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Assessment of pH and Total Dissolved Substances (TDS) in the Commercially Available Bottled Drinking Water

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Abstract: *This present paper deals with the pH and Total Dissolved solids (TDS) of the bottled drinking water. Due to rapid industrialization and over exploitation of ground water resources, there is a drastic change taking place in environment. Now a day's water pollution is a major problem. TDS correlates positively with conductivity and affects pH. The higher the TDS, the higher the conductivity and the lower the pH, towards the acidity. 14 domestic bottled water brands of Dhaka city, Bangladesh were analyzed for pH and TDS as water quality parameters. These parameters indicate the quality of drinking water. From the study of above parameters and observed that all the samples are in the permissible limits of Bangladesh Standards for drinking water and WHO guidelines for drinking water. So bottled water in Dhaka, Bangladesh is suitable for drinking.*

Keywords: *TDS, pH, Bottled Drinking Water*

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I. Introduction

pH is a measure of how acidic/basic water is. The range goes from 0-14, with 7 being neutral. pH of less than 7 indicate acidity, whereas a pH of greater than 7 indicates a base. pH is really a measure of the relative amount of free hydrogen and hydroxyl ions in the water. Water that has more free hydrogen ions is acidic, whereas water that has more free hydroxyl ions is basic. Since pH can be affected by chemicals in the water, pH is an important indicator of water that is changing chemically (1).

The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). For example, in addition to affecting how much and what form of phosphorus is most abundant in the water, pH also determines whether aquatic life can use it. In the case of heavy metals, the degree to which they are soluble determines their toxicity. Metals tend to be more toxic at lower pH because they are more soluble (1).

Excessively high and low pHs can be detrimental for the use of water. High pH causes a bitter taste, water pipes and water-using appliances become encrusted with deposits, and it depresses the effectiveness of the disinfection of chlorine, thereby causing the need for additional chlorine when pH is high. Low-pH water will corrode or dissolve metals and other substances (1).

Pollution can change a water's pH, which in turn can harm animals and plants living in the water. For instance, water coming out of an abandoned coal mine can have a pH of 2, which is very acidic and would definitely affect any fish crazy enough to try to live in it! By using the logarithm scale, this mine-drainage water would be 100,000 times more acidic than neutral water-so stay out of abandoned mines (1).

Total dissolved solids (TDS) is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogencarbonate, chloride, sulfate, and nitrate anions (2).

Water containing not less than 250 parts per million (ppm) total dissolved solids (TDS), coming from a source tapped at one or more bore holes or springs, originating from a geologically and physically protected underground water source, may be "mineral water." Mineral water shall be distinguished from other types of water by its constant level and relative proportions of minerals and trace elements at the point of emergence from the source, due account being taken of the cycles of natural fluctuations. No minerals may be added to this water [3].

Total Dissolved Solids (TDS) correlates positively with conductivity and affects pH. The higher the TDS, the higher the conductivity and the lower the pH, towards acidity.

The presence of dissolved solids in water may affect its taste [4]. The palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent, less than 300mg/L; good, between 300 and 600mg/L; fair, between 600 and 900 mg/L; poor, between 900 and 1200mg/L; and unacceptable, greater than 1200mg/L [4]. Water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste [4].

It is important to monitor the TDS level and the pH of drinking water for several reasons. When a water source has a high level of TDS or a low pH, it is likely that there are other harmful contaminants in the water. Both TDS and pH are also easy to measure and if something is happening to a water, such as pollution, chances are both TDS and pH levels will change so keeping track of those changes can act as an early warning signal that something is happening to the water. For these reasons, it is important to monitor the TDS and pH levels, so that if they change, action can be taken immediately [5]. For this reason we designed our study to assess pH and TDS levels of bottled drinking water in Dhaka, Bangladesh.

II. Materials and Methods

Materials

Study Setting and Design:

This study was carried out in at the Environmental Microbiology Laboratory, icddr,b in Dhaka, the capital city of Bangladesh. Dhaka is divided administratively into 2 city corporations, namely, Dhaka north and Dhaka south. It covers a total area of 306.38 square kilometers with a population of 8,906,039. Available sources of drinking water in the city include bottled water, piped water, wells, boreholes, and rivers. Safe drinking water is a major issue in Bangladesh. There are over 20 bottled water brands in Bangladesh and around 15 of them are in Dhaka. However, the common brands on market are 10-14.

