Evaluation on the Quality of Bangkok Tap Water with Other Drinking Purpose Water

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Abstract
The concern of drinking purposed water quality in Bangkok, Nonthaburi, and Samutprakarn provinces has been a problem for over fifteen years. Metropolitan Water Works Authority (MWA) of Thailand is fully responsible for providing water supply to the mentioned areas. The objective of Drinkable Tap Water Project is to make people realize in quality of tap water. Communities, school, government agencies, hotels, hospitals, department stores, and other organizations are participating in this project. MWA have collected at least 3 samples of water from the corresponding places and the samples have to meet the World Health Organization (WHO) guidelines level. This study is to evaluate water quality of tap water, storage water, filtered water, and filtered water dispenser. The water samples from 2,354 attending places are collected and analyzed. From October 2011 to September 2016, MWA analyzed 32,711 samples. The analyzed water parameters are free residual chlorine, appearance color, turbidity, pH, conductivity, total dissolved solids (TDS), and pathogenic bacteria; *E.coli*. The results indicated that a number of tap water samples had the highest number compliance with WHO guidelines levels at 98.40%. The filtered water, filtered water dispenser, and storage water were received 96.71%, 95.63%, and 90.88%, respectively. However, the several samples fail to pass WHO guideline level because they were contaminated by *E.coli*. The result is that tap water has the highest score among other sources probably because tap water has chlorine for disinfection and always is monitored by professional team round-the-clock services compared to the other water sources with less maintenance or cleaning. Also, water quality reports are continuously sent to customers by mail addresses. Tap water quality data are shown on MWA websites and Facebook. All these steps of work should enhance the confidence of tap water quality.

Keywords
Tap water; water quality; water supply; Metropolitan Water Works Authority (MWA); drinking water quality

INTRODUCTION

Metropolitan Waterworks Authority (MWA) is a State Enterprise, which has a major responsibility for tap water production in Bangkok, Nonthaburi, and Samut Prakarn Provinces in Thailand. Service areas cover 2,358-kilometer square and they are divided into 18 branches. MWA has four Water Treatment Plants and ten pumping stations. The production capacity is about 5.9 million cubic meters per day. The Chao Phraya River and Mae Klong River are water resources. Integrated water quality monitoring is managed for water resources and tap water quality. Bio monitoring and online raw water monitoring are used for raw water sources. Moreover, generally, the water samples are analyzed with Laboratories certified by ISO/IEC 17025 every month. In the crisis, the water is closely monitored with water treatment process by certified ISO 9001:2015, ISO 14001:2015 and HACCP. Furthermore, tap water is monitored, analyzed, and quality controlled by our scientists round-the-clock. (MWA Annual Report 2016) During the flooding crisis of Bangkok, although, MWA tap water had confidently complied with WHO guidelines level 2011 (Kitkaew, et.al, 2013), customers have lost trust on drinking water supply so one of the strategies is building trust by conducting a project "Drinkable Tap Water Project." Building up confidence for the customers is the key factor, the activities composed of 1) in-house water quality check, 2)

maintaining water quality in storage tanks consultancy, 3) filter container or install correct pumps on communities, government agencies, educational institutions, hotels, hospitals, and private enterprises. Water quality for participating organizations which comply to WHO guidelines for drinking will be certified, and water quality will be continually mornitored at least once a year.

Table 1. Recommended minimum sample numbers for faecal indicator testing in distribution systems* of MWA referenced by WHO guidelines.

Type of water supply and population	Total number of samples per year
Point sources	Progressive sampling of all sources over 3-to 5-years cycles (maximum)
Piped supplies	
< 5000	12
5000-100 000	12 per 5000 population
> 100 000-500 000	12 per 10 000 population plus an additional 120 samples
> 500 000	12 per 50 000 population plus an additional 600 samples

* Parameters such as chlorine, turbidity and pH should be tested more frequently as part of operational and verification monitoring.

In distribution systems, we also have plans and goals in water quality monitoring comply with WHO guidelines. As shown in Table 1, recommended minimum sample numbers for faecal indicator testing is 12 per 50,000 plus an additional 600 samples in the case of population is more than 500,000. (WHO 2011) MWA has clients about 10 million population in our services area (Annual Report 2016) so we have sampling plan in distribution systems about 3,000 samples per year. The number of samples collected from tap water pipes in distribution systems at customers' places cover all our services area; 18 branches, are shown in Fig.1. The distribution of collected sample is determined by the density of population in each service areas to analyze physical, chemical, and biological parameters.

