

# Water Use Quality Situation over 10 Years (2010 to 2019) of Hospitals under the Ministry of Public Health, Thailand

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Received: March 22, 2022; Revised: April 19, 2022; Accepted: April 25, 2022

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## Abstract

This study aimed to investigate the situation of hospital water use quality and determined concern parameters contributing to health risk factor. A total of 15,560 water use samples from hospitals in all regions of Thailand between 2010 to 2019 were sampled and analyzed. Inferential statistics were employed to determine significant differences and relationships among water quality parameters. Hospital water use came from various sources. The probability of water use without treatment involved quality parameters not meeting the standard criteria than those treated water around 1.8 - 9.3 times. Chemical water quality parameters always remained under the standard requirement of pH (9.5%) and turbidity (5.6%). The majority of problems involved microbial indicators; total coliform bacteria (43.9%) and fecal coliform bacteria (33.2%). Water parameters related to exceeded total and fecal coliform bacteria standards included turbidity, nitrate, chloride and pH levels. The highest explicit turbidity relationship of occurrence probability exceeded the quality standards with total and fecal coliform bacteria 3.7 and 4.3 fold, respectively. Onsite hospital water treatment is needed to ensure safe conditions. The significant chemical parameters can be used as a rapid tool to estimate the situation of microbial indicators. Constant and frequent monitoring of water quality should be implemented for all stakeholders.

**Keywords:** Water Use; Hospital; Water Quality; Chemical parameter; Coliform bacteria

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## 1. Introduction

The water uses in Thailand come from various resources. They can be divided in two major sources which are surface and ground water. However, in some areas, rain water is also used as drinking water and other purposes. The main reasons selecting the location are availability and quality.

Regarding the water quality situation of Southeast Asian population, a survey of the World Health Organization indicated that most people cannot access clean water supply for drinking and other uses (WHO, 2017). People have reportedly died from drinking contaminated water especially involving

pesticides and chemicals from industrial effluent (WHO, 2017; Carrard *et al.*, 2019). In some area of Thailand, people have to drink water contaminated with chemicals and germs because treatment is unavailable before drink and a lack of awareness, knowledge, and understanding of drinking clean water exists especially regarding mountain and ground water supplies. A study by the Department of Health, Ministry of Public Health in 2018 and 2019 found surface water supplies had lowered quality and were unsuitable for drinking (Department of Health, 2018a). The major causation, more than 50%, was from coliform bacteria contamination.

Water quality depends primarily on the source it come from. Most raw water quality for water supply production was lowered due to pathogenic microbial and toxic substances discharged from human activities. The survey reports of drinking water supply in Thailand found surface water quality often encountered physical problems such as turbidity and color while those of ground water faced chemical constituents; hardness, iron, manganese, chloride, fluoride and sulfate (WHO, 2017; Department of Health, 2018b). Moreover, both surface and ground water also exhibited high contamination by total coliform and fecal coliform bacteria. A variety of contamination occurred during water supply and distribution processes. Most are subjected to conventional treatment processes before use; however, some do not. Thus, people would experience health risks when consuming these unqualified and contaminated water samples.

In urban communities where many significant institutes are located, water supply for health promotion centers and hospitals remains vitally important. It has been used for multi-purposes similar to those of community institutions and also for medical services. The water use quality should meet all essential drinking water parameter standards. The water quality has direct impact to patient health and hygienic performance of medical services. During 2019, 10,545 health promotion centers and hospitals were administered under the Ministry of Public Health, Thailand (Office of the Permanent Secretary, 2016). They totaled 9,750 health promotion centers, 644 community hospitals, and 151 general and large hospitals. These hospitals spend water use around 1,000 to 1,200 liter/bed/day (Chokewinyoo and Khanayai, 2013). Critical contamination factors involving this huge volume for these health service centers and hospitals should be well managed and monitored.

The study aimed to investigate the water quality being used in hospitals under the Ministry of Public Health, Thailand. The long term water characteristics and related data would express the trend fingerprint describing the water use situation, relationship, and risk issues. It could be used to develop strategic and surveillance plans to administer water

supply systems as a holistic measure for health sectors in Thailand and similar environment countries.

