Concentrations of Magnesium, Calcium and Potassium in Drinking Water; A Comparison between Tap Water and Bore Water

Michelle Ling Wang Jing[1], Siti Marwanis Anua[1*], Nurzafirah Mazlan [2]

[1]Environmental and Occupational Health Programme, School of Health Sciences, Health Campus, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia.
[2]Department of Diagnostic and Allied Health Sciences, Faculty of Health and Life Sciences, Management and Science University, University Drive, Seksyen 13, 40100 Shah Alam, Selangor, Malaysia.
Corresponding author: smarwanis@usm.my

Abstract

Minerals content in drinking water are essential for human health. Hence, this cross sectional study aims to determine the concentration of minerals in tap water and bore water consumed among staffs and students of School of Health Sciences, Universiti Sains Malaysia Health Campus. Utilising convenience sampling method, 32 respondents were recruited into this study who agreed for home visit and completed the questionnaires. Based on availability of water samples at home (raw, boiled and filtered), 22 tap water and 10 bore water were collected into 200 ml sampling bottle, in triplicate. Concentration of minerals (magnesium, calcium and potassium) in water samples were analysed using Flame Atomic Absorption Spectrometry (FAAS). There was higher concentration of magnesium, calcium and potassium in tap water compared to bore water but the difference was statistically significance for calcium only (p=0.007). No significant differences were found in all minerals for both tap water and bore water after filtration or boiling. Concentration of minerals from filtered water samples was found to be higher in galvanised steel pipes compared to polyvinyl chloride. In conclusion, water samples provided by respondents were safe for drinking and cooking as the mineral contents for consumption are below the maximum value of Drinking Water Quality Standard.

Keywords: Tap water; bore water; magnesium; calcium; potassium

1.0 INTRODUCTION

Water is an essential component for living things which includes human beings, animals and plants. Safe and readily available water is important for drinking, food preparation and cleaning purposes [1]. Bore water is groundwater which can be accessed via drilling a borehole into the underground water storage [2]. The underground water storage can be known as aquifers. An electric or gasoline-powered pump is used to pump the underground water to the surface so that the water can be used. The underground water is transported from underground to surface by using pipes. The source of water for tap water is normally from either surface water or groundwater [3]. Groundwater is a good source of water supply as it is less polluted and when the water flows through the soil, the minerals from the soil will be transported into the groundwater [4]. The water from either surface water or groundwater is treated through several processes; such as aeration, coagulation and clotting, deposition, filtration, chlorination and pH adjustment before the treated water is send to the water storage tank. Then, the water in the water storage tank is transported via pipes and released from tap. Human beings are required to drink about two litres of water per day to obtain the necessary minerals that is important to human health. Several minerals that can be obtained from water are potassium, sodium, calcium and magnesium [5].

Potassium and sodium are important electrolytes for cellular homeostasis maintenance such as osmotic pressure and water

distribution in body fluid compartments. These two ions are also crucial for renal regulation of acid-base balance to substitute hydrogen ions in renal tubule. Sodium-potassium flux can be found in nerve cells for generation of electrical potential to aid the conduction of nerve impulses. Eventually, the muscle contractions and heartbeat regulations are generated from the conduction of nerve impulses. Calcium and magnesium are important for bone formation and cardiovascular system. Calcium is an essential element for nerve impulses transmission and blood clotting [6]. The Recommended Dietary Allowance (RDA) of potassium for adults is 4700 mg per day while sodium maximum daily intake is 2300 mg per day [7]. The RDA for magnesium is 400 to 420 mg per day for males and 310 to 320 mg per day for females [8] while for calcium is 1000 mg per day for adults [9].

The major elements dissolved in groundwater such as magnesium and potassium with concentration of 1 to 10 mg/L is probably essential for human health [10]. Meanwhile, dissolved sodium and calcium concentration which is probably essential for human health is ranging from 10 to 100 mg/L. A previous study conducted in determining potassium and calcium level in bore water samples which were collected from five different villages in Gua Musang, Jeli and Tanah Merah were ranged 227.89-691.44 ppm and 0.00-36.71 ppm respectively [11]. According to Drinking Water Quality Standard, there is no maximum acceptable value for both potassium and calcium. This is due to the concentration of potassium and calcium in drinking water is well below to give any human health concern [12]. Whereas the results from a study in Najran showed that the mean concentration of the minerals such as potassium, sodium, magnesium and calcium were higher in groundwater than treated drinking water [13]. Depletion of the minerals content in treated drinking water was proven due to water treatment processes.

