



## Water Quality of Water Vending Machines in Gombak, Selangor

Khaerun Nisaa Ansahrullah<sup>a, b</sup>, Farah Ayuni Shafie<sup>\*a</sup>

<sup>a</sup> Centre of Environmental Health and Safety, Faculty of Health Sciences, Universiti Teknologi MARA Selangor

<sup>b</sup> Pejabat Kesihatan Daerah Gombak, Batu Caves Selangor

\*Corresponding author: [farahayuni@uitm.edu.my](mailto:farahayuni@uitm.edu.my)

### Abstract

Water vending machines (WVMs) are commonly found in public areas and it is an alternative for public easier to buy drinking water with much cheaper price. However, majority of the WVM in Gombak, Selangor were not registered under Ministry of Health (MOH) and have raised a concern on the drinking water quality from these machines. The aim of this study was to assess the physical, chemical, microbiological parameters from the drinking WVMs, as well as to perform environmental assessments of 20 water vending machines (10 registered, 10 non-registered water vending machines) in Gombak, and to compare the results between registered and non-registered WVMs. According to the results for water quality tests, one registered WVM violated pH and total coliform standard (10%). On the other hand, five non-registered WVMs (50%) were found not aligned with the MOH water quality standard. A number of four out of five of non-registered WVMs (80%) were found to violate pH standard and one non-registered WVM (10%) was violating total coliform standard. Environmental assessment also showed that registered WVMs have better machine conditions as well as cleaner surroundings compared to the nonregistered counterparts. The findings in this study showed that non-registered WVMs have higher tendencies to violate any water quality parameters as well as poorer WVM conditions and surroundings. These factors could pose health threats to the public who consume drinking water from these machines.

**Keywords:** Water vending machines, water quality, environmental assessment, pH, total coliform

© 2021 MAEH Research Centre  
 All rights reserved

### INTRODUCTION

Water vending machine (WVM) is an automated self-service machine that dispenses water into a container in exchange for a mentioned price (Price et al., 2006). However, the quality of drinking water from WVMs are prone to contamination from the lack of hygienic practice and maintenance of the machines. Thus, manufacturers of the vending machine need to obey and adhere to the procedure listed in Regulation 360C (Standard for Packaged, Drinking Water and Vended Water, 2012), the Malaysian Drinking Water Quality, Ministry of Health to ensure the safety and quality of water (Food Safety and Quality Ministry of Health, 2020). All WVMs in Malaysia must be registered to Health Offices of their respective districts so that these WVMs will be constantly inspected by Health Officers to ensure the quality of drinking water at all time. However, most WVMs are not registered and this could pose a health threats to all the public. As of November 2019, the licenses of 78 out of 88 registered vending machines (88.4%) have expired and not being renewed. Meanwhile, about 150 WVMs are suspected not registered in the Gombak district alone.

### METHODOLOGY

### Water sampling and analysis

Water samples were collected from selected 20 WVMs from Gombak's four mukims. Ten samples were from registered WVMs and another ten samples were from non-registered WVMs. All water samples were sent to an outsource laboratory and each samples undergone physical, chemical and microbiological test (Table 1).

Table 1 Test Parameters and techniques

Parameter	Techniques
<b>Physical test</b>	pH: APHA 4500-H <sup>+</sup> B(2005) turbidity: turbidity meter (APHA 2130 B) colour: APHA 2120 B (2005)
<b>Chemical test</b>	Aluminium - APHA 3500 Al Chloroform - USEPA 5021A Nitrite (NO <sub>2</sub> ) - APHA 4500 NO3 B
<b>Microbiological test</b>	Membrane Filtration (APHA 9222 B)

### Environmental assessments

WVMs were evaluated on three aspects, which were the availability of dispensing nozzle cover, overall machine conditions, and surrounding's cleanliness. The surrounding area may also affect the water quality as the WVMs are normally situated in open spaces and can be contaminated with dust, droppings and others.

### RESULTS AND DISCUSSION

#### Water sampling results

All water sampling results were depicted in Table 2. According to Table 2, chloroform content and nitrite (NO<sub>2</sub>) content were observed to have little to none in all 20 samples tested. Besides that, colour parameter results showed that all samples obtained 5 (HU) which aligned with the standard by MOH.