Table 2. Annual list of analyzed MWA Tap water quality parameters

Order	Water Quality	Parameters	Frequency
1	Physical	Color, odor, turbidity	Everyday
2	Chemical	Free residual chlorine, iron, conductivity, total dissolve solid	everyday
		Insight chemical 40 parameters	Once/month
3	Bacteria	*E.coli*	Everyday
4	Heavy metal	Lead, chromium, cadmium, mercury, copper, zinc, arsenic	Once/month
5	Carcinogen	Total organic carbon (TOC), Trihalomethane (THMs)	Once/month
6	Agricultural toxin	Organochlorine, organophosphate	Twice/year
7	Pathogenic bacteria	*Vibrio Cholerae* serotype o:1 , *Vibrio Cholerae* serotype non o:1, *Samonella* sp., *Shigella* sp., *Staphylococcus aureus*, *Clostridium perfringens*	Three times /year
8	Protozoa	*Cryptosporidium* spp., *Giardia* spp., *Cyclospora* spp.	Once/year
9	Virus	Rotavirus, poliovirus, Hepatitis virus , Norovirus	Once/year
10	Radioactive	Beta and alpha	Twice/year
11	Microcystin	MC-LR, MC-YR, MC-RR	4 times/years
12	Phenol	Phenol	4 times/years
13	Cyanine	Cyanine	4 times/years

Moreover, we plan to monitor water quality monitoring in toxic parameters, which cause deleterious effects to health; such as heavy metal, pesticide, agricultural toxin, carcinogen (trihalomethane), radioactive, and pathogenic bacteria, as shown in Table 2.

This study is to assure that tap water quality produced under responsibility of MWA, conforms to WHO guidelines for drinking water quality and does not differ from the other drinking water purpose. Many researchers found that tap water and bottled water had quite the same water quality. (Kornprabha et al. 2005, Marie Eliza Z. S. et al 2008, and Rosa et al 2011) In addition, this research disseminate tap water quality data to users in order to build their trust on MWA tap water quality and realize the importance of frequently cleaning water storage as well as related equipment in their places. The finding can resume the users' confidence in tap water consumption.

Fig. 1 Scheme of total water samples shown by number of sample per branches per years

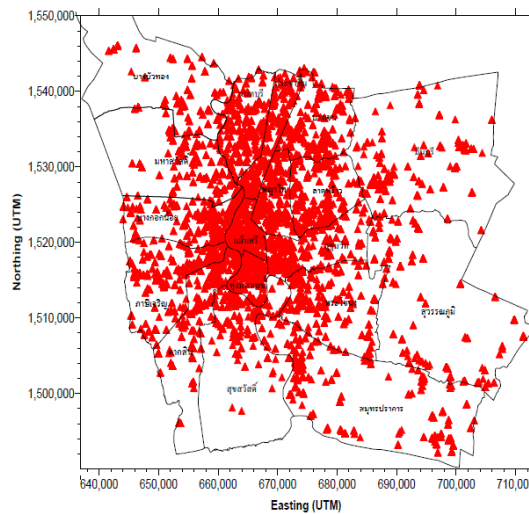**Fig.2** Observation data map of annual water sampling points

MATERIAL AND METHODS

Water samples from participating in Drinkable Tap Water Project amount 2,354 places were collected during October 2011 to September 2016. The samples were collected from tap water pipes in distribution systems, storage tanks, filter tanks, filter dispensers, for at least three samples each places. The samples were analyzed in seven parameters; free residual chlorine (analyzed in the sampling points), appearance color, turbidity, pH, conductivity, total dissolve solid (TDS), and *E.coli*. The analytical methods are shown in Table 3. The samples were collected in appropriate containers. Polyethylene plastic bottles (250 ml) were used for physical and chemical parameters. For bacteria parameter, we used volume 120 ml glasses, which had Sodiumthiosulfate ($Na_2S_2O_3$) 3% amount of 0.1 ml, maintained in metal box to prevent being broken during transportation. The bacteria containers must be sterilized at 170± 10 ºC in 2 hours. (APHA 2012)