## 2. Materials and Methods

### 2.1 Water sampling

Water use samples of hospitals from all provinces in Thailand were randomly sampled by trained Public Health or Sanitary or Environmental Health officers working in hospitals, health centers, and provincial public health offices. They used aseptic techniques and specific water samples at the Laboratory Center, Department of Health, Ministry of Public Health, Thailand.

### 2.2 Analytical methods and water quality analysis

Water samples were analyzed immediately. In the case of time limitation, they were kept below 4°C. All samples were analyzed at the Laboratory Center, Department of Health, Ministry of Public Health, Thailand. Water samples from 2010 to 2019 totaled 16,066. Quality was determined using 20 quality parameters including pH, color, turbidity, total dissolved solids, iron, manganese, copper, zinc, lead, chromium, arsenic, mercury, sulfate, chloride, nitrate, fluoride, total coliform bacteria and fecal coliform bacteria. The analytical methods followed Standard Methods for the Examination of Water and Wastewater (APHA *et al.* 2017).

### 2.3 Statistical analysis

The water quality data was statistically processed and analyzed by comparing with the drinking water supply standard of the Department of Health, Ministry of Public Health B.E. 2553 (AD 2010) (Department of Health, 2010). The explanation statistics, number, frequency and percentage were used to explain physical, chemical and biological water qualities according to type of water and trends in last ten years. Inferential statistics such as Chi-square, Fisher's exact test, odd ratio, and multiple logistic regression analyses were studied to ascertain significant

differences and relationships among water quality parameters. Fisher’s exact test was used instead Chi-square, when more than 20% of cells have expected frequencies lower than 5. Real Statistics Resource Pack for Excel was used in statistical analysis.

### 3. Results and Discussion

#### Results

The investigation of hospital water use quality over ten years collected a total of 16,066 water samples accounting for around 1,607 samples/year. However, after statistical processing for data accuracy and completion, the number of samples which could be used for this study was reduced to 15,560.

The studied water samples originated from a variety of sources. However, they were grouped and classified in five types as described in Table 1.

The water samples were further grouped as with and without treatment before use. Water type 1 was without treatment and types 2 to 5 were with treatment. The overall water quality situation of these two groups compared with the drinking water supply standards (Department of Health, 2010) of Department of Health, Ministry of Public Health over the last ten years is described in Tables 2 and 3.

Chemical water quality parameters of the studied water sample were always under the standard required pH (9.5%). Acidified water (8.4%) was found more than alkaline water (1.2%). This problem was identified in all water types. The unqualified water pH occurred in this order; pond, deep and shallow well water 22.8%; raw water 20.1%; RO water 15.1%; filtered water 14.1%; closed container water 13.2%; bottled water 10.6%; and water supply, drinking and ground drinking water 10.2%.

**Table 1.** Type and amount of studied water samples

Type of studied water sample	Description	Number of water sample	Percent
1	Ground water, deep well water, shallow well water, pond water, rainwater, and raw water	331	2.1
2	Water supply, village water supply, surface water supply, municipality water supply, health promotion center water supply and hospital water supply	6,423	41.3
3	Drinking water, drinking water supply, drinking ground water and use and drinking water	6,852	44
4	Bottled water and water in closed container	439	2.8
5	RO (Reverse Osmosis) water, filtered drinking water, filtered or strained water supply and purified water	1,515	9.8
<b>Total</b>		<b>15,560</b>	<b>100</b>