Table 2 Water Sampling results

Registered Water Vending Machines Unit	pH @ 25°C	Aluminium mg/l	Chloroform mg/l	Parameters			
				Nitrite as NO <sub>2</sub> mg/l	Colour Hazen Unit (HU)	Turbidity NTU	Total Coliform CFU/100 ml
<b>Limit</b>	6.5 - 8.5	0.04	0.0006	0.04	5	0.1	<10
<b>Sampling ID</b>	<b>RESULTS</b>						
<b>Registered WVMs</b>							
<b>A</b>	7.32	0.024	ND<0.01	ND<0.01	5	0.04	ND<1
<b>B</b>	6.58	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	ND<1
<b>C</b>	6.97	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	4
<b>D</b>	6.37	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	10
<b>E</b>	6.75	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	ND<1
<b>F</b>	6.54	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	ND<1
<b>G</b>	6.71	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	ND<1
<b>H</b>	6.73	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	ND<1
<b>I</b>	6.88	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	ND<1
<b>J</b>	6.77	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	ND<1
<b>Non-registered WVMs</b>							
<b>K</b>	7	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	ND<1
<b>L</b>	6.23	0.022	ND<0.01	ND<0.01	5	ND<0.01	ND<1
<b>M</b>	6.82	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	ND<1
<b>N</b>	6.28	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	ND<1
<b>O</b>	6.29	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	ND<1
<b>P</b>	6.68	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	13
<b>Q</b>	6.31	0.031	ND<0.01	ND<0.01	5	ND<0.01	ND<1
<b>R</b>	6.49	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	ND<1
<b>S</b>	6.81	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	2
<b>T</b>	6.88	ND<0.014	ND<0.01	ND<0.01	5	ND<0.01	ND<1

Mean of pH value for water sample from registered machine was higher (mean: 6.76, SD: 0.26) than mean of pH value for water sample from non-registered machine (mean: 6.57, SD: 0.29). Nevertheless, independent t-test analysis shows that there is no significant difference in pH value between water samples from registered WVMs and non-registered WVMs (t = 1.482, p>0.05)(Table 3).

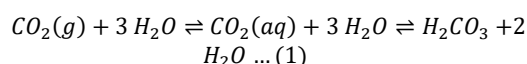
Table 3: Independent sample T-test for pH Value

Parameter	Mean / Std Division		t	P. Value
	Registered WVM	Non-Registered WVM		
<b>pH value</b>	6.76 ± 0.26	6.57 ± 0.29	1.482	> 0.05

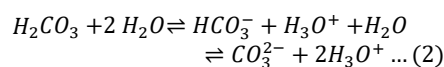
The difference of pH for registered and non-registered WVMs were not significant due to small sample size. Where only 10 samples were taken from each registered and non-registered WVMs.

Despite that, these samples' results were still not aligned with pH standard of 6.5 – 8.5 set by Food Safety and Quality, Ministry of Health.

Oxides of sulphurs and nitrogen produced by either natural occurrences such as volcano eruptions or from human activities like fossil fuel consumption are the main factor of acid rain occurrences and acidifying water resources around the world (Baselga et al., 2011). The acidity of water also influenced by the formation of carbonic acid from the reaction of carbon dioxide, CO<sub>2</sub> in water (Eq. 1).



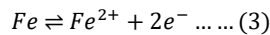
And carbonic acid will undergoes further reaction resulting bicarbonate (HCO<sub>3</sub><sup>-</sup>) and carbonate (CO<sub>3</sub><sup>2-</sup>) as per (Eq. 2).



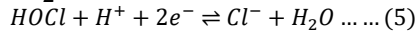
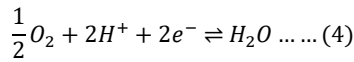
The result has caused the decrease in pH (Adamczyk et al., 2009). Acidic pH condition could corrode the water piping system and possibly causing toxic metal such as copper, lead and iron

leached into the drinking water (Apera Instrument, 2017).

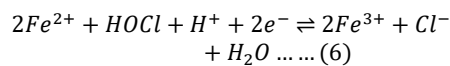
For example, the corrosion reaction is associated with oxidation of iron:



And the reduction process of free chlorine in water:



(Eq.3) showed that the reduction of free chlorine in water has contributed to acidic pH.



Free chlorine resulted from reaction 3 could oxidized ferrous iron (Fe<sup>2+</sup>) from (1) into ferric ions (Fe<sup>3+</sup>) and causing iron corrosion. (Frateur et al., 1999). Prolong negligence on pipe maintenance of WVM could possessed threats on harmful side-effects due to consumption on water from rusted piping.

