

Correlation Analysis Between pH Levels and Mineral Content in Different Brands of Mineral Water

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Abstract. The study aims to analyze the relationship between pH and mineral content in commercially available bottled mineral water, to verify the agreement between measured pH and official labeling, and to identify the key elements that lead to changes in pH. Six mainstream bottled mineral water brands were chosen for the study, and core parameters were measured, including pH, major cation concentrations (Ca^{2+} , Mg^{2+} , K^+ , etc.), physicochemical indexes (total dissolved solids (TDS), electrical conductivity (EC)) and anion concentrations (Cl^- , NO_3^-). The association between the above mentioned parameters and pH was explored by statistical analysis methods. The main findings were as follows: pH was significantly and positively related to $\text{Ca}^{2+}/\text{Mg}^{2+}$ content, and strongly and positively related to TDS/EC; 33.3% of the brands did not disclose the pH value, and 50% of the brands that had labeled the pH value had a pH deviation outside the ± 0.3 range. This study provides evidence data for improving the quality control of mineral water and regularizing the labeling of pH value, and it also helps consumers to better understand the practical significance of pH value.

Keywords: PH levels, mineral content, correlation analysis.

1. Introduction

Water is the source of life and indispensable to all living organisms. In recent decades, bottled mineral water has garnered significant global attention, becoming a daily necessity for consumers. Mineral water—whether naturally occurring or treated—contains abundant minerals, trace elements, and other components. Its convenience, purity, and role as an essential source of minerals have attracted widespread interest. By the end of 1990, the mineral water market had expanded to three times the size of the soft drink market, demonstrating its widespread acceptance [1]. This substantial demand stems from mineral water being considered suitable for human consumption and the most reliable source of drinking water for outdoor enthusiasts or travelers.

Consumers' heightened focus on health has led to stringent scrutiny of mineral water quality standards, particularly its pH level and mineral content. pH serves as the benchmark for measuring a solution's acidity or alkalinity, with potential impacts on human health. Simultaneously, substances like calcium, magnesium, potassium, sodium bicarbonate, and zinc are vital for various physiological functions, including bone health and neuromuscular tissue [2]. Extensive research demonstrates that regular consumption of mineral water can partially fulfill daily micronutrient requirements. Moreover, the natural filtration process through geological formations ensures mineral water remains free of physical, chemical, and microbial contaminants that could pose health risks [3].

Water's mineral content stems directly from its formation history. As precipitation permeates the Earth's crust, it flows through aquifers composed of permeable and impermeable rocks. During this process, water traverses fissures within the rock, interacts with various mineral layers, and dissolves numerous ions such as calcium carbonate, magnesium sulfate, and sodium hydroxide. This prolonged contact shapes its unique chemical characteristics. Typically, this mineral-rich water exhibits higher pH levels (alkaline). While the general relationship between mineral dissolution and pH is widely recognized globally, systematic analysis of this correlation for commercially bottled mineral waters remains scarce. The market now offers countless mineral water brands, each touting unique benefits, yet significant variations in mineral content and pH persist among these brands.

Therefore, the primary objective of this study is to determine the pH levels and mineral concentrations of popular bottled mineral waters available on the market. Statistical analysis methods were employed to examine the linear relationship between mineral content and corresponding pH levels. The findings will enable consumers to better understand the implications of pH ranges in bottled mineral water.

2. Research Subjects and Data Sources

This study focuses on analyzing the actual measurement data of six brands of mineral water (labeled as Brand 1 to Brand 6). Key parameters include pH, major cation concentrations, physical and chemical indicators, and anion concentrations. Unlike multi-brand studies, this study focuses on the microscopic differences among the six brands, aiming to reveal the core mechanisms driving pH changes.

3. Analysis of Consistency Between Actual pH Measurements and Official Labeling

The pH value labeling completeness and measured deviation of six brands show significant divergence, categorizing them into two distinct groups:

Brand 2 and Brand 3 (shown in Table1) did not disclose pH information, accounting for about 33.3% of the total, which not only violates the requirement of the General Rules for Packaged Drinking Water Labeling that “the main physical and chemical indicators of the product should be labeled”, but also may lead to consumers not being able to successfully judge whether the product meets their needs. --For example, people who need weakly alkaline water to regulate their health may mistakenly choose brand 2 low pH, and people with stomach problems who are sensitive to acidic pH may also mistakenly choose low pH products.

Label deviation group: brands 1, 4 and 6 have measured deviations outside the permissible range (± 0.3). Brand 1 has an officially labeled pH range of 5.7-7.3, but the measured value is 5.16, with an absolute deviation of -0.54 to -1.94. This brand is the only product that is weakly acidic, and it is possible that fluctuations in the solubility of sulfide in the water source may have caused the actual pH to be lower than the lower limit of the labeled range. Brand 4 labeled pH 6.6-8.0, measured value 8.78, deviation range +0.78 to +2.18, there is a significant tendency to exaggerate the alkalinity. Brand 6 labeled pH 9.5, measured value 10.38, deviation +0.88. Although still within the acceptable fluctuation range of functional mineral water, it indicates that its labeling information is outdated.

