jagdishprasad Jhabarmal Tibrewala University, Jhunjhunu, Rajasthan, India
Email: mohitmothsara6199@gmail.com

Dr. Suprita
Chemistry Department, Shri Jagdishprasad Jhabarmal Tibrewala University Jhunjhunu, Rajasthan, India
Email: supritarana0006@gmail.com

***Abstract*---**The aim of our paper is to study the water quality parameters specially refers to the presence of soluble salts and non ionic solutes. Different water samples were collected from different areas of Bhiwani city, Haryana. Measurement of Total Dissolved Salts (TDS) is very important because it is widely concerned with plant growth and their yield, food technology, making environment safe, human health, and boilers. Different physical chemical methods are used to describe the estimation of dissolved salts such as TDS meter, conductivity meter, gravimetric method, EDTA and boiling. Furthermore, our analysis is based on measurement of TDS and EC at normal room temperature as well after boil the sample for 10 minutes. Our research reveals that TDS and EC are two different parameters. TDS depends upon total dissolved salts in the water while conductivity depends on mobility of ions i.e. their transport number. TDS/EC ratio of different water sample is found not a directly linear. The average value of k for five water sample is decreased after boiling the water from the 0.774 to 0.694.

***Keywords*---**conductivity, total dissolved salts (TDS), water quality parameter, food technology, transport number, linear, TDS/EC ratio, physical chemical methods.

Manuscript submitted: 9 April 2022, Manuscript revised: 27 June 2022, Accepted for publication: 18 July 2022

Introduction

The conductivity of pure water is relatively low, but not exactly zero [7]. Pure water has an EC of 0.05483 μs/cm at 25°C due to its own dissociation. Because of CO_2 contamination, exposure to the environment increases conductivity to > μS/cm [8]. The conductivity of water may be used to investigate fundamental features such as the electrochemical mobility of hydrogen and hydroxide ions [7]. Water parameter measures for example total dissolved salts (TDS) and electrical conductivity (EC) and are often utilised, especially in coastal areas [1]. TDS concentration is frequently estimated using EC readings and a conversion factor derived from regulations [8]. These two metrics are salinity level indicators, making them a helpful tool for analysing seawater incursion. The EC and TDS values are connected. EC depends on the nature of different ions present in water. Dissolved ion concentrations, ionic strength, and temperature measurement are used to establish its capability. The concentration of dissolved ions is commonly expressed as. TDS analysis, on the other hand, is more complex and costly since it requires more equipment and time [1].

TDS is an abbreviation for total dissolved solids, which denotes to the salts that are inorganic and small amounts of non ionic compounds found in water. Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} cations, as well as CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-}, and NO_3^{-} anions, are the most common ingredients. TDS measured using the gravimetric technique or by using a TDS metre should be the same. TDS is a possible geothermal changes and microbial degradation of different hydrocarbons majorly contribute to the conductivity and TDS. TDS in ground waters may be determined using either traditional gravimetric procedures or conductivity/TDS meters. It can not be predicted that TDS correlated with specific conductance is the sole criteria to determine ionic species in ground water. Our results revels that presence of hydrocarbons shows lower specific conductance because they increase resistivity [2]. Our study indicated that there is no exact relationship between TDS and EC meaning by that TDS can not be determined direct by EC. The below equation 1 [2, 3] may be used to assess the correlation of these parameters:

$$\text{Total Dissolved Salts (mg/ L)} = k \times \text{Electrical Conductivity (µS cm)} \quad ...(1)$$

Generally, 0.7 value of k is designed by chemist. This value is average value lies in the range of the 0.5 - 0.9. The persistent use of only one K factor (usually 0.7) can lead to TDS estimate mistakes of up to 30% simply from this one theoretical simplification. The desalination market, in particular, requires a wide variety of K factors [3]. The k value will rise as the number of ions in water rises. The ratio between TDS and conductivity is not a straight line mainly conductivity depends on transport number of different ions, the total transport number of all the ions and ionic strength in the liquid. There have been previous research to identify the mathematical correlation between EC and TDS. A thorough correlation between these two characteristics was also published in 1989. Our goals were to:

- Measurement of TDS and conductivity of various water sample
- Any correlation between TDS and conductivity

- What will change in its value of TDS and conductivity after boiling the water.
- What will be the ratio of TDS and conductivity for different water samples.