Besides that, violations of pH in drinking water could be from the absent or un-maintained neutralizing filters of the machines. Neutralizing filter is a part of the treatment device to increase the pH level of water and placed at intake point. This part consist of calcium carbonate (limestone) to reduce the pH and synthetic magnesium oxide to increase the pH of water (United State of Department of Agriculture, 2019). Moreover, neutralizing filters need to be backwashed periodically to remove solid particles in the water. Besides that, machines owners needs to periodically refilling the neutralizing material to ensure this filter is able to work efficiently (United States Environmental Protection Agency New England, 2007).

Although there was no certain correlation between consuming weak acidic water and health threat, pH of water are often related to the water quality aspects. This is because pH of water able to influence the level of metal corrosion, disinfection effectiveness, and heavy metal poisoning due to ingestion of dissolved metals. Besides that, low pH water could corrode piping system in the machine and could cause very serious faulty to the machine itself (World Health Organisation, 2007). Heavy metal exposure has been reported to pose more severe side effect to children such as developmental delays, mental retardation, heart disease, respiratory problems, and many more (Al Osman et al., 2019).

**Total coliform results in water samples**

Table 4 depicted the samples that recorded total coliform counts.

Table 4: Total coliform counts

Sampling ID	Sampling Point	Total coliform count (CFU/100 ml)
C	Bandar Country Homes	4
D	Taman Sri Batu Caves	10
P	Taman Melawati	13
S	Bukit Indah, Ampang	2

Four samples were detected to consist of total coliforms. Firstly, sample number C, which located at Bandar Country Homes in Rawang was recorded to have 4 CFU/100 ml of total coliforms. Secondly, sample number D in Taman Sri Batu Caves of Batu was reported to have 10 CFU/100 ml of total coliforms. Both of these machines are registered WVMs.

For non-registered WVMs, there were also two machines that were recorded to have the presence of total coliforms. Those were from samples number P and S which located in the mukim of Hulu Kelang. P were recorded to consist of 13 (CFU/100 ml) while S were 2 (CFU/100 ml) of total coliforms. From this result, only P was violating the standards by exceeding 10 (CFU/100 ml).

Table 5 shows the independent sample T-test for total coliform counts for both registered and non-registered WVMs.

Table 5 Independent t-test for total coliform

Parameter	Mean / Std Division		t	P-value
	Registered WVM	Non-Registered WVM		
Total Coliform	1.40 ± 3.27	1.50 ± 4.08	-0.06	> 0.05

Mean of total coliform value for water sample from registered machine was higher (mean: 1.40, SD: 1.50) than mean of total coliform value for water sample from non-registered machine (mean: 1.50, SD: 4.08). Nevertheless, independent t-test analysis shows that there is no significant difference in total coliform value between water samples from registered WVMs and non-registered WVMs (t= -0.06, p>0.05).

Similar to pH result, the difference of total coliform for registered and non-registered WVMs were not significant due to small sample size. Where only 10 samples were taken from each registered and non-registered WVMs. Despite that, these samples' results were still not aligned with total coliform standard <10 CFU/100ml set by Food Safety and Quality, Ministry of Health.

Two of the highest recorded total coliform counts were observed to have garbage placed nearby the WVMs and unsanitary machine and surrounding

conditions. There are high chances that water dispensed from both machines were contaminated by insects like flies that were present at the garbage piles nearby. These flies could also have been perched on the nozzle of these machines which may pollute the water came out from it.

According to Guidelines for Drinking-water Quality by WHO, total coliforms parameters were able to describe the cleanliness and integrity of distribution system and the presence of biofilms. Total coliforms should not be presence in well-sanitized machine and this parameters were giving the rough idea on maintenance sufficiency and machines' condition. Drinking water also may be contaminated during storage as biofilms reformations or cross-contaminations occurrences between stored drinking water with foreign contaminants (World Health Organisation, 2017).

Other possible factors might be the formation of biofilms inside the piping system and inside the nozzle due to lack of maintenance and improper sanitation of the WVMs. Water contaminations during storage could also be happened due to insufficient regulations, limited understanding and awareness among public (Zamberlan da Silva et al., 2008).

