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Original research article

Physical and chemical properties of bottled drinking water in the Mandalay Region, Myanmar: A preliminary study

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ABSTRACT

A total of fifty-five samples of bottled drinking water (BDW) were collected from different retail shops in the Mandalay Region, Myanmar, to determine the safety aspects of physical and chemical properties of bottled drinking water in Mandalay. Collected samples were analyzed for pH, turbidity, total alkalinity (as $CaCO_3$), bicarbonate alkalinity (HCO_3^-), total hardness (as $CaCO_3$), sulfate (SO_4^{2-}), chloride (Cl^-), sodium chloride (NaCl), lead (Pb), and arsenic (As). The pH was determined by a Hanna instruments HI 98129 pH meter which was calibrated at pH 4.0, 7.0 and 9.0. Turbidity was measured by spectrophotometry at the wavelength of 455 nm. Total hardness as $CaCO_3$ concentration was determined by EDTA titrimetric method APHA 2340 C. Total alkalinity, sulfate, chloride (Cl^- and NaCl) concentrations were determined by APHA 2320 B, 4500-SO_4^{2-} C and 4500-Cl^- B, respectively. Lead concentration in BDW was determined by atomic absorption spectroscopy (AAS) and arsenic (As) was determined by a Lovibond Arsenic Test Kit (Part Number 400700). The pH values of BDW samples were found to be within WHO and National (Myanmar) Drinking Water Standards expect for three samples (S-40, S-51 and S-55) which were found in slightly acidic condition. Total hardness values ranged from 0.21 mg/L to 20.2 mg/L as $CaCO_3$. Sulfate concentrations ranged from 3.3 mg/L to 9.5 mg/L as SO_4^{2-}. Chloride and sodium chloride concentrations ranged from 1.44 mg/L to 14.58 mg/L as Cl^- and 5.8 mg/L to 24.1 mg/L as NaCl, respectively. Very low concentrations of heavy metals such as lead (Pb) and arsenic (As) were found in all collected BDW samples. In this study, the overall results showed that all collected bottled drinking water samples in Mandalay were found within WHO and Myanmar National Drinking Water Standards and to be physical and chemically safe for drinking.

Keywords: bottled water, physico-chemical analysis, heavy metals, food safety

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https://li01.tci-thaijo.org/index.php/JBAP

1. Introduction

Water is a useful resource for domestic, industrial and agricultural purposes and it plays a vital role in the body's metabolism and for the proper functioning of its cells.[1] Water covers most of the earth's surface and it makes up most of the human body; this illustrates the critical linkages between water, health and ecosystems.[2] Approximately 60% of the human body is composed of water. Although 75% of the earth's surface is covered by water, only 1% of that is drinkable.[3] Bottled water is the most popular beverage in the world, and sales continue to grow.[4] Consumption of bottled water is increasing by ten percent every year worldwide, with the fastest growth seen in the developing countries of Asia and South America.[5] This increase in consumption of bottled water can be attributed to the claims about its higher quality compared to tap water and its health benefits.[4] The evaluation of water quality has gained worldwide attention because the majority of diseases that cause morbidity and mortality are water related. Over at least the past two decades, there has been increased concern regarding the quality of tap water due to pollution and its undesirable taste and odor.[6] Although people consider bottled water safe, it can also be contaminated with chemical and biological agents.[7] The chemical quality of drinking water during recent years has deteriorated considerably due to the presence of toxic elements, which even in trace amounts can cause serious health hazards.[8]

The 2019 the Intercensal Survey provided the first large-scale review of the safety of drinking water through testing for fecal contaminants. There are still many unknowns however, including the presence of heavy metal contaminants such as arsenic in households' drinking water in some area of Myanmar.[9] The availability of safe drinking water depends on reservoirs, communal ponds, private collection of rainwater and groundwater. Future socio-economic perspectives and the associated pressure these have on water, need to be taken into account.[10] According to a UN/WHO report (2014), water treatment at home is estimated to be carried out by 34.5% of the population: treatment by cloth is carried out by 76.2%, boiling by 1.4%, and water filtration by 0.6%. It is also estimated that 12.2% of the population does not use water treatment, and unsafe drinking water coverage is 33.1%. These figures show that water treatment is inadequate and that water safety plan follow up actions need to be promoted in Myanmar.[11]