Methods

Sample collection:

A total of 14 samples (42 bottles) of all the common brands of bottled water available on market during the months of July-August, 2017 were collected for this study. A total of 14 brands of bottled water were sampled. All samples were purchased randomly from several retail outlets and supermarkets in the selected trading centers of Dhaka. At the retail outlets, three samples of water of each brand and of the different batches were procured. All the samples were retained in their original sealed containers and clearly marked for identification with sample 1 to 42 water samples. They were transported to the Environmental Microbiology Laboratory, icddr,b, Dhaka.

pH Measurement:

Electrochemical method was used to measure pH of bottled drinking water by using pH meter of Thermoscientific, USA (model: Thermoscientific™ Orion™ 2-Star pH benchtop).

TDS Measurement:

TDS was measured by using TDS meter of HACH, USA (Model: sensION™+ EC71). This meter measures conductivity, salinity, TDS and temperature. Measurement data can be stored and transferred to a printer or PC. TDS is measured by using electrical conductivity of water. Electrical conductivity of water is directly related to the concentration of dissolved ionized solids in the water. Ions from the dissolved solids in water create the ability for that water to conduct an electric current, which can be measured using a conventional conductivity meter or TDS meter. When correlated with laboratory TDS measurements, conductivity provides an approximate value for the TDS concentration, usually to within ten-percent accuracy.

III. Results

From the Table-1 the pH values were found to be varied 6.54 to 8.22. As per Bangladesh standard for drinking water and WHO guidelines for drinking water the pH of drinking water in between 6.5 to 8.5. Obtained result lied between standard specifications. Basically, the pH value is a good indicator of whether water is hard or soft. The pH of pure water is 7. In general, water with a pH lower than 7 is considered acidic, and with a pH greater than 7 is considered basic. The normal range for pH in surface water systems is 6.5 to 8.5, and the pH range for groundwater systems is between 6 to 8.5. Alkalinity is a measure of the capacity of the water to resist a change in pH that would tend to make the water more acidic.

Table-1: pH levels in the samples

Sl. No.	pH Specifications (mg/L)		pH Results	Average
	Bangladesh Standard for Drinking Water (6)	WHO Guideline for Drinking Water (7)		
Sample 1	6.5-8.5	6.5-8.5	7.99	8.22
	6.5-8.5	6.5-8.5	8.41	
	6.5-8.5	6.5-8.5	8.25	
Sample 2	6.5-8.5	6.5-8.5	7.57	7.65
	6.5-8.5	6.5-8.5	7.63	
	6.5-8.5	6.5-8.5	7.74	
Sample 3	6.5-8.5	6.5-8.5	7.89	7.91
	6.5-8.5	6.5-8.5	8.00	
	6.5-8.5	6.5-8.5	7.84	
Sample 4	6.5-8.5	6.5-8.5	7.02	7.11
	6.5-8.5	6.5-8.5	7.18	
	6.5-8.5	6.5-8.5	7.14	
Sample 5	6.5-8.5	6.5-8.5	7.05	7.07
	6.5-8.5	6.5-8.5	7.04	
	6.5-8.5	6.5-8.5	7.12	
Sample 6	6.5-8.5	6.5-8.5	6.51	6.54
	6.5-8.5	6.5-8.5	6.55	
	6.5-8.5	6.5-8.5	6.55	
Sample 7	6.5-8.5	6.5-8.5	7.12	7.13
	6.5-8.5	6.5-8.5	7.01	
	6.5-8.5	6.5-8.5	7.26	
Sample 8	6.5-8.5	6.5-8.5	7.19	7.3
	6.5-8.5	6.5-8.5	7.41	
	6.5-8.5	6.5-8.5	7.29	
Sample 9	6.5-8.5	6.5-8.5	7.45	7.48
	6.5-8.5	6.5-8.5	7.43	
	6.5-8.5	6.5-8.5	7.55	
Sample 10	6.5-8.5	6.5-8.5	7.02	6.95
	6.5-8.5	6.5-8.5	6.89	
	6.5-8.5	6.5-8.5	6.95	
Sample 11	6.5-8.5	6.5-8.5	7.03	6.94
	6.5-8.5	6.5-8.5	6.67	
	6.5-8.5	6.5-8.5	7.11	
Sample 12	6.5-8.5	6.5-8.5	6.86	6.92
	6.5-8.5	6.5-8.5	6.85	
	6.5-8.5	6.5-8.5	7.06	
Sample 13	6.5-8.5	6.5-8.5	7.01	6.99
	6.5-8.5	6.5-8.5	7.06	
	6.5-8.5	6.5-8.5	6.89	
Sample 14	6.5-8.5	6.5-8.5	6.8	6.93
	6.5-8.5	6.5-8.5	6.67	
	6.5-8.5	6.5-8.5	7.31	