Table 3. Analytical methods and references of seven parameters for water quality evaluation covered physical, chemical, and biological aspects

Parameters	Analytical methods	References
Free residual Chlorine	DPD Colorimetric Method	APHA,AWWA,WEF 4500-CL G.
Physical characteristic		
Appearance color	Visual Comparison Method	APHA,AWWA,WEF 2120 B.
Turbidity	Nephelometric Method	APHA,AWWA,WEF 2130 B.
Conductivity	Electrical Conductivity Method	APHA,AWWA,WEF 2510 B.
pH	Electrometric Method	APHA,AWWA,WEF 4500-H^+ B.
Chemical characteristic		
Total Dissolved Solids (TDS)	Total Dissolved Solids Dried at 180 ºC	In house method based on APHA,AWWA,WEF 2540 C.
Biological characteristic		
Escherichia coli (*E.coli*)	Fluorogenic Substrate Test	APHA,AWWA,WEF 9221 F.

Note;   APHA = American Public Health Association, WEF = Water Environment Federation, AWWA = American Water Works Association

Fig.3 Observation data map of water sampling points during October 2011 to September 2016

FINDINGS AND DISSCUSSTION

The samples from participating were collected during October 2011 to September 2016, MWA analyzed 32,711 samples. Seven parameters according to MWA water quality standard (MWA Standard 2013) were implemented for analysis, some of which were reported in this paper as shown in Fig.4. The results showed that tap water, filtered water, filtered dispenser water, and storage water were clear appearance and low turbidity. Their appearance colors were less than 15 TCU. Average turbidity was in the range of 0.17 to 23.4 NTU, the lowest turbidity of which was from filtered water because it had filter for removing particles. Average conductivity ranged from 2 to 3700 µS/cm. The high conductivity was from contaminated tap water and filter water. In case of tap water, that is probably because the effect of seawater intruded during drought season, resulting from conventional water technology. In case of filter water, that it feasible because filters did not clan wash. Average total dissolved solids (TDS) tended to be same way of conductivity in the range of 1 to 2220 mg/l possibly due to the mineral in the water. Average pH values in the range of 5.80 to 10.55. Their free residual chlorine values were in the range of 0.00 to 2.00 mg/l. The highest free residual chlorine values were from tap water. However, the others were lower free residual chlorine values than the one probably resulting from loss of chlorine during stored in storage tanks or trapped in the filters. Moreover, the results indicate that four types of water were not difference in statistical significance at 0.95-confidence level, as shown in Table 4.

Table 4. Water quality of water tap water, filtered water, filtered water dispenser, and storage water

Parameters	Tap water			filtered water			Filtered water dispenser			Storage water		
	max	min	P 95	max	min	P 95	max	min	P 95	max	min	P 95
Free residual chlorine	2.00	0.00	1.06	1.13	0.00	0.00	1.03	0.00	0.00	1.71	0.00	0.14
Turbidity	15.5	0.23	1.13	14.0	0.17	0.77	17.8	0.20	0.67	23.4	0.24	1.15
pH	10.55	6.48	7.70	9.89	5.80	7.76	9.53	5.93	7.85	10.12	6.29	7.76
Conductivity	2374	120	501	2264	3	502	3240	2	488	3700	8	503
Total Dissolved Solid (TDS)	1424	72	301	1358	2	301	1944	1	293	2220	5	302