In Malaysia, there are two types of common water filter systems used for household, namely point-of-use system and whole house system where it has been reported that around 86% of residents installed at least one water filter system [14]. Point-of-use system only treat the water that is for drinking or usage which is installed near the sink. Whole house system treats the water before it accesses into the house which is installed near the water meter or pressurised storage tank [15]. Nanofiltration uses a lower pressure process to remove the large solids or molecules in water. The membrane used in nanofiltration is nanometre-sized cylindrical pores, which is slightly larger than the membrane used in reverse osmosis. The larger pores membrane allows the water and solutes to pass through easily which in turn causes lower pressure and energy needed, lower solutes removal and higher flow rate. The characteristics of the nanofiltration membrane is suitable to be used for water which has low total dissolved solids [16-18].

Reverse osmosis is a process of water filtration which involves the usage of semipermeable membrane. Reverse osmosis is achieved in which there is an applied pressure on the concentrated side of the membrane. This results in the reverse of natural osmosis which overwhelms the natural osmotic pressure. This process forces the fresh water back through the membrane, or in short can be known as revert the flow of water. The contaminants or salts are remained at the concentrated side of the membrane. The size and electrical charge of ions are the features that impact the removal of ions using reverse osmosis method. Effectiveness of reverse osmosis is based on the raw water characteristics, applied pressure, temperature of raw water and others [17, 18]. The semi permeable membrane used in reverse osmosis is highly permeable to water which makes it effective in removing metals ions and aqueous salts, for instance sodium, chloride, copper, chromium and lead [19]. Despite the high efficiency of reverse osmosis in ions removal, this technique required high operating pressure and high membrane area per unit volume [20].

Water quality has been main concern of the society as water is needed by human beings to survive. Besides, human beings also obtain some necessary minerals from water instead of food consumption. These minerals are important to maintain the human health and carry out daily functions and processes. Although these minerals act as the key role to several functions in human body, excessive or insufficient of these minerals will affect human's health.

Most of the residents in Kelantan use bore water as their source of water supply due to several limitations. The Kelantan residents complained that their white uniforms were permanently stained after washing by the tap water. The bore water is clearer, gives no permanent stain on white clothes and tastes better than tap water. Residents use tap water as the source of water supply because they did not have access to bore water hence alternatively opted to use filtration system, as normally the supplied tap water contains residues. However, the filtration system would not last long because it was easily clogged by sediments [21].

It is thus necessary to analyse the minerals content in the daily drinking water for both the common sources of daily drinking water among Kelantan residents which are tap water and bore water. However, this current study only preliminarily compares the minerals concentration between the bore water and tap water from the homes of staffs and students of School of Health Sciences (PPSK), Universiti Sains Malaysia (USM).

2.0 METHODOLOGY

2.1 Subject Recruitment and Questionnaire Distribution

This was a cross-sectional study design, utilising purposive sampling method and recruited 32 research participants. Staffs and students who consumed tap water and bore water for drinking or cooking were invited to participate into the study via email circulation. Arrangement for home visit were made with those who voluntarily agreed to participate in this study. During the home visit, participants were asked to complete a questionnaire after they have agreed and signed the informed consent form (the study has been granted approval by the USM human ethical board). The questionnaire used in this study was modified from World Health Organisation (WHO) and United Nations Children's Fund (UNICEF) [22]. The questionnaires consisted of four sections, gathering information on sociodemographic, drinking water system, drinking water filter system and drinking water preferences.

2.2 Water Sampling

Tap water and bore water were collected from the homes of the staffs and students of the Health Campus, USM. Water samples were collected based on the availability of the types of water samples of either filtered, boiled or raw. The tap water and bore water were required to flow for about 3 to 5 minutes. 500 ml polyethylene bottle was rinsed at least three times with running water before it was filled carefully with the water until full. Each polyethylene bottle was tightly capped and was labelled appropriately with date, time and specific location of sampling. The water samples were transported to the laboratory immediately in ice box. Water samples were preserved by adding 5 ml of concentrated nitric acid immediately once arrived at the laboratory [23] and stored under 4°C prior analysis.