Temperature is one of the major factor that affect the growth of total coliforms. One study shows that total coliform growth increases when temperature is higher than 15 °C (Moosa et al., 2015b). *E. coli* growth was reported to be increased when the temperature is between 12-30°C (Prest et al., 2016). With Malaysia experiencing humid weather and averaging daily temperature between 21 - 32°C, total coliform occurrences were expected to be high.

Total coliforms are made from few bacteria which in majority does not possess harm to human health. However, some of the bacteria in water such as *Escherichia coli* (*E. coli*) and *Klebsiella spp.* could possess health hazards to consumers. *E. coli* is the typical form of faecal bacteria, which not only found in human intestinal tract and other warmed-blooded animals, also in faecal-contaminated water supply (An et al., 2002). Despite most of the *E. coli* strains are harmless, but some strains causes' diarrhoea, pneumonia, respiratory disease and many more.

**Aluminium content, contributing factors, and possible health effects**

Table 6 listed 3 samples that recorded aluminium content reading and their pH value.

Table 6: Aluminium Content vs. pH and turbidity

Sampling ID	Aluminium content (mg/l)	pH @ 25 °C	Turbidity (NTU)
A	0.024	7.32	0.04
L	0.022	6.23	ND<0.01
Q	0.031	6.31	ND<0.01

According to the Water Vending Machine Guidelines from Ministry of Health, the standard for aluminium content is not more than 0.04 mg/l. In this case, all of the samples were within the permissible limit.

One of the samples from registered WVMs, A with 0.024 mg/l of aluminium content with pH of 7.32, but detected a slight reading of turbidity of 0.04 NTU (Turbidity Standard: 0.1 NTU). Interestingly, the other two samples from unregistered WVMs that were recorded aluminium content results; samples L and Q; were violating pH limit but no detectable turbidity were recorded.

Concentration of alum and pH determines the efficiency for turbidity removal (Jaeel & Zaalán, 2017). The most efficient concentration of alum are between 20-30 mg/l where the turbidity removal percentage were between 80-95%. However, when the concentration of alum are at 40 mg/l, a noticeable decrease of turbidity removal percentage were observed. In the same study, the highest turbidity removal were observed at pH 6.1 -6.2 (Jaeel & Zaalán, 2017). A study by Pernitsky and Edzwald also agreed that alum coagulant were very effective in eliminating turbidity at pH 6-7 (Pernitsky & Edzwald, 2006).

Besides that, exposure of high concentration of aluminium in dialysis fluid also could cause dementia among dialysis patients. Long period exposure of high level of aluminium also could impair cognitive function in human such as Alzheimer (Fawell, 2010). Aluminium originally added to dialysate in form of aluminium salts as phosphate binder. However, due to this patients were diagnosed with elevated aluminium concentration in brain tissue and plasma. Due to its high affinity towards proteins, the affected patient showed disorientation, and memory loss and could causing dementia when memory impairment at advance stages (Klotz et al., 2017). According to the safety data sheet of alum by thermo fisher, the lethal dosage, LD<sub>50</sub> for alum is 2g/kg via ingestion route, but no data for LD<sub>50</sub> of dermal and inhalation route (Thermo Fisher Scientific, 2012).

**Environmental assessments and health impacts**

All WVMs were evaluated on three aspects, which were the availability of dispensing nozzle cover, overall machine conditions, and surrounding cleanliness and the rating were depicted in Table 7.

According to the observations, out of ten registered WVMs, only six of them has cover for the dispensing nozzles and surprisingly all of the non-registered WVMs has cover for the dispensing nozzles.

Table 7: Environmental assessments results.

	Dispensing Nozzle Cover	
	Registered WVM	Non-registered WVM
<b>Yes</b>	6	10
<b>No</b>	4	0
Overall machine conditions		
	Registered WVM	Non-registered WVM
<b>Good</b>	6	3
<b>Satisfactory</b>	3	4
<b>Poor</b>	1	3
Surroundings cleanliness		
	Registered WVM	Non-registered WVM
<b>Good</b>	7	2
<b>Satisfactory</b>	2	5
<b>Poor</b>	1	3

For overall machine conditions, registered WVMs in general has better machine conditions where six units of WVMs were in good conditions and three units were in satisfactory conditions and only one unit in poor conditions. Meanwhile non-registered WVMs, only three units were in good conditions, four units in satisfactory conditions, and three units were in poor conditions. For machines' surrounding cleanliness criteria, in overall registered WVMs were in better surroundings compared to non-registered ones where seven machines had clean surroundings, two had satisfactory surroundings and only one machine were in dirty surroundings. In the other hand, only three non-registered WVMs had clean surroundings, five were satisfactory, and three were in very poor surroundings.