From the Table-2 the TDS values were found to be varied 10.99 to 317.29mg/L. As per Bangladesh standard for drinking water and WHO guidelines for drinking water the TDS of drinking water in between 1000mg/L and <1000mg/L respectively. Obtained result lied between standard specifications. Basically, the TDS value is a good indicator of whether water is happening or not. The TDS of pure water is 1000mg/L or <1000mg/L. In general, water with a TDS lower than 300 is considered excellent, and with a TDS greater than 1000 is unacceptable.

Table-2: TDS levels in the samples

Sl. No.	TDS Specifications (mg/L)		TDS Results	Average
	Bangladesh Standard for Drinking Water (6)	WHO Guideline for Drinking Water (7)		
Sample 1	1000	<1000	11.88	12.28
	1000	<1000	12.71	
	1000	<1000	12.24	
Sample 2	1000	<1000	22.20	24.04
	1000	<1000	26.40	
	1000	<1000	23.52	
Sample 3	1000	<1000	11.92	10.99
	1000	<1000	2.53	
	1000	<1000	18.52	
Sample 4	1000	<1000	122.81	114.06

	1000	<1000	109.14	
	1000	<1000	110.23	
Sample 5	1000	<1000	84.47	83.86
	1000	<1000	76.78	
	1000	<1000	90.33	
Sample 6	1000	<1000	59.19	61.92
	1000	<1000	71.37	
	1000	<1000	55.21	
Sample 7	1000	<1000	112.16	110.51
	1000	<1000	102.84	
	1000	<1000	116.54	
Sample 8	1000	<1000	87.87	88.85
	1000	<1000	90.53	
	1000	<1000	88.15	
Sample 9	1000	<1000	23.06	22.90
	1000	<1000	22.13	
	1000	<1000	23.50	
Sample 10	1000	<1000	214.54	194.47
	1000	<1000	192.32	
	1000	<1000	176.56	
Sample 11	1000	<1000	10.49	12.37
	1000	<1000	12.84	
	1000	<1000	13.78	
Sample 12	1000	<1000	140.09	170.19
	1000	<1000	180.23	
	1000	<1000	190.24	
Sample 13	1000	<1000	92.45	91.91
	1000	<1000	83.78	
	1000	<1000	99.51	
Sample 14	1000	<1000	324.53	317.29
	1000	<1000	340.22	
	1000	<1000	287.12	

IV. Discussion

The indicator for acidity and alkalinity is known as the pH value. A pH value of 7 means a substance is neutral. The lower value indicates acidity, and a higher value is a sign of alkalinity. To better understand the range in pH, take a look at these examples: apple juice 3, orange juice 3.5, coffee 5.5, milk 6.2, baking soda 8.5, soapy water 10, bleach 12 [(8)].

Basically, the pH value is a good indicator of whether water is hard or soft. The pH of pure water is 7. In general, water with a pH lower than 7 is considered acidic, and with a pH greater than 7 is considered basic. The normal range for pH in surface water systems is 6.5 to 8.5, and the pH range for groundwater systems is between 6 to 8.5. Alkalinity is a measure of the capacity of the water to resist a change in pH that would tend to make the water more acidic. The measurement of alkalinity and pH is needed to determine the corrosiveness of the water [(8)].

Consuming excessively acidic or alkaline water is harmful, warns the Environmental Protection Agency (EPA). Drinking water must have a pH value of 6.5-8.5 to fall within EPA standards, and they further note that even within the acceptable pH range, slightly high- or low-pH water can be unappealing for several reasons [(8)].