Besides, the results revealed that a number of MWA tap water samples from distribution system had the highest number in compliance with WHO guidelines values for drinking water quality 2011 at 98.40%. The filtered water, filtered water dispenser, and storage water were registered at 96.71%, 95.63%, and 90.88%, respectively as shown in Fig. 5. Interestingly, the consequence of this study showed that a number of water samples classified by water type annually met WHO guidelines levels had a tendency to be same results as those classified by water type during fiscal year 2011 to 2016 (October, 2011 – September, 2016). Results were illustrated in Fig. 6 as following. Furthermore, the water quality of all water types tended to increase compliance with WHO guidelines levels.
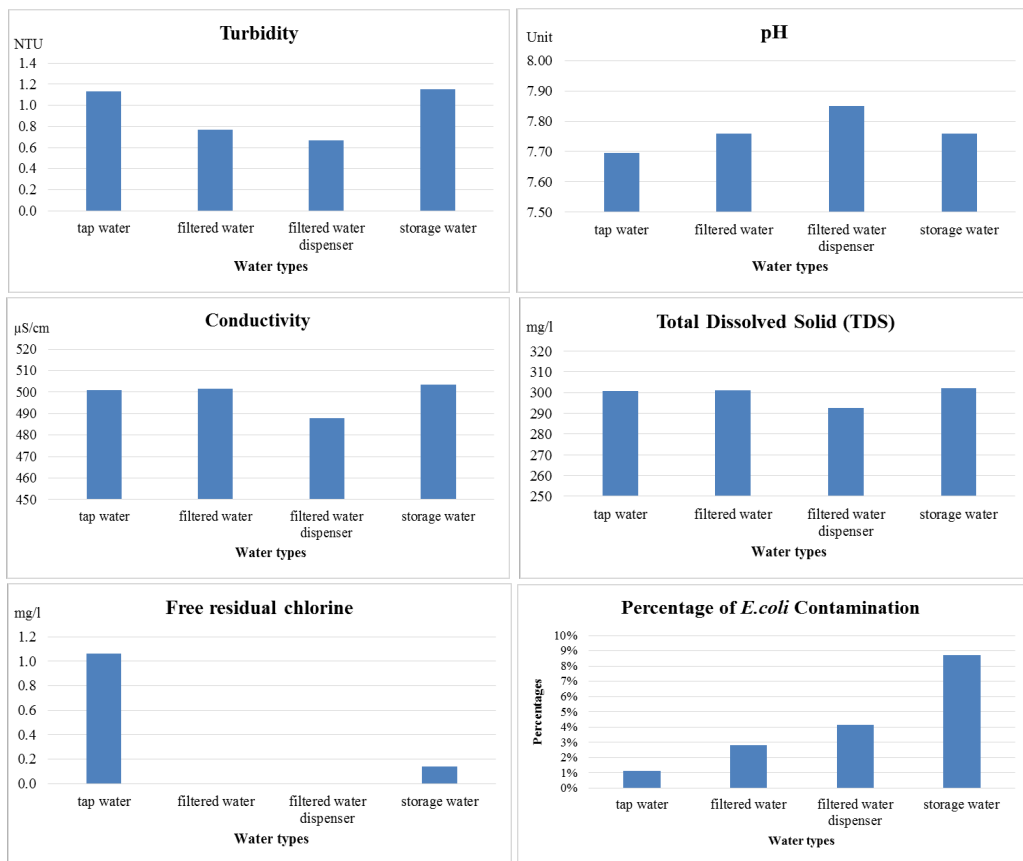
Fig. 4 Average water quality from tap water, filtered water, filtered water dispenser, and storage water classified by parameters

As shown in Fig. 4, the results indicated that the parameters, which were not compliance with WHO guidelines levels, were presence of bacteria *E.coli*, at 3.78% of all samples. The pH, turbidity, and TDS gotten above WHO guidelines level were recorded 0.43%, 0.28%, and 0.07%, of all samples respectively.

The results showed that the storage water had a highest number of samples, which did not meet WHO guidelines values, at 8.73%. The percentage of 4.13, 2.82, and 1.10 were not compliance with WHO guidelines levels, which were from filtered water dispenser, filtered water, and tap water, respectively. According to free residual chlorine chart (fig. 4), the tap water had higher chlorine values than the others. Therefore, it had a lowest chance to contaminate with bacteria *E.coli* from various causes such as broken of a storage tank, lack of water equipment maintenance or stain accumulation resulting in *E.coli* contaminated. WHO recommended in distribution system should be free residual chlorine above 0.2 mg/l to prevent post contamination. (WHO 2011) Moreover, tap water from distribution systems of MWA were compliance with WHO guidelines values probably because water quality monitoring was frequently monitored as WHO guidelines values both quality and quantity. Besides, MWA has 50 online monitoring stations for surveillance tap water quality. The stations are scattering settled cover our services area. Free residual chlorine, turbidity,