2.3 Standard Preparation of Minerals and Water Sample Analysis

Water samples were filtered by using Millipore filter paper [24] before being analysed by Flame Atomic Absorption Spectroscopy (FAAS). Stock standard solution and quality control samples for each mineral analysed (magnesium, calcium and potassium) were prepared for calibration following the manufacturer's procedure with concentration of 1000 parts-per-million (ppm). The calibration standard solution and quality control samples were prepared by using molarity standard equation, $M_1V_1=M_2V_2$, where M was the concentration of stock standard solution or quality control samples while V was the volume of stock standard solution. Calibration standard solutions were prepared in 50 ml volumetric flasks while quality control samples were prepared in 100 ml volumetric flasks. The calibration standard solutions were analyzed first in generating calibration graph curve. Then, both the quality control samples and water samples were analyzed by FAAS. Results were well recorded.

2.4 Data Analysis

The Statistical Package for the Social Science (SPSS) version 24 was used for data analysis, at significance level of $p<0.05$. The results were analysed descriptively and presented in mean and standard deviation (SD). Comparison on the the concentration of minerals between raw and filtered bore water and tap water levels was conducted using Independent Samples T test. The Paired T Test was utilised to compare the concentration of minerals between raw bore water and tap water after filtration and boiling. Fisher's Exact Test was used to determine the association between perception of research participants on drinking water preferences and water filtration system.

3.0 RESULTS AND DISCUSSION

3.1 Sociodemographic Information of Research Participants

Research participants' age falls between 27 years old to 65 years old. Majority of the research participants are female (56.8%, n=18). Half of the research participants are PPSK staffs such as lecturer (25.0%, n=8), lab assistant (3.1%, n=1), administrative officer or supporting staff (21.9%, n=7). The occupation others than PPSK staffs are students' parents who were housewives, marketing, teachers, retirees, businessman, tutor, office admin assistants and rubber tapper. The research participants had consented 10 bore water and 22 tap water to be collected from their homes. The total number of water samples that were collected

were 22 raw tap water, 18 filtered tap water, 8 boiled tap water, 10 raw bore water, 10 filtered bore water and one boiled bore water.

3.2 Information on the Drinking Water System of Research Participants

Table 1 gathers the information on the drinking water system of the research participants. Fifty percent (n=5) of the research participants who provided bore water reported that they boiled the water before drinking and 54.5% (n=12) consume boiled tap water. All the research participants boiled their water by using kettle. Most of the research participants (bore water: 62.5%; tap water: 37.5%) cleaned their water storage tanks at least once a year. Most of the research participants who provided tap water (81.8%) in this study stated that they use polyvinyl chloride (PVC) pipes in their house. Meanwhile, all the research participants who provided bore water also used PVC. Most of the research participants did not boil their filtered water before they drink (bore water: 80.0%; tap water: 72.6%). Among research participants who provided bore water, 60.0% (n=6) of them knew the type of water filter that they installed in their houses. However, among research participants who provided tap water, 63.6% (n=14) of them did not know the type of water filter that they installed in their houses (Table 1).

Table 1 Drinking water system of research participants

Drinking Water System	Frequency (%)		
	Bore Water	**Tap Water**	**Total**
Boil drinking water before drink			
Yes	5 (50.0)	12 (54.4)	17 (53.1)
No	5 (50.0)	10 (45.5)	15 (46.9)
Water pass through water storage tank			
Yes	8 (80.0)	16 (72.7)	24 (75.0)
No	2 (20.0)	6 (27.3)	8 (25.0)
Frequency of cleaning water storage tank			
Never	1 (12.5)	3 (18.8)	4 (16.7)
At least once a year	5 (62.5)	6 (37.5)	11 (45.8)
Once every two years	1 (12.5)	2 (12.5)	3 (12.5)
Not sure	1 (12.5)	5 (31.2)	6 (25.0)
Types of water pipes used in house			
Galvanized steel	0 (0.0)	4 (18.2)	4 (12.5)
Polyvinyl chloride (PVC)	10 (100.0)	18 (81.8)	28 (87.5)
Filter drinking water before drink			
Yes	10 (100.0)	18 (81.8)	28 (87.5)
No	0 (0.0)	4 (18.2)	4 (12.5)
Boil filtered drinking water before drink			
Yes	2 (20.0)	6 (27.3)	8 (25.0)
No	8 (80.0)	16 (72.7)	24 (75.0)
Point-of-use water filter system available			
Yes	8 (80.0)	16 (72.7)	24 (75.0)
No	2 (20.0)	6 (27.3)	8 (25.0)
Whole-house water filter system available			
Yes	6 (60.0)	8 (36.4)	14 (43.8)
No	4 (40.0)	14 (63.6)	18 (56.2)
Know type of water filter used			
Yes	6 (60.0)	8 (36.4)	14 (43.8)
No	4 (40.0)	14 (63.6)	18 (56.2)
Types of water filter used			
Activated carbon filter	2 (33.3)	4 (50.0)	6 (42.9)
Ion exchange units	0 (0.00)	1 (12.5)	1 (7.1)
Reverse osmosis	2 (33.3)	2 (25.0)	4 (28.6)
Distillation units	1 (16.7)	0 (0.0)	1 (7.1)
Nanofiltration	1 (16.7)	1 (12.5)	2 (14.3)