The habit of drinking bottled water has also reached Myanmar and the bottled water industry has grown substantially over the past decades.[7] According to the 2021 data of the Food and Drug Administration, 1138 bottled drinking water companies were situated in Myanmar. More than 250 bottled drinking water production companies are situated in the Mandalay Region (Fig. 1). Public belief is that bottled water is free from germs and unhealthy entities. As bottled water is marketed by various companies, it is essential to check whether these waters are really safe for public health or not.[1] In addition to concerns about the safety of bottled water, the adverse environmental health and social impacts associated with bottled water production, distribution, consumption, and reliance are considerable.[12] A study of water quality in Yangon, Myanmar, found that 13 samples were contaminated with *E. coli*, and 18 samples were contaminated with coliform bacteria, in a total of 19 tap water samples. Five samples from a total of 7 bottled drinking water samples were contaminated with *E. coli* and 6 samples were contaminated with coliform bacteria.[13] Another study of bottled water quality in Myanmar (2019) found that of the 19 brands tested, 37% were contaminated and unsafe to drink.[14] Due to increased public concern about the quality of bottled drinking water, the objective of this study is to evaluate the quality of BDW sold in Mandalay, Myanmar.

This study also aims to obtain physical and chemical status and to determine the drinking water safety of selected bottled water brands in Mandalay.

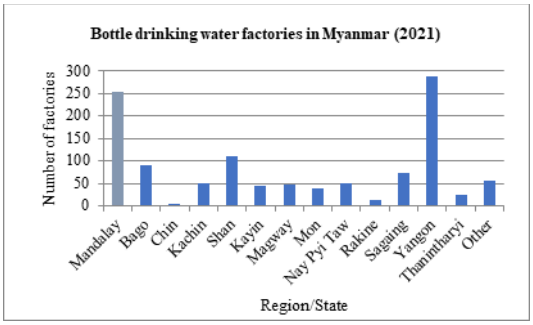

Fig. 1. Number of bottled drinking water factories in Myanmar (2021).

2. Materials and Methods

2.1 Sample Sites and Collection

Difference brands of a total of fifty-five bottled drinking water samples (S = 55; S1 to S55) were collected from different retail shops in Mandalay, Myanmar. The samples were bought as 0.5-liter, 0.6 liter and 1 liter polyethylene terephthalate (PET) packaged bottles and analyzed for physical and chemical properties of the water. Collected BDW samples were analyzed by WHO Drinking Water Standard[16] and Myanmar National Drinking Water Quality Standard (MNDWQS)[17] recommended standard method; standard methods for the examination of water and wastewater (APHA).[15]

2.2 Physical and Chemical Analysis

The collected BDW samples' pH, turbidity, total alkalinity (as $CaCO_3$), bicarbonate alkalinity (HCO_3^-), total hardness (as $CaCO_3$), sulfate (SO_4^{2-}), chloride (Cl^-), sodium chloride (NaCl), lead (Pb), and arsenic (As) were determined. The pH was measured with a Hanna instruments HI 98129 pH meter calibrated for pH 4.0, 7.0 and 9.0. Turbidity was measured by spectrophotometry at the wavelength of 455 nm. Total hardness as $CaCO_3$ concentration was determined by EDTA titrimetric method APHA 2340 C.[15] Total alkalinity, sulfate, chloride (Cl^- and NaCl) concentrations were determined by APHA 2320 B, 4500-SO_4^{2-}C and 4500-Cl^- B, respectively.[15] Lead concentration in BDW was determined by Atomic Absorption Spectroscopy (AAS) and arsenic (As) was determined by Lovibond Arsenic Test Kit (Part Number 400700). For drinking purposes, results were compared with the WHO Drinking Water Standard[16] and the Myanmar National Drinking Water Quality Standard MNDWQS).[17]

Table 1. Drinking Water Quality Standards.

Water Quality Parameters*	Standards	
	WHO	MNDWQS
pH	6.5-8.5	6.5-8.5
Turbidity (NTU)	≤5	≤5
Total Hardness	N/A	500
Total Alkalinity	N/A	N/A
Bicarbonate Alkalinity	N/A	N/A
Sulfate	≤250	≤250
Chloride	≤250	≤250
Sodium Chloride	N/A	N/A
Lead	≤0.01	≤0.01
Arsenic	≤0.01	≤0.05

*All units are in mg/L or ppm except for pH and turbidity (Nephelometric Turbidity Unit; NTU).

3. Results and Discussion

3.1 Physical Properties

The pH of the BDW samples varied between 5.7 and 7.6 and were within WHO and National Drinking Water Standards (6.5-8.5) except for S-14 (6.40), S-40 (5.90), S-51 (5.70) and S-55 (5.80). The results are shown in Fig. 2. The turbidities of the BDW samples were all found to be within the standard value (≤5 NTU).