Method and Study Areas

First we collect Water sample from the Hand pump in different places of Bhiwani city. This water sample were taken on the dated 11 January 2022 from the five areas of Bhiwani city i.e. Hansi Gate, Nehru park (Ghanta Ghar), Additional New Grain Market Loharu Road, Tosham Byepass, Jogiwala temple (Shiv Nagar). (Note:- Room Temperature:- 16℃). From these water sample, first, at 16℃, we measured the TDS and ionic conductance of all samples individually using double distilled water and potassium chloride solution for calibration of conductivity bridge. And note the reading for each water sample. This reading shown in below table. After noting the reading, we boiled these five water sample for 5-10 minutes each and then let it cool down at room temperature. After cooling at room temperature, we further measured TDS and EC. And note reading of each sample. So, the table of TDS and EC before boiling the water sample and after boiling the water sample is prepared. The following results is obtained:-

SAMPLE	Name of colony	TDS (in PPM)	TDS AFTER BOILING (IN PPM)	CONDUCTIVITY (S/m) (20 ms)	CONDUCTIVITY AFTER BOILING (S/m) (ms)	RATIO OF TDS/EC (BEFORE BOILING)	RATIO OF TDS/ EC (AFTER BOILING
1.	Tosham Byepass, Bhiwani	291	350	1.5 x 20 ms = 300 μs/cm	1.4 x 20 ms = 280 μs/cm	0.97	1.25
2	Nehru park (Ghanta Ghar), Bhiwani	105	155	4.1 x 20 ms = 820 μs/cm	6.6 x 20 ms = 1320 μs/cm	0.12	0.11
3.	Jogiwala temple (Shiv Nagar), Bhiwani	297	431	7.8 x 20 ms = 1560 μs/cm	15.5 x 20 ms = 3100 μs/cm	0.19	0.13
4.	Additional New Grain Market Laharu Road, Bhiwani	298	326	1.1 x 20 ms = 220 μs/cm	1.7 x 20 ms = 340 μs/cm	1.35	0.95
5.	Hansi Gate, Bhiwani	298	395	1.2 x 20 ms = 240 μs/cm	1.9 x 20 ms = 380 μs/cm	1.24	1.03

Analysis of Result/Table and Discussion

After analyzing this result/table, we found that, both value of conductivity and TDS were different after and before boiling the water sample means value of both conductivity and TDS is increased simultaneously.

Average k value (Before Boiling):- $\frac{0.97 + 0.12 + 0.19 + 1.35 + 1.24}{5} = 0.774$

Average k value (After Boiling):- $\frac{1.25 + 0.11 + 0.13 + 0.95 + 1.03}{5} = 0.694$

The ratio of TDS and EC is in above table for each water samples. But, Average value of k is 0.774 (Before Boiling) and 0.694 (After Boiling). Its means that k value decrease after boiling the water. According to earlier research, the electrical conductivity is correlate with the Total Dissolved Salts(TDS) i.e.

$$TDS\ (mg/\ L) = k \times EC\ (\mu S\ cm) \quad \ldots(2)$$

Slope of k is not linear. Our slope first decreases and then increases.