conductivity, and pH are shown in online monitoring so that this information is used for immediately water quality management. In addition, chlorination at nine pumping stations is one of the MWA methods to improve tap water quality.
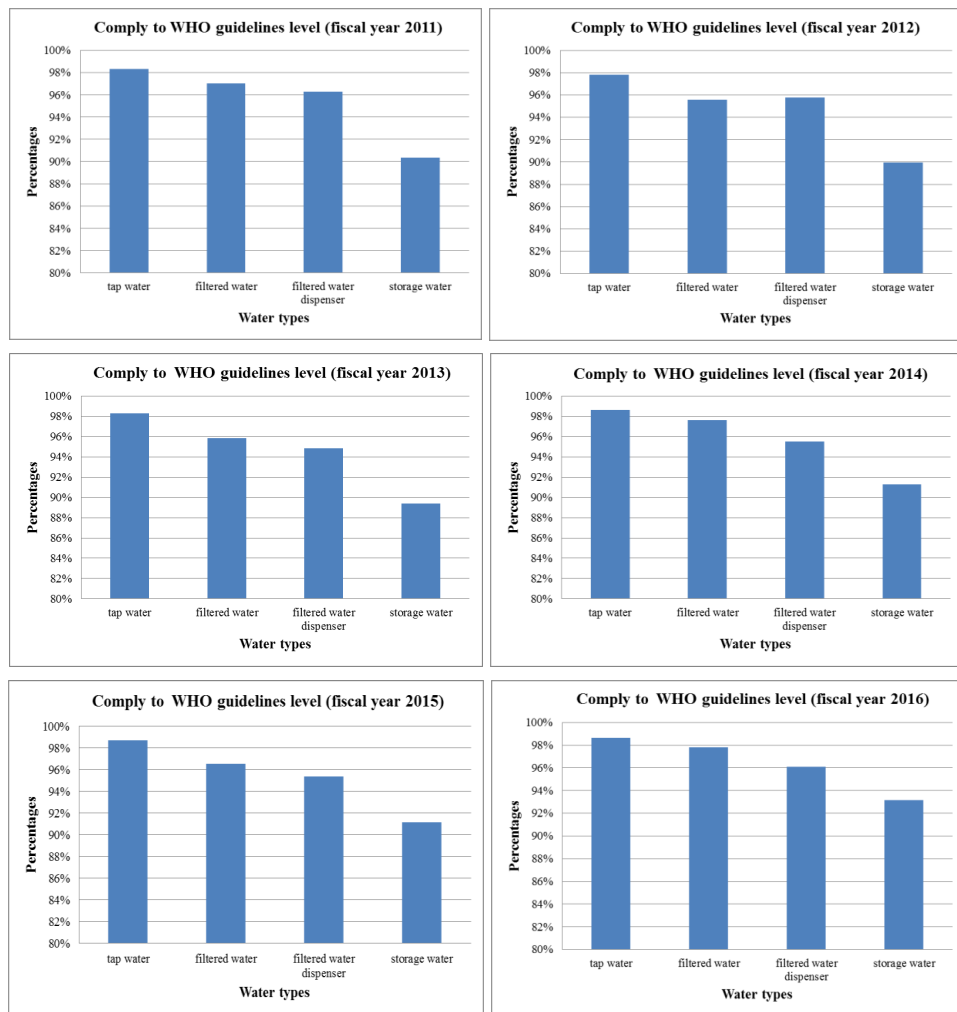
Table 5. WHO guideline values for drinking water quality 2011

Parameters	Units	WHO guidelines values for drinking water quality 2011
Free residual Chlorine	mg/l	-
Appearance color	True Color Unit (TCU)	Less than 15
Turbidity	Nephelo Turbidity Unit (NTU)	4.0
Conductivity	µS/cm	-
pH	-	6.5 - 8.5
Total Dissolved Solid (TDS)	mg/l	1000
Escherichia coli (*E.coli*)	P-A/100 ml	Absence