**Table 2.** Detail of hospital water quality parameters exceeding the standard\* requirement

Parameter (unit)	Water without treatment (n = 331)		Water with treatment (n = 15,229)		Total (n = 15,560)	
	Number exceeding standard	Percent	Number exceeding standard	Percent	Number exceeding standard	Percent
pH	52	15.7	1428	9.4	1480	9.5
<6.5	31	9.4	1270	8.3	1301	8.4
>8.5	21	6.3	158	1.0	179	1.2
Turbidity (NTU)	73	22.1	801	5.3	874	5.6
Color (Pt/Co)	40	12.1	354	2.3	394	2.5
TDS (mg/L)	9	2.7	332	2.2	341	2.2
Hardness (mg/L)	2	0.6	202	1.3	204	1.3
NO <sub>3</sub> (mg/L)	4	1.2	81	0.5	85	0.5
SO <sub>4</sub> (mg/L)	8	2.4	161	1.1	169	1.1
Fluoride (mg/L)	12	3.6	562	3.7	574	3.7
Chloride (mg/L)	7	2.1	367	2.4	374	2.4
Fe (mg/L)	35	10.6	487	3.2	522	3.4
Mn (mg/L)	38	11.5	420	2.8	458	2.9
Cu (mg/L)	0	0	1	0.01	1	0.01
Zn (mg/L)	1	0.3	16	0.1	17	0.1
Cr (mg/L)	1	0.3	0	0.0	1	0.01
Cd (mg/L)	0	0.0	7	0.1	7	0.01
Pb (mg/L)	2	0.6	10	0.1	12	0.1
Arsenic (mg/L)	1	0.3	28	0.2	29	0.2
Hg (mg/L)	1	0.3	1	0.01	2	0.01
Coliform bacteria (MPN/100 mL)	217	65.6	6608	43.4	6825	43.9
Fecal Coliform bacteria (MPN/100 mL)	177	53.5	4,986	32.7	5,163	33.2

\* Notification of the Department of Health on criteria for drinking water supply, BE 2553 (AD 2010) (Department of Health, 2010).

Regarding biological water quality parameters, almost one half of studied samples detected coliform bacteria contamination above the standard criteria. Coliform bacteria comprised 6,825 samples (43.9%) and fecal coliform bacteria totaled 5,163 samples (33.2%). The comparison between bacterial contamination of each water type expressed that water type 1, which did not pass any treatment process before use revealed the highest contamination. Rainwater was contaminated with total coliform bacteria at 76.2% and fecal coliform bacteria at 66.7%, whereas those water samples from pond, deep and shallow wells found contamination at 63.2 and 43.9%, respectively. The treated commercial water; bottled and closed container water also found bacterial contamination exceeded the standard. Bottled water did not pass the standard requirement of total coliform and fecal coliform bacteria at 50.8% and 54.4%, respectively. In addition, the closed container water samples ranging from 37.0 to 38.8% also indicated similar conditions.

The water quality parameters were classified according to standard criteria and statistically analyzed to determine the parameter relationship as shown in Table 3. In all, 12 parameters (turbidity, total dissolved solids, total coliform bacteria, fecal coliform bacteria, pH, fluoride, hardness, nitrate, sulfate, chloride, iron and manganese) had significant relationship with type of water. In addition, from Table 4, the treatment before use (with and without treatment) exhibited a statistical relationship with 9 water quality parameters, i.e., turbidity, total coliform bacteria, fecal coliform bacteria, pH, nitrate, sulfate, iron, manganese and chromium. The overall finger-prints of water without treatment before use indicated that they always did not meet the standard requirement and had higher proportions than those water samples passing the treatment process. The three water quality parameters: hardness, fluoride, and chloride were clearly foreseen.

**Table 3.** Relationship between water quality parameter value (classified according to standard\* requirement) and type of hospital water samples