High-pH water has a slippery feel, tastes a bit like baking soda, and may leave deposits on fixtures, according to the EPA website. Low-pH water, on the other hand, may have a bitter or metallic taste, and may contribute to fixture corrosion [(8)].

Wilkes University points out a further problem associated with drinking water and pH: High-pH water is often hard. They note that hard water "does not pose a health risk, but can cause aesthetic problems." Among problems associated with hard water, they list formation of scale on fixtures, a bitter flavor, difficulty getting soaps to lather, and decreased water-heater efficiency. They suggest that water can be softened with ion-exchange water-softening devices [(8)].

According to a Wilkes University study, the association of pH with atmospheric gases and temperature is the primary reason why water samples should be tested on a regular basis. The study says that the pH value of the water is not a measure of the strength of the acidic or basic solution, and alone cannot provide a full picture of the characteristics or limitations with the water supply [(8)].

While the ideal pH level of drinking water should be between 6-8.5, the human body maintains pH equilibrium on a constant basis and will not be affected by water consumption. For example, our stomachs have a naturally low pH level of 2 which is a beneficial acidity that helps us with food digestion [(9)]. Our pH results were found in between 6.54 to 8.22 and as per scientific backgrounds our results were satisfactory.

Since the beginning of time, water has been both praised and blamed for good health and human ills. We now know the real functions of water in the human body are to serve as a solvent and medium for the transport of nutrients and wastes to and from cells throughout the body, a regulator of temperature, a lubricator of joints and other tissues, and a participant in our body's biochemical reactions. It is the H_2O in water and not the dissolved and suspended minerals and other constituents that carry out these functions. TDS is a measure of the combined content of all inorganic and organic matter which is found in solution in water. Water low in TDS is defined in this paper as that containing between 1-100 milligrams per liter (mg/L) of TDS. This is typical of the water quality obtained from distillation, reverse osmosis, and deionization point-of-use water treatment of public or private water supplies that are generally available to consumers in the world. Worldwide, there are no agencies having scientific data to support that drinking water with low TDS will have adverse health effects. There is a recommendation regarding high TDS, which is to drink water with less than 500mg/L. Some people speculate that drinking highly purified water, treated by distillation, reverse osmosis, or deionization, "leaches" minerals from the body and thus causes mineral deficiencies with subsequent ill health effects [10]. Our results showed that 9 of 14 samples contained <100mg/L, 2 of 14 samples contained <150mg/L, 2 of 14 samples contained <200mg/L and 1 of 14 samples contained <350mg/L.

An isolated report, a summary of Russian studies available through the World Health Organization, has recommended that fluid and electrolytes are better replaced with water containing a minimum of 100mg/L of TDS. However, this may pertain more to situations in the human body during heavy exertion and sweating. This situation does not have anything to do with low TDS or demineralized water for normal drinking and cooking purposes. Even in warm weather exercise, the greatest danger is that of dehydration, and the proper advice to ward it off is to drink lots of plain water. It is the market for sports drinks which are formulated to help replace the sugar compounds, glucose in the blood and glycogen in the muscles that are burned in prolonged exercise. Sports drinks are formulated to help replace the sugar compounds-glucose in the blood, glycogen in the muscles and electrolytes-salt, calcium, and potassium that keep cells in proper electrolytic balance-that may be burned and depleted after an hour or more of hard exercise [10]. Our result showed that 5 of 14 samples contained minimum 100mg/L of TDS.

The scope of this paper is limited to answering whether low TDS water contributes to the loss of minerals from body tissues, producing associated harmful side effects. The types of minerals-e.g., calcium versus sodium, or hard water versus soft water and the toxicity of minerals e.g., lead, cadmium, brackish, or saline waters are not an issue in this report. Information on the body's homeostasis mechanisms, community water supplies with natural TDS less than 50mg/L, historic use of distilled water with less than 3mg/L TDS on board Navy ships, the US Environmental Protection Agency's (USEPA) response to this issue, and other evidence are presented to demonstrate that the consumption of water with low levels of minerals is safe [10].

The US Navy has used distilled sea water for human consumption for approximately 40 years. 3 TDS levels below 3mg/L have been reported and consumption of this water for months at a time is common on submarines. No health problems have been reported by the Navy. The US Army uses reverse osmosis units to provide drinking water for soldiers in the field. The USEPA conducted a project in San Ysidro, New Mexico in which the TDS was dropped from 800mg/L to a range of 40 to 70mg/L. No health effects were observed. NASA has reported no ill effects from the consumption of approximately 0.05mg/L TDS water on board space craft [11].