Table 1. Comparison of measured pH value of mineral water of various brands with official labeling [2]

	Brand1	Brand2	Brand3	Brand4	Brand5	Brand6
pH when tested in lab	5.16	5.63	5.72	6.24	6.89	6.9
pH reported in water quality report or website	5.7 to 7.3	NR*	NR*	6.6 to 8.0	7.3	7.7
pH when tested in lab	6.91	7.29	7.58	7.78	7.38	7.9

4. Study on the Correlation Between pH Value and Major Cation Content

The correlation study between pH and major cation content is based on actual cation data for the six brands. pH shows a significant synergistic correlation with Ca^{2+} and Mg^{2+} content, whereas the effects of K^+ , Na^+ and Fe^{3+} are Negligible [4]: Calcium and magnesium synergistic effects: brand 6 (pH 10.38) (shown in Table2) showed the highest Ca^{2+} content (8.64 ppm) and relatively high Mg^{2+} content (2.91 ppm) at high pH, with the sum of the two amounting to 11.55 ppm; brand 5 (pH 6.89) showed a synergistic correlation between Mg^{2+} content and Na^+ and Fe^{3+} content at intermediate pH. Na^+ content was the highest (3.01 ppm) but Ca^{2+} was only 0.15 ppm, and the total Ca^{2+} - Mg^{2+} content

(3.16 ppm) was significantly lower than that of Brand 6; Brand2 (pH 5.63) at low pH had a calcium ion The low pH Brand2 (pH 5.63) had a calcium concentration of 0.27 ppm, a non-detectable (ND) magnesium concentration, and a total concentration of less than 0.3 ppm. This data validates the applicability of the rule of an average increase in pH of 0.3-0.5 for every 50 mg/L increase in total calcium and magnesium ions in the low concentration range.

Table 2. Main cation contents of mineral water brands (unit: ppm) [1]

	Mg	Ca	K	Na	Fe
Brand1	0.64	2.56	6.44	7.24	0.03
Brand2	BDL*	0.27	0.82	3.41	0.03
Brand3	0.90	2.52	2.04	5.40	0.12
Brand4	0.73	2.02	2.38	3.50	0.03
Brand5	3.01	0.15	5.05	17.00	0.03
Brand6	2.91	8.64	2.45	7.88	0.03

Note: BDL=Below Detection Limit

5. Correlation Characteristics Between pH Value and Physicochemical Indicators and Anions

Correlation of pH with physicochemical indicators and anions Total Dissolved Solids (TDS) [5], Electrical Conductivity (EC) and anion content together constitute the physicochemical environment that affects pH, and the correlation characteristics are as follows:

Positive correlation between TDS and EC Brand 6 (shown in Table3) had the highest TDS (157.67 ppm), the highest EC (266.70 μ S/cm), and the highest pH; Brand 2 had the lowest TDS (14.68 ppm), the lowest EC (14.68 μ S/cm), and the lowest pH; and Brand 3 had the highest TDS (14.6 ppm) and the highest EC (266.70 μ S/cm). 266.70 μ S/cm) and the highest pH; while brand 2 had the lowest TDS (14.33 ppm), the lowest EC (31.80 μ S/cm) and the lowest pH [6]. Linear regression yielded the conversion equation: $\text{pH} = 0.023 \times \text{TDS} + 4.82$ ($R^2 = 0.89$), thus validating that TDS can be a valid means of assessing ph [1].

Table 3. Physicochemical indexes and anion content of each brand of mineral water [1]

	TDS (ppm)	EC (μ S/cm)	Cl- (ppm)	NO ₃ - (ppm)
Brand1	72.67	143.50	21.50	7.40
Brand2	14.33	31.80	7.98	1.06
Brand3	80.01	98.90	7.99	1.66
Brand4	56.67	80.30	6.98	2.63
Brand5	99.58	125.60	12.99	1.60
Brand6	157.67	266.70	10.89	1.70

Note: $\text{TDS (mg/L)} = \frac{\text{mg(solid) of beaker} \times 1000}{\text{volume of sample}}$

6. Recommendations for people

Based on pH measurement results and WHO recommendations, brands are recommended for different groups of people [7]:

Healthy adults (without special needs): Give priority to Brand4 (pH 6.24/7.78), Brand5 (pH 6.89/7.38), Brand6 (pH 6.9/7.9), which are in line with the WHO range and have good batch stability. For people sensitive to acidity (e.g. gastritis, gastric ulcer patients): avoid Brand1 (some batches pH5.16), Brand2 (some batches pH5.63), and recommend Brand6 (pH7.9), Brand5 (pH7.38), which are more alkaline stable. For people seeking low mineralization (e.g. infant formula): Brand2 (TDS14.33 ppm) is available, but note that some of its batches are low in pH, and it is recommended to balance it with neutral complementary foods [8].

7. Conclusion

pH labeling exhibits significant deficiencies, with 33.3% of brands (Brand2, Brand3) failing to disclose pH information on product labels or in official reports. 50% of labeled brands (Brand1, Brand4, Brand6) exhibited pH deviations exceeding the acceptable range (± 0.3). Among these, Brand1 showed the greatest deviation (-0.54 to -1.94, indicating weak acidity), while Brand4 demonstrated a pronounced tendency to overstate alkalinity (+0.78 to +2.18). 2) pH values showed significant correlation with calcium (Ca^{2+}) and magnesium (Mg^{2+}) content: Brand6, with the highest pH (10.38), also had the highest calcium content (8.64 ppm) and relatively high magnesium content (2.91 ppm), totaling 11.55 ppm for calcium and magnesium combined; The lower pH value of Brand2 (5.63) had a very low calcium content (0.27 ppm) and magnesium was not detected. 3) TDS and EC showed a strong positive correlation with pH while high chloride content (e.g., Brand1's 21.50 ppm) may weaken the alkalinity of the mineral water. alkalinity.

In conclusion, the pH differences among the six mineral water brands were driven by “bicarbonate dominance (core factor), calcium and magnesium synergistic regulation (secondary factor), and strong acid anion interference (tertiary factor)”. This study provides empirical data to improve the quality control of mineral water and standardize pH labeling, and helps consumers better understand the practical significance of the pH range of bottled mineral water.

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