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INFLUENCE OF TEMPERATURE ON THE MEASUREMENT OF TOTAL DISSOLVED SOLIDS (TDS) IN WATER

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Abstract: Mostly, surface waters do not have properties that meet consumer requirements due to their circuit through the environment that contaminates them with dissolved and suspended substances. Their content of total dissolved solids (TDS) is an indicator of quality, giving taste and smell to the water. This study aims to investigate the variation of total dissolved solids (TDS) with the temperature of a water sample. For the experiment, unfiltered water was collected from a spring. During the heating of the water sample on an electric hub, the temperature and TDS values were recorded with digital meters. The increase in the concentration of TDS with temperature was observed quantitatively.

Keywords: total dissolved solids (TDS), electrical conductivity meter, water quality

INTRODUCTION

Substances that can be dissolved in surface waters, having a size of less than one micron, can be: *mineral substances* (chlorides, carbonates and bicarbonates, sulfates, oxides, sodium nitrates, potassium, calcium, magnesium, iron, silicon), *organic substances* (plant and animal residues, compounds containing carbon, hydrogen and sometimes oxygen and nitrogen) or *gases* (oxygen, nitrogen, carbon dioxide, methane, hydrogen sulfide) [1]. The ions of these substances give the electrical conductivity of water that increases as their concentration is higher [1, 2]. Also, an increase in water temperature leads to a decrease in viscosity and an increase in mobility and number of ions (due to the dissociation of molecules), which will increase electrical conductivity [2]. Moreover, the solubility of certain substances in water may change, which will have the effect of increasing the value of total dissolved solids (TDS) in water [3]. Thus, a directly proportional dependence was observed between the water temperature and the values of electrical conductivity and TDS [1, 3].

Several papers address the influence of temperature on the TDS level in water. For example, the work of B.B. Wang [1] focuses on lowering TDS in tap water by several methods. By the heating method, the 1L samples are heated to different temperatures and observed during cooling for up to 1 hour, with data for longer durations being estimated. It has been observed that TDS values decrease with a decrease in temperature. From the studied heating range of 40°C–100°C, the maximum TDS value was recorded at 60°C. In this experiment, the difference between the TDS values at maximum and initial temperature is 58.42 ppm (from 204 ppm at 60°C, the TDS value decreases to 145.58 ppm at 26.9°C after 94.8 min.). The author concluded that the temperature range of 40°C–60°C is optimal for reducing TDS (the largest experimentally observed decrease in TDS is 16% at 50°C), rather than heating to a higher temperature.

A.T. Ahmed et al. [4] analyzed the impact of temperature on the quality of drinking water stored in plastic bottles. Their experiments consisted in heating water in plastic bottles from room temperature (20°C) up to 30°C, 50°C, and 70°C by three heating methods (sun, oven, and microwave). Among the physicochemical properties analyzed, TDS measurements showed a direct relationship with temperature increase. The authors reported that increased heating and exposure to sunlight leads to increased TDS of bottled water samples due to the release of heavy metal ions into the water.

S. P. Fitri et al. [5] conducted experiments on a reverse osmosis (RO) desalination plant equipped with a solar thermal collector. An increase in TDS levels was also observed due to an increase in TDS in the raw feed water after the heating process in the solar collector at 31°C, 35°C and 40°C, respectively. They concluded that the best results regarding the quality of the TDS water product, the amount of water produced and the ability to repel salt were obtained at lower temperature.

So, determining the TDS level as a function of water temperature is of interest not only in terms of the taste of drinking water [1, 4], but also the implications of increasing TDS in high–temperature water applications such as water boilers or other industrial processes [5].

According to the Romanian standard STAS 4706–88, given their use, surface waters (natural or landscaped watercourses, natural lakes and reservoirs) are classified into three quality categories, for which the TDS accepted levels are presented in table 1.