Homeostasis is the maintenance of static or constant conditions in the internal body environment. This natural process controls the mineral (ion) and the water concentrations in the body fluids within narrow limits inside and outside all the cells in all the organs and tissues of the body. The kidneys are most important in maintaining constant ion concentrations (including sodium, potassium, calcium, etc.) through elimination and reabsorption. In homeostasis, three body fluids are involved: plasma (approximately 3/5 of the blood volume); interstitial fluid (the fluid between cells); and intracellular (fluid inside the cells). The concentration of sodium ions is highest outside the cell and that of potassium ions is highest inside the cell. When the osmotic pressure is high on one side of the cell membrane (high concentration of ions) and low on the other side, water moves across the cell membrane from the dilute side toward the other side to equalize the osmotic pressure. This phenomenon is known as osmosis. This is unlike reverse osmosis which occurs when outside pressure is applied to the concentrated side, pushing the water back to the dilute side. The normal osmolality (concentration of ions) of all these fluids is about 300 milliosmoles per liter (mOsm/L), or 9,000mg/L. Any changes from normal in ion concentration across the cell membrane is corrected in one minute or less because water moves quickly through cell membranes. Thus, small changes in osmolality from drinking purified water (0-100 mg/L TDS) are quickly brought to equilibrium [10].

The kidneys control the overall concentration of the constituents of body fluids. It filters about 180 liters (165 quarts) of water per day, but over 99% is reabsorbed and only 1.0-1.5 liters are eliminated as urine. If the osmolality of the fluid to be filtered by the kidney is lower than normal (low solute concentration-such as low TDS water) nervous and hormonal feedback mechanisms cause the kidney to excrete more water than normal and thus maintain the ion concentration in the body fluid to normal values. The opposite is true if the ion concentration of the fluid to be filtered is higher than normal. This kidney homeostatic mechanism keeps the body fluid osmolality normal. The osmolality of the fluid to be filtered by the kidney is controlled to ± 3% to maintain it at the normal level of 300mOsm/L. The three basic hormonal and nervous control systems triggered by abnormal ion concentration in the body fluids to be filtered by the kidney are antidiuretic hormone (ADH) from the pituitary gland, aldosterone from the adrenal glands, and thirst (as osmolality rise of about 1% causes thirst) (10).

Because of these kidney control mechanisms, drinking one liter of water would cause the urine output to increase about nine times after about 45 minutes (due to absorption of water in the gut) and continue for about two hours. Thus, the concentrations of solutes in the blood and other body fluids are quickly maintained by the kidney through homeostasis. These control mechanisms keep the sodium concentration at ±7%. Calcium secretion is controlled by Parathyroid hormone to ± a few percent in the extracellular body fluid. Also, saliva increases the ion concentrations during water intake. The concentration of sodium chloride in saliva is typically 15 milliequivalents per liter (mEq/L) or 877mg/L; that of potassium ion is about 30mEq/L (1170mg/L). As low TDS water is consumed, it is combined with saliva which increases the TDS before it reaches the gut to be absorbed, (e.g., each one mL of saliva can increase the TDS level in eight ounces of water consumed by about 10mg/L) (10).

Therefore, it is evident that consumption by a healthy person of low TDS water alone cannot cause unhealthy systems. 'Healthy person' means free of disease, hormonal problems, etc., and not necessarily a healthy diet. Homeostasis is maintained by diet as are other body functions. If homeostasis is not maintained because of major diet deficiencies, disease, or hormonal dysfunction, consuming low TDS water would be a minor (if any) factor in any observed symptoms. It is apparent that disease, physiological dysfunction, or major nutritional deficiencies may cause a "leaching" problem, but not consuming one to two liters of low TDS water on a daily basis (12). Our results showed that maximum samples contained low TDS and scientific databases supported that our samples are qualitatively fit for drinking.

V. Conclusion

It was observed that the bottled drinking water samples were found qualitatively okay during our study. The pH and TDS of the bottled drinking water samples were found within the permissible limits so this water is suitable for drinking purposes and in case of TDS 64% samples contained low amount of TDS that means <100mg/L..

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