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Evaluation of Heavy Metals Content in Different Local Brands of Bottled Drinking Water

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ABSTRACT

A high concentration of heavy metals in bottled drinking water has affected many people around the world in a long-term effect. This study investigates the physical and chemical properties of local brands of bottled drinking water. Thus, the aims of this study are to determine selected heavy metals concentration and to estimate health risks. Four different local brands of drinking water were purchased from the supermarket as the samples in this study. All water samples were labelled as Sample A, B, C, and D. The pH, temperature, and types of heavy metals present in the drinking water samples were identified and the Chronic Daily Intake (CDI) and Hazard Quotient (HQ) were estimated. All samples were analysed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) for determining the concentration of heavy metals. The pH for all drinking water samples was within the limits. The temperature for all samples was ranged from 23.5 to 23.9 °C. The types of heavy metals that exist in the drinking water samples were Al, Fe, and Mg with a range of metals between 0.02 – 0.09 mg/l. In conclusion, all drinking water samples are safe to consume as all water samples were HQ < 1 and within the acceptable range of metals in water.

Keywords: *bottled drinking water; health risk; heavy metal*

1. INTRODUCTION

Water is a major basic need for living organisms as we need about 2.5 litres of water throughout a day for an optimally healthy body. United Nations already declared that having reliable drinking water is one of the human rights [1]. Problems arise when people in the world are having poor drinking water resources. About one billion people in the world have deficient access to secure drinking water and 2.5 billion do not have a connection to sufficient sanitation services [2, 3]. Around 844 million people worldwide still did not obtain their drinking water from permitted sources [1]. These drinking water sources are usually contaminated by toxic substance which will also lead to health effects on humans. More than 6 million children died each year from various types of waterborne disease [2, 3]. According to [4], WHO estimates that around 1.1 billion people around the world drink unsafe water and about 88% of diarrhoea disease globally related to unreliable water, sanitation, and hygiene.

In recent decades, the consumption of bottled drinking water has increased which led to the curiosity of the population toward the quality of the water itself and the packaging material [5] Currently, plastic bottled drinking water has been widely used rather than packed in glass container [6]. The familiar plastic used for packaging material for drinking water is polyethylene terephthalate (PET) which is highly favourable due to its ability in providing an adequate gas barrier against oxygen, carbon dioxide, and moisture, has a lightweight and have

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good recyclability [5]. However, there is a high probability of infection by heavy metals and toxic substances in water resources [1].

Heavy metals are usually introduced into the water system through weathering of rocks, the disintegration of aerosol molecules obtained from the atmosphere, and human activities [7]. Nowadays, human activities or also known as anthropogenic activities for examples industrialization and urbanization has driven many environmental deterioration problems [8]. Another source of pollution of heavy metal in drinking water includes leakage of heavy metals through the pipeline systems during water distribution and due to ecological contagion of the areas that the water originates from [9]. Discharge of effluents into aquatic systems may contaminate sources of drinking water such as groundwater and surface water. This contamination will result in the irrigation of water quality itself. Therefore, toxic metals in drinking water quality research and exposure to human health have become people's interest. Water connections for pipeline treatment, public risers and protected wells are improved sources of drinking water [10]. Use the piping system of the water plant to distribute the treated water as tap water to consumers [10]. Therefore, it is important to control water quality before allocating it to communities.

Thus, analysis of the quality of bottled drinking water and potential health risks due to ingestion of heavy metals have become the aim of this study. The results were compared with drinking water quality guidelines set by the World Health Organization (WHO) and Malaysia Ministry of Health (MMOH) to ensure that the drinking water examined are under the permissible limit and safe to be consumed.