Parameter*	Type 1		Type 2		Type 3		Type 4		Type 5		Chi-square (df)	p-value
	n	%	n	%	n	%	n	%	n	%		
Turbidity (NTU)											189.34 (4)	< 0.001
> 5	73	22.1	391	6.1	328	4.8	13	3.0	69	4.6		
< 5	258	77.9	6032	93.9	6524	95.2	426	97.0	1446	95.4		
TDS (mg/L)											41.34 (4)	< 0.001
> 1000	9	2.7	196	3.1	100	1.5	10	2.3	26	1.7		
< 1000	322	97.3	6227	96.9	6752	98.5	429	97.7	1489	98.3		
Coliform bacteria (MPN/100 mL)											90.05 (4)	< 0.001
> 1.8	217	65.6	2858	44.5	2887	42.1	232	52.8	631	41.7		
< 1.8	114	34.4	3565	55.5	3965	57.9	207	47.2	884	58.3		
Fecal coliform bacteria (MPN/100 mL)											86.99 (4)	< 0.001
> 1.8	177	53.5	2214	34.5	2141	31.2	167	38.0	464	30.6		
< 1.8	154	46.5	4209	65.5	4711	68.8	272	62.0	1051	69.4		
pH											167.51 (8)	< 0.001
< 6.5	31	9.4	417	6.5	604	8.8	49	11.2	200	13.2		
6.5-8.5	279	84.3	5951	92.7	6165	90.0	386	87.9	1299	85.7		
> 8.5	21	6.3	55	.9	83	1.2	4	.9	16	1.1		
Fluoride (mg/L)											54.88 (4)	< 0.001
> 0.7	12	3.6	332	5.2	192	2.8	9	2.1	29	1.9		
< 0.7	319	96.4	6091	94.8	6660	97.2	430	97.9	1486	98.1		
Hardness (mg/L)											23.54 (4)	< 0.001
> 500	2	.6	116	1.8	57	.8	8	1.8	21	1.4		
< 500	329	99.4	6307	98.2	6795	99.2	431	98.2	1494	98.6		
NO <sub>3</sub> (mg/L)											51.35 (4)	< 0.001
> 50	4	1.2	36	.6	18	.3	1	.2	26	1.7		
< 50	327	98.8	6387	99.4	6834	99.7	438	99.8	1489	98.3		
SO <sub>4</sub> (mg/L)											8.19 (4)	0.021
> 250	8	2.4	77	1.2	70	1.0	3	.7	11	.7		
< 250	323	97.6	6346	98.8	6782	99.0	436	99.3	1504	99.3		
Chloride (mg/L)											70.32 (4)	< 0.001
> 250	7	2.1	236	3.7	96	1.4	9	2.1	26	1.7		
< 250	324	97.9	6187	96.3	6756	98.6	430	97.9	1489	98.3		
Fe (mg/L)											45.53 (4)	< 0.001
> 0.5	35	10.6	208	3.2	220	3.2	10	2.3	49	3.2		
< 0.5	296	89.4	6215	96.8	6632	96.8	429	97.7	1466	96.8		
Mn (mg/L)											58.96 (4)	< 0.001
> 0.3	38	11.5	208	3.2	179	2.6	4	.9	29	1.9		
< 0.3	293	88.5	6215	96.8	6673	97.4	435	99.1	1486	98.1		

\*Notification of the Department of Health on criteria for drinking water supply, B.E. 2553 (A.D. 2010) (Department of Health, 2010).

f=Fisher's exact test

**Table 4.** Relationship between water quality parameter value (classified according to standard\* requirement) and treatment of hospital water samples