In general, all WVMs have their own dispensing nozzle cover which functioned to protect the dispensing nozzles from cross contamination caused by dust, wild animals, and etc. Four units of registered WVMs which do not have the cover were because the cover doors were broken and yet to be fixed. These might compromised the water safety as the dispensing nozzles were opened to any contamination from the surroundings.

Overall machine conditions for registered WVMs, three registered WVMs were graded as satisfactory due to the missing nozzle cover but the machine conditions were clean. And one unit of registered WVMs was graded as poor because of missing nozzle cover and poor machine conditions where there were many dirty stains as well as rust stains were spotted all over the machine.

For non-registered WVMs, four of the machines were graded satisfactory were either because of dirty and rust stains or some food leftover were spotted on the machine. Meanwhile, three units were graded as poor were because of not only the machine were very dirty, some of the machines were observed to have algae grown inside the dispensing nozzles. These shown that those machines were had little to no maintenance at all. The final criteria is the surrounding conditions which the cleanliness of machines' circumambient were evaluated. Two of the registered and five non-registered WVMs were

graded as satisfactory due to the discovery of some water puddles underneath the machines, some rubbish, and grass grown nearby. Whereas one registered and three registered WVMs were graded as poor were due to some machines were placed besides very dirty drains, huge amount of garbage, or wild animals like rats and flies were spotted nearby the machines.

In general, environmental assessment towards WVMs and its surroundings giving the rough ideas on whether the water came from the machines are safe to be consumed. Poorly maintained WVMs could pollute the water from the rust of the piping system and the inefficiency of badly maintained filtration system. An article from The Star in 2019 mentioned that, our treated water was reported had a hardness level below 100 mg due to the presence of dissolved heavy metals such as cadmium, copper and lead. These water has high tendency to corrode piping system (The Star, 2019).

Hardness in drinking water plays an important role for aesthetic acceptability as well as operational considerations (Sengupta, 2013). Besides that, locations of the WVMs also plays an important role in determining the safety of drinking water. In this study, four of 20 WVMs rates as poor for both machine conditions and surrounding cleanliness. They are B, D, P, and S. According to water sample results obtained, these 4 samples were reported to have total coliform reading from the respective samples. The Centre for Disease Control (CDC) of United States estimated that around 32 million cases of annual acute gastrointestinal illness were from public drinking water system (Wright et al., 2004).

**CONCLUSION**

The water quality assessment and environmental assessment were found to be effective in this study. The results acquired were able to indicate the overall water quality as well as its safety between water from registered and non-registered water vending machines from all over Gombak district.

For physical characteristic assessments which involving pH, colour, and turbidity level; only one samples from registered WVM was violating pH standard while four samples from non-registered WVM were under the pH standard. Out of 20 samples from both registered and non-registered WVM, only one sample from registered WVM recorded a turbidity level reading but it was still within the permissible level. Meanwhile, there were no samples neither from registered nor non-registered WVM were violating colour standard.

For chemical parameters, both chloroform and nitrite (NO<sub>2</sub><sup>-</sup>) were not detected in any samples neither from registered nor non-registered WVM. In the meantime, aluminium concentration were detected in one samples from WVM (0.24 mg/l) and two samples (0.022 and 0.031 mg/l) from non-registered WVMs. However all three reading were still within standard of 0.04 mg/l.

For microorganism parameters, total coliform reading has been detected in four samples. Two samples from registered WVMs were recorded 4 and 10 CFU/100 ml, while two samples from non-registered WVMs were recorded 2 and 13 CFU/100 ml of total coliform. Finally for environmental assessment, registered WVMs collectively were in better conditions compared to non-registered water vending machines. Besides that, registered water vending machines also have cleaner surrounding compared to the non-registered ones.

In overall, only two registered WVMs were violating any of the parameters' standard. On the other hand, 6 out of 10 samples from non-registered WVMs were violating any other parameters. In conclusion, registered WVMs were better in both water quality analysis and environmental assessment compared to non-registered WVMs.