3.3 Drinking Water Preferences

Research participants were asked to choose or specify the reasons they preferred their types of drinking water. Most of the research participants preferred drinking water with no taste or odour. Four of the research participants specified the reasons that the tap water is more favourable as it was the only source of drinking water available. One of the research participants specified the reasons he/she preferred bore water because chlorine was not added into bore water. However, a study showed that the taste

sensitivity did not predict the drinking water preferences [25]. However, taste was not the prominent factor as the odours may also affected the preference of drinking water [26].

3.4 Comparison of Minerals between Bore Water and Tap Water

There were no significant differences in concentration of minerals between raw bore water and tap water for magnesium (p=0.087) and potassium (p=0.244). The mean concentration of calcium in raw tap water (mean: 1.794 mg/L, SD: 1.031 mg/L) is significantly higher than the mean concentration of calcium in raw bore water (mean: 0.801 mg/L, SD: 0.483 mg/L), p=0.007 (Table 2). The findings of this study contradicted with the results from the study in Najran showed that the mean concentration of the minerals such as magnesium, calcium, potassium, and sodium were higher in groundwater compared to treated drinking water [13]. Such no statistical significant difference of minerals concentration found between raw bore water and tap water may be due to the sources of tap water samples were from groundwater instead of surface water, in which was the same sources of bore water [3]. However, the mean concentration of calcium in raw bore water was significantly lower than the mean concentration of calcium of raw tap water in this study might be contributed by the process of leaching of the rocks into the groundwater [27]. Concentration of calcium ions in groundwater might be increasing due to the leaching process. High calcium ions intake by human may cause human heart to stop in systole, which eventually may cause respiratory and cardiac failure [28]. Water treatment processes can decrease the minerals content in treated drinking water [13]. Besides, calcium-based fertilisers such as calcium ammonium nitrate may cause the high concentration of calcium in underground due to water infiltration which carry calcium ions from fertilisers [29].

Table 2 Comparison of minerals between bore water and tap water

Type of minerals	n	Mean (SD) (mg/L)			t statistic	p-value
		Bore Water	n	Tap Water		
Raw						
Magnesium	10	0.178 (0.090)	22	0.294 (0.197)	1.768	0.087
Calcium	10	0.801 (0.483)	22	1.794 (1.031)	2.886	0.007*
Potassium	10	0.310 (0.117)	22	0.361 (0.111)	1.188	0.244
Filtered						
Magnesium	10	0.173 (0.107)	18	0.275 (0.220)	1.362	0.185
Calcium	10	1.103 (1.209)	18	1.652 (1.141)	1.195	0.243
Potassium	10	0.280 (0.101)	18	0.337 (0.158)	1.028	0.313

*Significant different at p<0.05; Statistical test – Independent Samples T Test; SD – Standard Deviation

3.4.1 Comparison of Minerals Between Filtered And Non-Filtered of Bore Water and Tap Water

There was no statistical significant difference between mean concentration of minerals between raw and filtered water for both bore water and tap water (Table 3). This finding might be explained by the household water filter system installed was not able to filter out the minerals analysed in this study. In which these minerals (magnesium, calcium, potassium) are essential for human health. In this study, activated carbon was the mostly used water filter system by research participants. Activated carbon was effective for adsorbing natural and synthetic compounds and removing taste and odour in drinking water treatment. Besides, few chemical compounds such as mercury, chromium and arsenic can be removed by granular activated carbon [30] while powdered activated carbon can only adsorb organic chemical, microbial and radiological compounds instead of essential minerals to human health [31]. Other water filtration method such as nanofiltration and reverse osmosis also show high efficiency in removal of fluoride ions in water [32-34]. Additionally, reverse osmosis shows high efficiency in removal of protozoa, bacteria and viruses. However, instead of removal, it may reduce few minerals including the minerals studied in this research [35].