Table 1. TDS levels of surface waters in accordance with STAS 4706–88

Quality category	Designated use of surface water	TDS in ppm (mg/L)
I	centralized supply of drinking water and livestock units, food industry, certain irrigation, fish farming (for salmonids), swimming pools	750
II	industry, fish farming (except salmonids), leisure and urban needs	1000
III	irrigation, supplying hydropower plants, cooling aggregates, supplying washing stations	1200

In table 1, the TDS values were determined as dry filterable residue (fixed residue) at 105°C. The EPA recommends that the TDS level for drinking water be below 500 ppm (mg/L) [6]. At TDS levels greater than 1000 ppm (mg/L) water becomes unpalatable [6].

The TDS level in water can be determined with digital meters (conductivity method) [4, 7–10] or measured in the laboratory under standardized conditions (gravimetric method) [11]. Determinations made with digital meters have several advantages such as: quick direct on–site measurement, detects and provides the value of dissolved solids in a sample without involving further data processing or sample preparation, high degree of precision and accuracy [12].

This study aims to quantitatively determine the dependence between water temperature and total dissolved solids (TDS). TDS measurements were performed with a digital meter during heating the water sample on an electric hob. TDS and temperature variations with heating time were recorded at 1–minute intervals.

MATERIALS AND METHODS

In order to study the influence of the temperature on the TDS level in water, the water sample was collected from an unfiltered source, i.e. from a natural spring. This is because springs are known to have higher levels of TDS than other sources, e.g. tap water [1], and its dependence on temperature can be better observed in a laboratory experiment. So, a sample of 500 ml of spring water was heated in a beaker on an electric hob.

Figure 1 shows a photo of the experimental setup. A digital thermometer and TDS meter were used to measure the temperature of the water sample (in °C) and total dissolved solids (in ppm) during heating, at 1–minute intervals. The meters were suspended in the water sample using a tripod with a clamp so that the immersion level of the TDS meter was respected. The temperature sensor has been positioned at the same height.

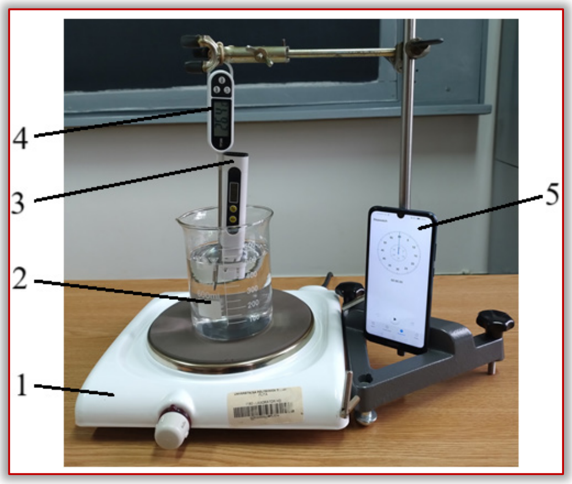

Figure 1. Photograph of the experimental setup: 1 – electric hob, 2 – beaker of 600 ml, 3 – digital TDS meter, 4 – thermometer, 5 – stopwatch.

The TDS meter works by measuring the electric current passing through the water sample between two titanium alloy electrodes, as an indicator of the number of ions existing. Electrical conductivity (in µS/cm) is converted to ppm units and displayed (conversion factor is 0.5 for NaCl standard calibration) [13].

A maximum heating temperature of 60°C was chosen due to the TDS meter's automatic temperature compensation range (ATC= 0÷60°C). At level 3 of 6 of the electric hob this temperature was reached after about 20 minutes of heating. This is the temperature up to which the TDS meter is calibrated to adjust the readings according to the temperature of the sample [2, 13].

The TDS meter adjusts readings taken at a certain temperature as if they were taken at a standardized temperature of 25°C [13].

RESULTS AND DISCUSSION

Table 2 shows the experimental results of temperature and TDS level in the water sample obtained as a function of heating time. Figure 2 and 3 show the graphical representation of these results.

In Figure 2, a polynomial trend line of order 4 (R^2 = 0.74) was used to best match the experimental values of TDS with the heating time, while in Figure 3, a linear trend line (R^2 = 0.97) proved to be the most suitable for the variation of water temperature over time.