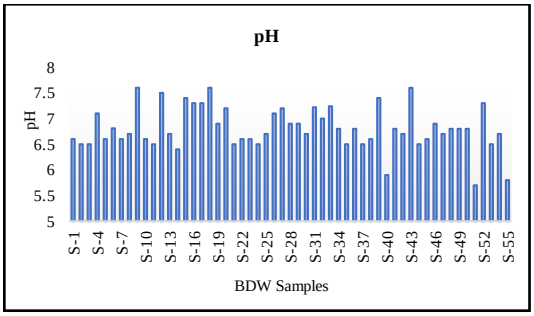

Fig. 2. pH values of BDW samples.

3.2 Chemical Properties

According to the WHO water hardness classification, all of the collected samples were found to be very soft. Total hardness values as $CaCO_3$ ranged from 0.21 mg/L to 20.2 mg/L and all BDW samples were found to be within the WHO and National Drinking Water Standards ($\leq$ 500 mg/L). The results are shown in Fig. 3. Total alkalinity as $CaCO_3$ concentration ranged from 9 mg/L to 52 mg/L. The results are shown in Fig. 4. Bicarbonate alkalinity as HCO_3^- concentration ranged from 9 mg/L to 52 mg/L. Low concentrations of bicarbonate were found in all BDW samples and the results are shown in Fig. 5. The amount of measured divalent metal cations is what is referred to as water hardness. Only two divalent cations; dissolved calcium (Ca^{2+}) and dissolved magnesium (Mg^{2+}) can be found in significant amounts in most fluids. Both calcium and magnesium are primarily found in natural water linked to bicarbonate, sulfate, or chloride. Bicarbonate changes to carbonate and precipitates with Ca^{2+} to produce calcium carbonate ($CaCO_3$) scale when hard water evaporates or is heated.[18] Potentially useful nutrients and minerals for human health include calcium, magnesium, and sodium. Magnesium prevents cardiovascular disease, potassium is good for muscles and the brain system, and calcium may help with bone development.[19] Additionally, studies have shown that drinking hard water can help prevent conditions including osteoporosis, cancer, diabetes mellitus, low birth weight, and impaired cognitive function in the elderly.[20] Low magnesium status has been associated with hypertension, coronary heart disease, type 2 diabetes mellitus, metabolic syndrome, increased vascular reactions, elevated circulating levels of C-reactive protein (a proinflammatory marker that is a risk factor for coronary heart disease), and decreased insulin sensitivity. When consumed in excess, magnesium salts may temporarily alter bowel habits (diarrhea), although they rarely result in hypermagnesemia in people with normal renal function. Increasing calcium consumption increases bone mass during childhood and lowers bone loss and fracture risk later in life, according to a vast body of primary research from randomized controlled trials, especially in people who have traditionally had low calcium intakes. The majority of people who should be concerned about excessive calcium consumption are those who are predisposed to milk alkali syndrome, which is characterized by the coexistence of hypercalcemia, metabolic alkalosis, and renal insufficiency. Although calcium can interact with minerals like iron, zinc, magnesium, and phosphorus in the intestine to inhibit their absorption, the evidence at hand does not indicate that these minerals are depleted when people consume calcium-rich diets over the recommended amounts.[21]

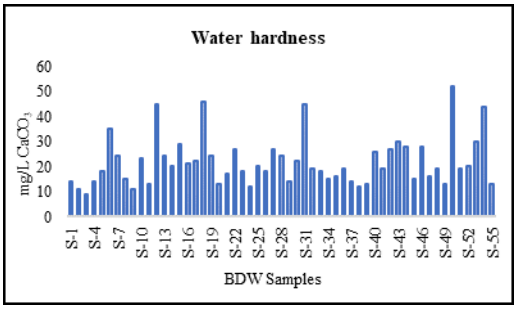

Fig. 3. Total hardness of BDW samples.

Table 2. WHO total hardness classification.[16]

Total hardness	Classification
< 60 mg/L	Soft
60-120 mg/L	Moderately Hard
120-180 mg/L	Hard
More than 180 mg/L	Very Hard

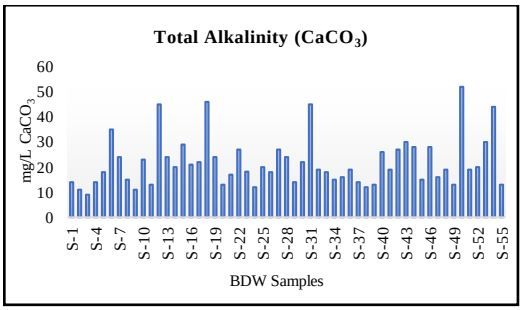

Fig. 4. Total alkalinity of BDW samples.