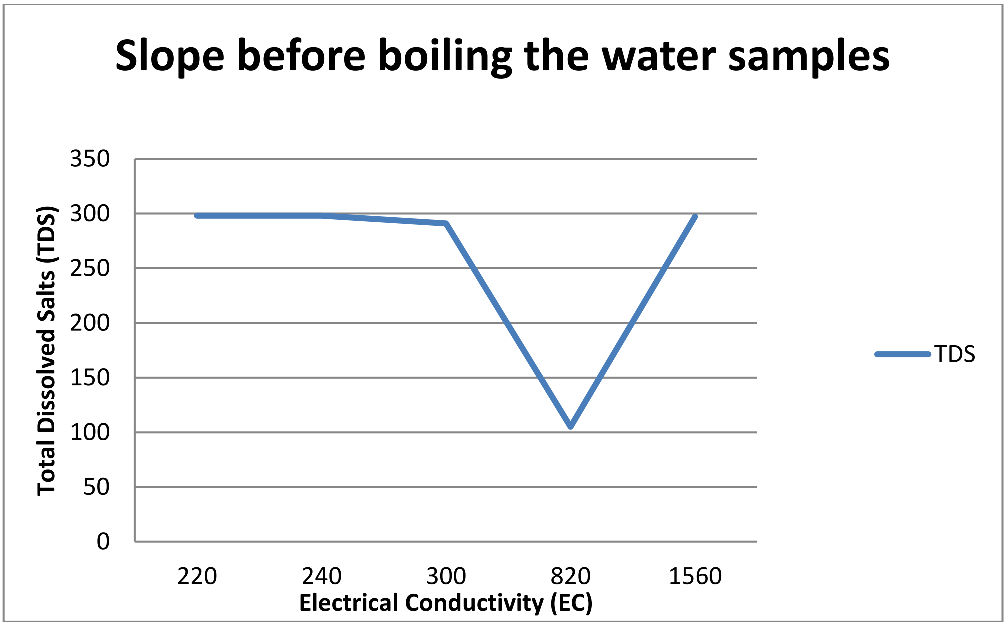

Figure 1. This Slope is of before the boiling the water samples

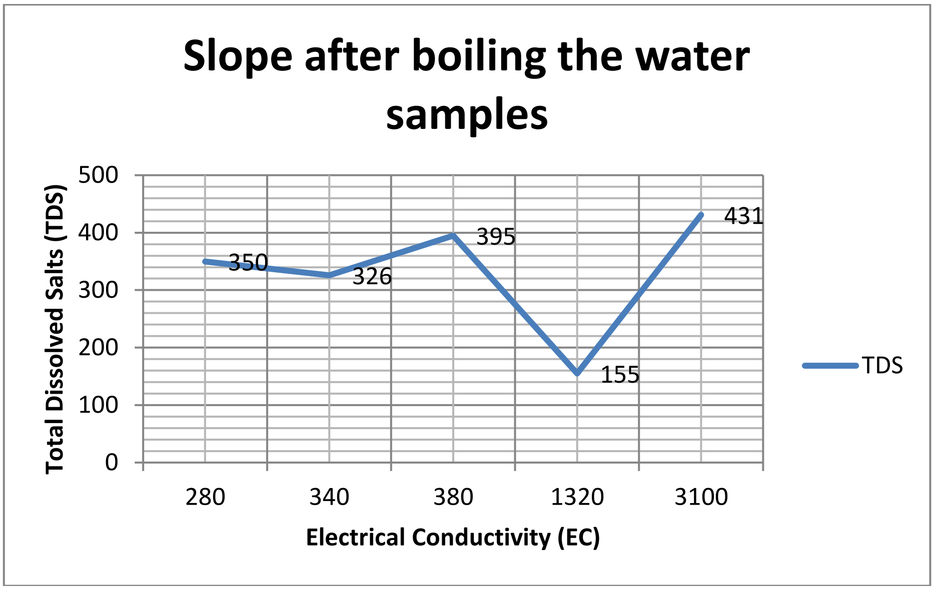

Figure 2. This graph is of after the boiling the water

From above table, we concluded that there is no relation between EC and TDS. Because these are both a different concept. TDS is depend on ionic salts and EC depends on mobility of different ions and mobility depends on transport number. Ionic salts have varying transport numbers. The concentrations of key ions like SO_4^{2-}, HCO_3^-, Cl^-, Na^+, and Mg^{2+} determine TDS. [5]. TDS levels ranged from 105 to 298 mg/L, according to the table. In general, water with a TDS of less than 300 is regarded good, whereas water with a TDS of more than 1000 is considered bad. Total Dissolved Solids (TDS) has a positive relationship with conductivity and has an impact on pH. If TDS increases then conductivity also increase, and the lower the pH, the more acidic the environment [6]. The concentration of dissolved electrolytes and gases determines electrical conductivity. Mobility of ions depends on charge and dissolved radius, their temperature and their viscosity of the solution and mobility depends on EC [8]. The conductivity temperature dependency, ST, of pure water is an important feature, as shown by [7].

$$S_T = 100 \left(\frac{\partial k}{\partial T}\right) \left(\frac{1}{k}\right) \quad \text{(Equation 3)}$$

Temperature has no direct impact on TDS, according to Pearson's Product Moment Correlation coefficient. TDS is affected by the temperature of the stream. The quantity of thermal energy in the water is represented by the stream temperature [9]. If the water is pure, The temperature sensitivity of ultrapure water is 7.4 percent per "C at 0'C. At 100°C, this sensitivity diminishes by a factor of three, to 2.3 percent per ℃; that is, a temperature measurement mistake of 0.1℃ corresponds to a conductivity error of 0.23 percent [7]. However, when the temperature rises from 0 to 100℃, the sensitivity decreases by a factor of 12. Most importantly, at 25°C, the sensitivity is 4% per ppb, whereas at 85%, it is 1% per ppb [7]. As the temperature of the solution varies, so does its conductivity. Ions in solution increases when temperature also increases. On increasing the temperature of the solution will enhance its conductivity. The majority of conductivity measurements are taken at 25°C. With the 1℃ change in temperature , the % change in EC is represented by Temperature Coefficient of Variation [4]. It is difficult to drive any relation between EC and TDS because of chemical composition and ionic strength and various chemical species in water samples. Change in temperature effect the EC because of change in the composition of ionic species due to their dissociation. So, keeping in this view EC must be find out by adjusting the temperature. Natural water's EC-temperature relationship is often nonlinear. However, The temperature range 0–30℃ is generally minor for the non linearity, and for given below relationship is used for the linearity.