Table 3. Comparison of minerals between filtered and non-filtered bore water and tap water

Type of minerals		Mean (SD) (mg/L)		t statistic	p-value
	n	Raw	Filtered		
Bore Water					
Magnesium	10	0.178 (0.090)	0.173 (0.107)	0.464	0.654
Calcium	10	0.801 (0.483)	1.103 (1.209)	-1.141	0.283
Potassium	10	0.310 (0.117)	0.280 (0.101)	0.964	0.360
Tap Water					
Magnesium	18	0.294 (0.197)	0.275 (0.220)	1.535	0.143
Calcium	18	1.794 (1.031)	1.652 (1.141)	1.754	0.098
Potassium	18	0.361 (0.111)	0.337 (0.158)	1.119	0.279

Statistical test – Paired T Test, SD – Standard Deviation

3.4.2   Comparison of Minerals Between Raw and Boiled Tap Water

There was no significant difference in mean concentration of minerals between raw tap water and boiled tap water (p=0.100 for magnesium; p=0.136 for calcium; p=0.142 for potassium) (Table 4). This may due to the boiling points of minerals were higher than the boiling point of water which was caused by the strong ionic bonds [36].

Table 4. Comparison of minerals between raw and boiled tap water

Type of minerals	Mean (SD) (mg/L)			t statistic	p-value
	n	Raw Tap Water	Boiled Tap Water		
Magnesium	8	0.324 (0.234)	0.219 (0.142)	1.893	0.100
Calcium	8	1.984 (1.181)	1.540 (0.894)	1.682	0.136
Potassium	8	0.382 (0.127)	0.326 (0.112)	1.656	0.142

Statistical test - Paired T Test, SD – Standard Deviation

3.5   Comparison of Minerals With Respect To Types of Water Pipes

There was significant difference in mean concentration of minerals for magnesium (p=0.021) and calcium (p=0.038) of raw water samples between galvanised steel pipe and polyvinyl chloride pipe. However no significant difference was found in mean concentration of potassium (p=0.137). Furthermore, the difference in mean concentration of minerals of filtered water samples was significant between galvanised steel pipe and polyvinyl chloride pipe for magnesium only (p=0.014). Table 5 shows that the mean concentration of minerals in raw and filtered water using galvanised steel was higher than the mean concentration of minerals in filtered water using polyvinyl chloride pipe. This may be due to the alloy used in galvanised steel pipes of research participants contained magnesium [37]. Besides, high temperature may cause the calcium and magnesium ions to form scale in the hot water system [38] which available in some water filter system. Corrosion of galvanised steel pipes may cause the built-up of calcium and magnesium on galvanised steel pipes wall in which can be released into the water.

Table 5. Comparison of minerals with respect to types of water pipes

Type of minerals	Mean (SD) (mg/L)				t statistic	p-value
	n	Galvanised Steel Pipe	n	Polyvinyl Chloride Pipe		
Raw						
Magnesium	4	0.445 (0.205)	28	0.231 (0.160)	2.426	0.021*
Calcium	4	2.449 (1.002)	28	1.346 (0.942)	2.176	0.038*
Potassium	4	0.425 (0.048)	28	0.334 (0.116)	1.527	0.137
Filtered						
Magnesium	4	0.450 (0.207)	24	0.203 (0.169)	2.635	0.014*
Calcium	4	2.501 (0.993)	24	1.281 (1.126)	2.032	0.052
Potassium	4	0.433 (0.069)	24	0.297 (0.142)	1.855	0.075
Boiled						
Magnesium	2	0.307 (0.210)	7	0.199 (0.115)	1.013	0.345
Calcium	2	2.074 (1.395)	7	1.267 (0.739)	1.165	0.282
Potassium	2	0.391 (0.078)	7	0.302 (0.109)	1.050	0.329

*Significant different at p<0.05; Statistical test - Independent Samples T Test; SD – Standard Deviation

4.0   CONCLUSION

Drinking water is essential for human health and well-being. Humans have the rights to access safe and quality drinking water. In this research, concentration of minerals of bore water and tap water were studied. Comparison between concentration of minerals of raw bore water and tap water had no significant difference except for calcium. Similarly, no significant result was observed for the comparison of concentration of minerals in bore water and tap water after filtered and boiling. Concentration of minerals in water samples were found to be higher in galvanised steel pipes compared to PVC types of piping. Low concentration of minerals reported in this study showed that all the water samples were complied to maximum value implemented by Drinking Water Quality Standard. This study can be very useful as the staffs and students can be informed about the mineral contents that available in their drinking water at their homes.

Acknowledgements

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