However, MWA tap water from distribution system compliance with WHO guidelines values is safety used and drunk. At present, many houses have storages tank for reserving water and solving low water pressure problem. People do not direct use water supply from distribution pipes so they water used is storage water. Filtered water and filtered water dispenser are used for drink because they need remove chlorine odor and reduce particles in the storage tanks. Nevertheless, the storage tanks and filter are a lot benefits. If they do not take care of equipment, they will make problems. For example, sediment in a bottom tank is collected when it does not clean or expiration filter results in biological contaminated and odor occurred. Therefore, taking care tanks and involved equipment have an effect on water quality.
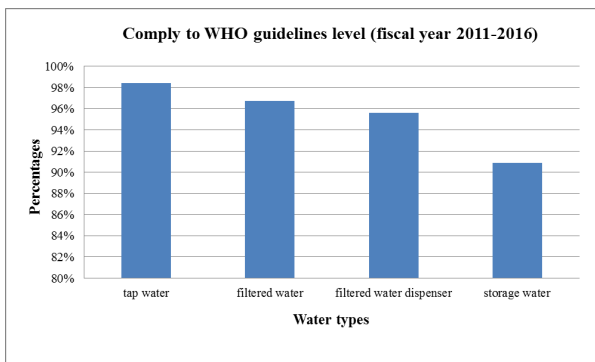
Fig. 5 The percentage of numbers of water sample compliances with WHO guideline values for drinking water quality 2011 classified by water type during fiscal year 2011 to 2016 (October, 2011 – September, 2016)

Fig.6 The percentage of numbers of water sample compliances with WHO guidelines values for drinking water quality 2011 classified by water type annually

CONCLUSIONS AND RECOMMENDATIONS

Consequence of this study, several samples were determined and complied with WHO guidelines for drinking water quality 2011. Tap water quality from pipelines in distribution system were not difference water quality from filter water, filtered water dispenser, and storage water. A number of tap water samples from those were a little many number samples complied with WHO level than any other samples. This is because MWA realized the importance of water quality and determined to improve water quality in the future. In order to build the trust of water supply as drinkable tap water, MWA has created Water Quality Integrated Center. The Water Quality Integrated Center was a hub of water quality management and control of remote automatic chlorination at pumping station. This systems will also increase an adequate amount of free residual chlorine in pipelines to prevent post contamination in faraway from water treatment plants. Moreover, MWA had sent water quality report of attended places to our customers by mail addresses. Customers could access

water quality information with themselves on the website http://twqonline.mwa.co.th, Facebook clean water clinic, or MWA on mobile application. The dissemination water quality information of tap water to customers would increase trustworthy of water supply and realize that the tap water gained international standard. Customers reached safe use and drink. However, using storage tanks, filter tanks, or filter dispensers should attend to always clean tanks and related equipment or change expired filter to eliminate bacteria contamination risk for safety water.

ACKNOWLEDGEMENT

REFERENCES

Duangta K., Chatchai C., Sopa C. (2013) Confidence of Tap Water for Drinking Purpose in Bangkok Metropolitan and Its Vicinity after Flooding Crisis. Proceeding *International Conference on Environmental and Hazardous Substance Management (EHSM 2013)*. Bangkok. Thailand. **O-J-08**, 1-8

Kornprabha K., Frank S., Andreas W., Jutta M., and Thomas P. K. (2005). Chemical water quality in Thailand and its impacts on the drinking water production in Thailand. *Science of the Total Environment*. **340**, 57-70

Marie Elize Z.S., Rosangela G.S., Marcio G., Iven C.F., Eliana H.E., Tania U.N., Celso V.N., and Benedito Prado P.D.F. (2008). *Int. J. Hyg. Environ. Health.* **211**, 504-509

Metropolitan Waterworks Authority (MWA): *Annual Report 2016 Metropolitan Waterworks Authority*. https://www.mwa.co.th/download/pln0201/annual2016/Annual_Report_2016_Eng.pdf (accessed 15 May 2017)

Metropolitan Waterworks Authority (MWA): *Metropolitan Waterworks Authority Standard*. (In Thai). https://www.mwa.co.th/download/prd01/tws/who2011.pdf (accessed April 2017)

Rosa C., Franco F., and Paolo T. (2011). Drinking water quality: Comparing inorganic components in bottled water and Italian tap water. *Journal of Food Composition and Analysis*. **24**, 184-193

Standard Methods for the Examination of Water and Wastewater (2012). 22nd edn, American Public Health Association, Washington DC, USA. Part 9060 A.2

Standard Methods for the Examination of Water and Wastewater (2012). 22nd edn, American Public Health Association, Washington DC, USA. Part 9060 B.

World Health Organization (WHO) 2011. Guidelines for Drinking Water Quality, 4rd ed, Geneva