Table 2. Experimental values

Time (min.)	TDS (ppm)	Temp. (ºC)
0	478	26.2
1	478	26.2
2	478	26.9
3	498	28.6
4	519	30.5
5	541	33.5
6	541	36.8
7	541	40
8	541	42.1
9	515	44.3
10	515	46
11	515	47.5
12	531	48.7
13	531	50
14	531	51
15	531	52.1
16	531	52.9
17	531	54.8
18	531	56.5
19	531	57.8
20	531	59.3

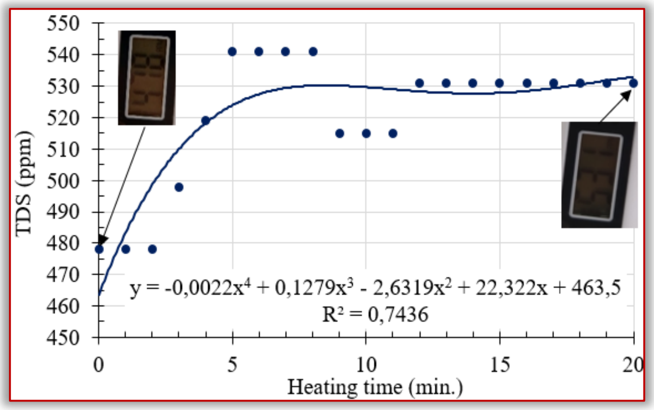

Figure 2. TDS variation vs. water sample heating time

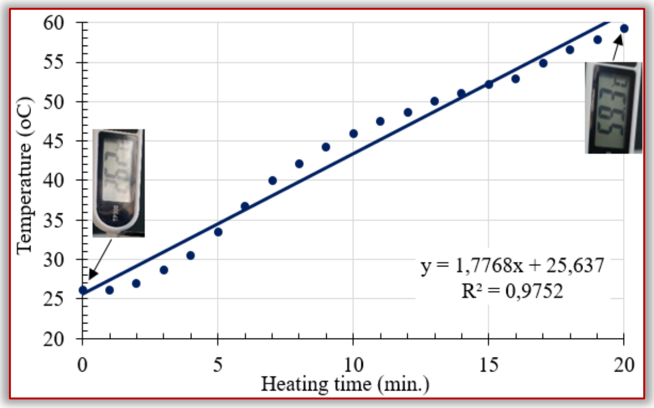

Figure 3. Temperature variation vs. water sample heating time

As can be seen from Figure 2, the TDS level in the water sample increases with heating time, from 478 ppm at 26.2°C to 531 ppm at 59.3°C. For the entire heating range, this represents a 10% increase in the TDS level (53 ppm for the entire range). A gap between 9 to 11 minutes of heating is observed, where the TDS level decreases, after which a constant value of 531 ppm is measured until the end of the experiment up to 20 min. After approx. 5 min. of heating, bubbles (dissolved oxygen and other gases) appeared in the volume of the water sample and probably adhered to the surface of the TDS meter electrodes that affected the readings.

Although constant mixing of the water sample was carried out during heating, the area near the electrodes was inaccessible. It is known that external factors, such as bubbles formed in the solution between the electrodes, can decrease TDS meter readings [13].

CONCLUSIONS

TDS level in water is a quality indicator which can be determined in standardized laboratory conditions by evaporation or by digital meters which are simple to use and reliable if are calibrated [7]. Certainly, high–precision measurements must be carried out under laboratory conditions.

Practical methods of removing TDS from water include: reverse and forward osmosis, nanofiltration, distillation, ultrafiltration, precipitation, desalination, electrocoagulation, ion exchange, electrochemical technologies, electrodialysis, adsorption, crystallization, and deionization [1, 14].

The proposed laboratory experiment aimed to quantitatively determine the direct proportional dependence between the TDS level in water and temperature, both measured with digital meters. Increasing the temperature from 26.2°C to almost 60°C, a 10% increase in the TDS level was observed.

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