2. METHODOLOGY

2.1 Sample Collection and Preparation

Four different local brands of bottled drinking water were randomly purchased from local retail stores with three replicates. The brand names of the bottled water were kept anonymous, and code names were given to the samples throughout the study. All types of bottled drinking water are distilled water and purified through distillation and reverse osmosis processes. All samples labelled as A, B, C, and D. All samples were purchased and collected on the same day and stored in the high-density polyethylene (HDPE) bottles. Then, the collected samples were acidified with 37 % of hydrochloric acid (HCl) and 65 % of nitric acid (HNO_3) in the ratio of 3:1 ml for every 100 ml of the water sample [11]. The samples were acidified to prevent further microbial growth [12]. All water samples were sealed and placed in a dark environment and incubated at 4 °C [1] to avoid any contamination and prevent the effects of light and temperature until the samples were analysed. Figure 1 shows the samples of bottled drinking water.

Figure 1: Samples of bottled drinking water

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2.2 Sample Analyses

All samples were analysed using ICP-OES (Model Perkin, Elmer-Optima 5100DV). The analysis of the heavy metal using ICP-OES is chosen as it can analyse multiple water samples simultaneously with a wide linear dynamic range. Five standard solutions (2 ppm, 4 ppm, 6 ppm, 8 ppm, 10 ppm for all metals) were used for calibration [13]. Three replications were performed for each sample [14]. The aluminium (Al), iron (Fe), and magnesium (Mg) metals can only be detected in the samples using ICP-OES. Figure 2 shows the analyses of heavy metals using ICP-OES.

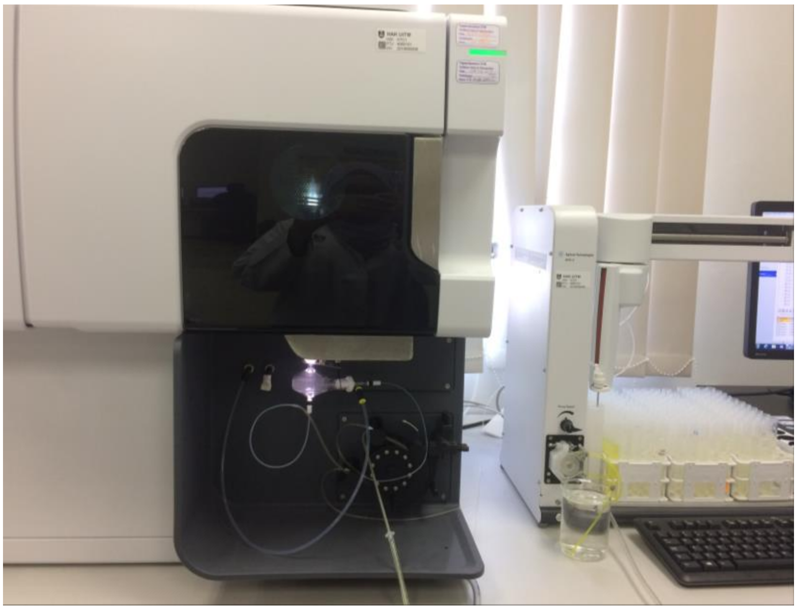

Figure 2: Analyses of heavy metal using ICP-OES

The analysis of different physicochemical parameters including pH and temperature were measured immediately after the collection of drinking water samples. A pH meter was used to measure the pH for the water samples. The pH meter was calibrated with two buffer solutions consisting of two different pH which are pH 4.0 and 7.0 before taking the measurements. The purpose of calibration of the pH meter is to obtain an accurate reading.

2.3 Health Risk Assessment

Humans may be exposed to chemical substances via three main pathways that are direct ingestion, inhalation, and dermal absorption [15]. In this study, direct ingestion was considered for health risk assessment. Health risk assessment was performed through Hazard Quotient (HQ) in equation 1:

$$HQ = CDI/RfD \tag{1}$$

Where CDI is chronic daily intake in mg/kg/day divided by reference dose (RfD) in mg/kg/day. Table 1 shows the oral reference dose for heavy metals.