## REFERENCES

- Adamczyk, K., Prémont-Schwarz, M., Pines, D., Pines, E., & Nibbering, E. T. J. (2009). Real-time observation of carbonic acid formation in aqueous solution. *Science*, 326(5960), 1690–1694.
- Al osman, M., Yang, F., & Massey, I. Y. (2019). Exposure routes and health effects of heavy metals on children. *BioMetals*, 32(4), 563–573.
- An, Y. J., Kampbell, D. H., & Peter Breidenbach, G. (2002). Escherichia coli and total coliforms in water and sediments at lake marinas. *Environmental Pollution*, 120(3), 771–778.
- Apera Instrument. (2017). *The Importance of PH*. Apera Instrument. <https://aperainst.com/blog/why-ph-is-important/>
- Fawell, M. J. K. (2010). Aluminium in drinking-water, Background document for development of WHO. *Journal of Guidelines for Drinking-Water Quality (GDWQ)*, 8–23.
- Food Safety and Quality Ministry of Health. (2020). *License Application Guidelines for Operating Water Selling Machines for Trade and Business*.
- Frature, I., Deslouis, C., Kiene, L., Levi, Y., & Tribollet, B. (1999). Free chlorine consumption induced by cast iron corrosion in drinking water distribution systems. *Water Research*, 33(8), 1781–1790.
- Jaeel, A. J., & Zaalán, S. A. (2017). Calculation the Optimum Alum Dosages Used in Several Drinking Water Treatment Plants in WASIT Governorate ( IRAQ ) and Investigation the Effect of pH on Alum Optimum Dosages . *Icocee – Cappadocia 2017, January*, 1–10.
- Klotz, K., Weistenhöfer, W., Neff, F., Hartwig, A., Van Thriel, C., & Drexler, H. (2017). The health effects of aluminum exposure. *Deutsches Arzteblatt International*, 114(39), 653–659.
- Moosa, M. E. Al, Khan, M. A., Alalami, U., & Hussain, A. (2015b). Microbiological Quality of Drinking Water from Water Dispenser Machines. *International Journal of Environmental Science and Development*, 6(9), 710–713.
- Pernitsky, D. J., & Edzwald, J. K. (2006). Selection of alum and polyaluminum coagulants: Principles and applications. *Journal of Water Supply: Research and Technology - AQUA*, 55(2), 121–141.
- Prest, E. I., Hammes, F., van Loosdrecht, M. C. M., & Vrouwenvelder, J. S. (2016). Biological stability of drinking water: Controlling factors, methods, and challenges. *Frontiers in Microbiology*, 7(FEB), 1–24.
- Price, J. H., Murnan, J., & Moore, B. (2006). Soft Drink Vending Machines in Schools: A clear and present danger. *American Journal of Health Education*, 37(5), 306–314.
- Sengupta, P. (2013). Potential health impacts of hard water. *International Journal of Preventive Medicine*, 4(8), 866–875.
- The Star. (2019). *4 reasons why your water purifier needs regular maintenance*.
- Thermo Fisher Scientific. (2012). Safety Data Sheet Aluminum Potassium Sulfate Dodecahydrate. *The OSHA Hazard Communication Standard 29 CFR 1910.1200*, 4(2), 1–6.
- United State of Department of Agriculture. (2019). *Drinking Water Treatment*. United State of Department of Agriculture. <https://drinking-water.extension.org/drinking-water-treatment-ph-adjustment/#:~:text=Soda ash%2F sodium hydroxide injection,-How soda ash&text=This treatment method is used,hardness problems in treated water.>
- United States Environmental Protection Agency New England. (2007). pH-Acidity of Private Drinking Water Wells. In *Healthy Drinking Waters of Massachusetts*.
- World Health Organisation. (2007). pH in drinking-water. *Guidelines for Drinking Water Quality*, 2(2), 1–7.
- World Health Organisation. (2017). *Guideline fo Drinking Water Quality*.
- Wright, J., Gundry, S., & Conroy, R. (2004). Household drinking water in developing countries: A systematic review of microbiological contamination between source and point-of-use. *Tropical Medicine and International Health*, 9(1), 106–117.
- Zamberlan da Silva, M. E., Santana, R. G., Guilhermetti, M., Filho, I. C., Endo, E. H., Ueda-Nakamura, T., Nakamura, C. V., & Dias Filho, B. P. (2008). Comparison of the bacteriological quality of tap water and bottled mineral water. *International Journal of Hygiene and Environmental Health*, 211(5–6), 504–509.