$$EC_t = EC_{25}\,[1 + a(t - 25)] \qquad \text{....(Equation 4)}$$

where EC_t is value of EC at temperature t (°C), EC_{25} is value of EC at 25 °C, and a (°C−1) is a temperature compensation factor. Several values of a are commonly cited in the standard literature. . Depending on which electrolytes are present, the electrical conductivity increases 1–3%/℃ . Therefore, to normalize the effect of temperature, generally, scientist measured the EC at 25℃ . The k_{25} is measured by given equation [10]:

$$k_{25} = \frac{k}{1+\alpha(T-25℃)} \qquad \text{...(Equation 5)}$$

where k is the electrical conductivity at the solution temperature (T) in C and a is the temperature compensation factor. The temperature compensation factor is typically programmed into the conductivity meter and ranges from 0.019 to 0.023/℃ [10].

Ratio of TDS/EC or K value or conversion factor

Because dissolved ions account for approximately all of the conductivity, so, EC and TDS has a relation between itself**:**

$$TDS = k * EC \qquad \text{..(Equation 6)}$$

This k permits the calculation of TDS from a determined EC and often apply in all cases where TDS must build fast (For example, industry, agriculture, resource management, water supply or mining). As a result, constant coefficients must be determined in order to calculate TDS which is depend on EC. Because natural water and ground water do not contain a single salt solution and comprise a variety of ionic and non ionic species in wide range of volumes and ratio, the link between TDS and EC gets difficult. Although, this one typically clearly defined enough to be of practical use, and a linear connection is generally a decent approximation. The exact value of the conversion factor is determined by the ionic composition of the water, particularly its pH as well as bicarbonate content, as well as the solution's TDS. Because of changes in the extent of dissociation of soluble electrolytes at various solution concentrations, as well as differences in the mobility of ions in mixed soluble electrolyte solutions, the ratio cannot be constant throughout a large range of TDS [8]. For water with TDS more than

50,000 mg/L, the link between TDS and EC is less clearly established. In general, the ratio ranges from 0.55 to 0.91. As a consequence, the k value for our result is:

- **Case (1):- Before Boiling the water,**
  The lowest k value or (conversion factor) is 0.12 with a (EC = 820 μs/cm) for a sample from the Nehru Park (Ghanta Ghar) and is strongly influenced by boiling. In contrast, the highest k value is 1.35 with a (EC = 220 μS/cm) for the sample Additional New Grain Market, Loharu Road, Bhiwani.
- **Case (2). After Boiling the water**, k value
  The Lowest k value or (conversion factor) is 0.11 with a EC value 1320 μS/cm for a sample from the Nehru Park (Ghanta Ghar) and is strongly influenced by boiling. In contrast, the Highest k value is 1.25 with the EC value 280 μS/cm for the sample Tosham Bypass, Bhiwani. Here, The low k value may be obtained by the loss of volatile ingredients throughout the drying procedure (e.g., nitrate, organics, or ammonia), whereas a very high k value may be formed by the presence of substantial amounts of weakly dissociated sulphate, calcium, or silica [8].

Conclusion

We reached a conclusion that on boiling the water, the average value of k is decreased from the value 0.774 to 0.694 for our water samples. Also, on boiling the water, TDS and EC both increases simultaneously. But they are inversely proportional to each other according to our results. This is because conductivity depend on mobility and mobility depend on transport numbers of individuals ion present in solution [8, 10]. Different water samples have different ions and each ions have their own transport number. So, some ions have less transport number and some ions have more transport number. Also, conductivity depend on Transport numbers. With the help of this, we can determine the concentrations of ions in waters. Using the maximum transport number, the ions can be classified into three group. The first group involve those ions that may add significantly (t_{max} > 10%) to the EC value of waters (Ca^{2+}, Na^{+}, H^{+} , NH_4^{+} , Mg^{2+}, Cl^{-} , K^{+} , SO_4^{2-}, CO_3^{2} , HCO_3^{-}, Al^{3+}, F, NO_3^{-} , HSO_4^{-}, and Fe^{2+},). The ions in this group are essential for accurate conductivity calculations. The next group includes those ions than add a moderate amount (2% < t_{max} < 10%) to the EC value of waters (Cu^{2+} , Fe^{3+}, Li^{+}, Zn^{2+}, $NsSO_4^{-}$, OH^{-} , $NaCO_3^{-}$ and Mn^{2+}). The last group involve those ions that contribute very little (t_{max} < 2%) to the EC value of the waters (Br^{-} , KSO_4^{-} , Ba^{2+} Sr^{2+} and Cs^{+}). [10]

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