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Table 1: Oral reference dose for heavy metals [10]

Heavy metal	RfD (mg/kg/day)
Al	1.0×10^{0}
Fe	7.0×10^{-1}
Mg	NA

Based on [10], CDI through ingestion of drinking water was calculated according to equation 2:

$$CDI = (C_{dw}\ x\ IR\ x\ EF\ x\ ED)/Bw\ x\ AT \quad (2)$$

Where

C_{dw} is the concentration of heavy metal (mg/kg/day)

IR is the ingestion rate (l/day)

EF is exposure frequency (365 days/year)

ED is exposure duration (70 years)

Bw is body weight (50 kg)

AT is averaging time for non-carcinogenic and carcinogenic (25,550 days).

3. RESULT AND DISCUSSIONS

3.1 Physicochemical Characteristics

The characteristics of water in term of its physical and chemical were influenced by many external factors such as atmospheric precipitation, the minerality of rocks throughout the water pathway, and the residence time of the surface or groundwater [16]. Table 2 shows the physicochemical characteristic of the water samples in this study.

Table 2: Physicochemical characteristic of water sample

Sample	**pH**	**Temperature (°C)**
A	6.81	23.9
B	7.10	23.5
C	6.90	23.7
D	6.90	23.7

Based on [17], the optimum pH value for all water samples are in the range of 6.5 to 8.5. If the water samples have a pH below 7 it is considered as acidic water that could lead to corrosion of metal pipes and plumping system. However, if the water exceeds pH 7, it is considered alkaline water which helps in the disinfection of water [18].

As for the temperature, there is no available standard value recommended by World Health Organization (WHO) and Malaysian Ministry of Health (MMOH) [19]. All the water samples

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temperatures recorded were ranged from 23.5 to 23.9 °C. The difference between all the water samples is not big, because the collected water samples are in the same place. Table 3 shows the drinking water quality guidelines from the WHO and MMOH were compared with physicochemical parameters of bottled drinking water.

Table 3: Comparison of physicochemical parameters of bottled drinking water with WHO and MMOH guidelines for water quality

Parameter	Unit	Mean pH	Mean Temperature	WHO [17]	MMOH [19]
pH	-	6.9	-	6.5 – 8.5	6.5 – 9.0
Temperature	ºC	-	23.7	-	NA

NA: not available

3.2 Heavy Metal Analyses

A few heavy metals have been identified in the drinking water which are Al, Fe, and Mg. Table 4 shows the analysed concentration of heavy metals in water samples.

Table 4: The analysed concentration of heavy metals in selected brands and control (mg/L) (mean ± standard deviation, n=3).

Sample (mg/L)	Al	Fe	Mg
A	UDL	0.09 ± 0.06	0.08 ± 0.02
B	0.04 ± 0.02	0.06 ± 0.01	0.02 ± 0.01
C	0.04 ± 0.03	0.06 ± 0.02	UDL
D	0.04 ± 0.02	0.05 ± 0.01	0.04 ± 0

UDL: under detection limit

As shown in Table 4, the highest mean concentration of Al was observed in all samples except for sample A which is 0.04 mg/L. Al usually occurs naturally in soils that will infiltrate into the water body [10]. There is a small presence of Al under the detection limit for sample A. This low concentration of Al might be removed during the water treatment process [20]. However, [21] stated that aluminium is a very strong neurotoxic substance. The concentration of aluminium in drinking water is linked to Alzheimer's disease or dialysis encephalopathy if consumed for a long time.

The sample with the highest Fe concentration is Sample A with 0.09 mg/L. Fe in water samples presents due to its abundance in the Earth’s crust [3]. The growth of bacteria could be encouraged by the existence of Fe in water sources and will lead to the irrigation of ducts and pipelines [15]. Thus, Fe will cause undesirable taste and colour to the supplied drinking water [10]. According to [22], Fe may not cause any harm to health, but when the concentration of Fe is high, it can give the water a bitter taste. People who consume drinking water with high Fe content suffer from taste, colour, corrosion of the piping system, and liver disease.