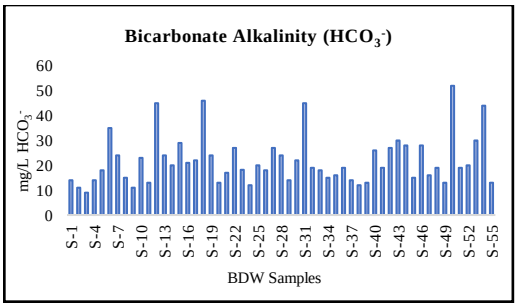

Fig. 5. Bicarbonate Alkalinity of BDW Samples.

Sulfate concentrations varied from 7.2 mg/L to 9.5 mg/L and the results were found to be within the WHO (≤ 250 mg/L) and Myanmar National Drinking Water Standards (≤ 250 mg/L). The results are shown in Fig. 6. The presence of sulfate in drinking water has given rise to a number of health issues, including the possibility that diarrhea could be brought on by consuming water with high sulfate concentrations.[20] Sulfates have a bitter taste when mixed with other ions, and high quantities of them have a purgative effect.[22]

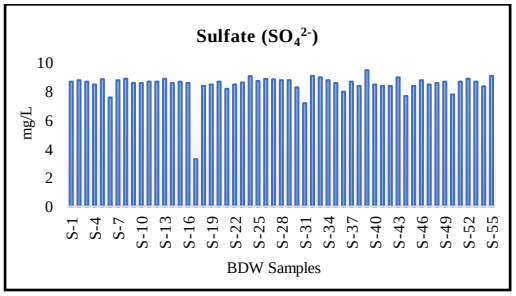

Fig. 6. Sulfate concentrations in BDW samples.

Chloride as Cl^- concentrations varied from 3.5 mg/L to 14.58 mg/L and the results were found to be within the WHO (≤ 250 mg/L) and Myanmar National Drinking Water Standards (≤ 250 mg/L). The results are shown in Fig. 7. Except in the rare circumstance of defective salt chloride metabolism, such as congestive heart failure, chloride poisoning has not been seen in people. Large amounts of chloride can be consumed by healthy people as long as fresh water is also consumed at the same time. The effects of long- term high dietary chloride intake are poorly understood. As with experimental animals, it appears that hypertension brought on by consuming sodium chloride is caused by the ion sodium rather than the ion chloride.[23]

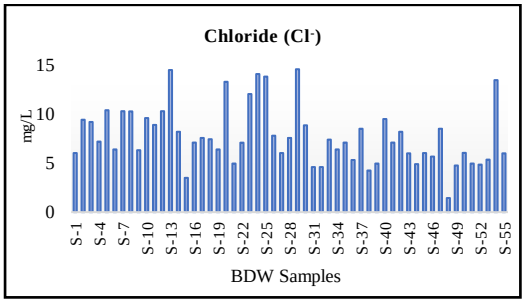

Fig. 7. Chloride concentration in BDW samples.

Sodium chloride concentrations varied from 5.8 mg/L to 24.1 mg/L. Low concentrations of sodium chloride were found in all BDW samples and the results are shown in Fig. 8.

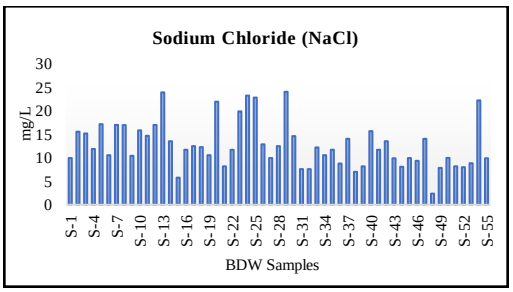

Fig. 8. Sodium chloride concentration in BDW samples.

Very low concentrations of heavy metals such as lead (Pb) and arsenic (As) were found in all collected BDW samples. Lead (Pb) and arsenic (As) concentration in BDW samples were <0. 001 mg/ L and <0.0025 mg/L, respectively. The results were found within WHO Drinking Water Standard (≤0.01 mg/L as Pb, ≤0.01 mg/L as As) and Myanmar National Drinking Water Standard (≤0.01 mg/L as Pb, ≤0.05 mg/L as As).

4. Conclusion

The overall results showed that all collected bottled drinking water samples in Mandalay were found to be physically and chemically safe for drinking purposes. The results were within the WHO Drinking Water Guideline and the Myanmar National Drinking Water Quality Standard values. Although the tested samples were physically and chemically safe for drinking, the microbiological quality of bottled drinking waters and food safety guidelines in bottled drinking water factories must also be monitored frequently. In addition, the increasing popularity of utilizing 20 liter PET bottled drinking water means that the physical, chemical and microbiological properties of 20 liters PET bottled drinking water should also be monitored and the factories need to implement good manufacturing practices (GMP), HACCP, ISO and other food safety rules and regulations in the processes of bottled drinking water production

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Conflicts of Interest

The authors declare no conflict of interest.

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