Magnesium is collectively referred to as the hardness of water [21]. The acidity of the water also affects the reabsorption of magnesium in the kidney tubules. Sample A with 0.08 mg/L found to have the highest concentration of it among the other samples followed by sample D

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with 0.04 mg/L. The pH of sample A is also the highest compared to other samples. Magnesium ions are the main component of various types of rocks, and the most common component present in natural water ranges from zero to several hundred mg/L [22, 23]. Percolation of water through the Mg-rich ultramafic rocks could be the possible leaching of Mg into water sources [24].

3.3 Comparison with permissible limit

The bottled drinking water samples were compared with the standard permissible limit provided by WHO and MMOH. Table 5 shows the comparison of these samples between the permissible limit. From the table, it has been shown that all the samples of bottled drinking water were below the standard permissible limit. Thus, all samples can be consumed safely and in sufficient quantity.

Table 5: Comparison of metals with standard permissible limit

	Al (mg/L)	Fe (mg/L)	Mg (mg/L)
WHO guideline value [17]	0.1	0.1	150
MOH Malaysia guideline value [19]	0.2	0.3	150
Sample A	UDL	0.09 ± 0.06	0.08 ± 0.02
Sample B	0.04 ± 0.02	0.06 ± 0.01	0.02 ± 0.01
Sample C	0.04 ± 0.03	0.06 ± 0.02	UDL
Sample D	0.04 ± 0.02	0.05 ± 0.01	0.04 ± 0

3.4 Health Risk Assessment

The chronic daily intake of heavy metals for drinking water was calculated to assess the health risks among the population [14]. Table 6 shows the CDI for the samples.

Table 6: The Chronic daily intake (CDI) of heavy metals in drinking water

Sample	Al (mg/L/day)	Fe (mg/L/day)	Mg (mg/L/day)
A	NA	1.8×10^{-3}	1.6×10^{-3}
B	8×10^{-4}	1.2×10^{-3}	4×10^{-4}
C	8×10^{-4}	1.2×10^{-3}	NA
D	8×10^{-4}	1.0×10^{-3}	8×10^{-4}

NA: not available

Based on Table 6, all the three samples which are Sample B, C, and D have the same value of Al with 8×10^{-4} mg/L/day. As for Fe, the highest chronic daily intake was found in Sample A with 1.8×10^{-3} mg/L/day, and the lowest in sample D with 1×10^{-3} mg/L/day. Sample A has the highest chronic daily intake of Mg with 1.6×10^{-3} mg/L/day compared to all samples.

The hazard quotient (HQ) was compared with the values of risk acceptability for non-carcinogenic health risks [17]. If HQ < 1, it is considered safe for human health and will pose low potential exposure to non-carcinogenic substance, however, the population is at risk when the HQ > 1 whereby it is considered as unsafe to human health because it has the potential to be exposed to a non-carcinogenic substances [25]. Table 7 shows the hazard quotient (HQ) of drinking water samples.

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Table 7: Hazard Quotient (HQ) of drinking water samples

Sample	Al	Fe	Mg
A	NA	2.57×10^{-3}	NA
B	8×10^{-4}	1.71×10^{-3}	NA
C	8×10^{-4}	1.71×10^{-3}	NA
D	8×10^{-4}	1.43×10^{-3}	NA

The HQ of all metals were smaller than unity, suggesting that these metal elements may pose a minimum health effect to consumer.

4. CONCLUSION

In this study, four local brands of bottled drinking water were assessed for the physical and chemical parameters. The physicochemical parameters were recorded in the optimum range as mentioned by [17] and [19]. The concentration of heavy metals in bottled drinking water was within the acceptable limit. This study presents baseline data for future guidelines, especially for bottled drinking water assessment. Analyses of more mineral ions (e.g. calcium, sodium, and potassium), other trace metals (e.g. arsenic, cadmium and lead), and potentially carcinogenic substances are important to maintain the safety of drinking water. The water samples were HQ < 1 and not exceeding the risk acceptability for non-carcinogenic health risks, therefore, safe to consume for human health.

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