Parameter*	Without treatment		With Treatment		Chi-square (df)	OR 95%CI	p-value
	n	%	n	%			
Turbidity (NTU)					172.36 (1)	5.097 (3.893,6.672)	< 0.001
> 5	73	22.1	801	5.3			
< 5	258	77.9	14428	94.7			
Coliform bacteria (MPN/100 mL)					64.654 (1)	2.483 (1.975,3.122)	< 0.001
> 1.8	217	65.6	6608	43.4			
< 1.8	114	34.4	8621	56.6			
Fecal Coliform bacteria (MPN/100 mL)					62.816 (1)	2.361 (1.898,2.938)	< 0.001
> 1.8	177	53.5	4986	32.7			
< 1.8	154	46.5	10243	67.3			
pH					81.154 (2)	1.801 (1.333,2.434)	< 0.001
< 6.5	31	9.4	1270	8.3			
6.5-8.5	279	84.3	13801	90.6			
> 8.5	21	6.3	158	1.0			
NO <sub>3</sub> (mg/L)						2.288 (0.833,6.280)	0.107 <sup>f</sup>
> 50	4	1.4	81	.6			
< 50	327	98.8	15148	99.5			
SO <sub>4</sub> (mg/L)						2.318 (1.130,4.755)	0.028 <sup>f</sup>
> 250	8	2.5	161	1.1			
< 250	323	97.6	15068	98.9			
Fe (mg/L)					54.364 (1)	3.579 (2.493,5.140)	< 0.001
> 0.5	35	10.6	487	3.2			
< 0.5	296	89.4	14742	96.8			
Mn (mg/L)					86.276 (1)	4.573 (3.217,6.500)	< 0.001
> 0.3	38	11.5	420	2.8			
< 0.3	293	88.5	14809	97.2			
Pb (mg/L)						9.252 (2.019,42.390)	0.026 <sup>f</sup>
> 0.01	2	0.6%	10	0.1%			
< 0.01	329	99.4%	15219	99.9%			

\*Notification of the Department of Health on criteria for drinking water supply, B.E. 2553 (A.D. 2010) (Department of Health, 2010).

<sup>f</sup>=Fisher's exact test

The statistical analysis results indicated the probability of water use without treatment would exhibit water quality parameters below the standard criteria accounting for the number of water use times with treatment in this ranked order: lead 9.252 times, turbidity 5.097 times, manganese 4.573 times, iron 3.579 times, total coliform bacteria 2.483 times, fecal coliform bacteria 2.361 times, sulfate 2.318 times, nitrate 2.288 times and pH 1.801 times.

Inferential statistics, bivariate analysis, was used for assess the relationship of physical and chemical water quality parameters with total coliform bacteria and fecal coliform bacteria. Six physical and chemical water quality parameters revealed a significant relationship with those coliform bacteria. The top three relationships with total

coliform bacteria ranged from high to low in ranked order: turbidity, nitrate and chloride. In addition, parameters related to fecal coliform bacteria ranged in ranked order as turbidity, chloride and hardness.

The relationship of studied water quality parameters was further analyzed using Multivariate with Multiple Logistic Regression. Parameters related to exceeded coliform bacteria standards were turbidity, nitrate, chloride and pH. These findings implied that water with turbidity over standard requirement would contain total coliform bacteria higher than standard value 3.745 fold than those water samples with acceptable turbidity value. This phenomenon was explained in the similar relationship of nitrate, chloride and pH which were 2.095, 1.969, and 1.177 folds, respectively.

The data bank of water quality parameters was further statistical analyzed to determine relationships to fecal coliform bacteria. The occurrence probability of exceeded water quality parameters and fecal coliform bacteria were pH, turbidity, hardness, chloride and nitrate and were 4.251, 1.974, 1.454, 1.363 and 1.296 fold for turbidity, chloride, hardness, nitrate and pH, respectively.

### Discussion

The overall performance of clean water services with piping water supply of Thailand shows an increasing area coverage tendency. The report of water supply survey of the whole country in 2015 from the Department of Health and Department of Local Administration pointed out 66,074 water supply systems were produced and operated under different organizations: 13 plants of the Metropolitan Waterworks Authority, 228 plants of the Provincial Waterworks Authority and 65,833 plants of Local Administration and Village Water Supply committees (Department of Health, 2015). It revealed water use quality depended primarily on the treatment and administration of each local administration. Many reports have indicated water contamination problems of the treated water in Thailand time by time. Water samples from village surface water supplies in Khon Kaen (Prapasamut and Sangsittisawat, 2006) and Ubon Ratchathani (Amnath *et al*, 2014) Provinces in northeast Thailand, did not pass drinking water standards by 90.91% and 48%, respectively. Moreover, the Department of Health inspected water samples from 445 village water supply all over Thailand in 2018 and found only 19.1% of total samples met the drinking water standard (Department of Health, 2018a). In addition, 72.4% was highly contaminated with coliform and fecal coliform bacteria.

Hospitals in Thailand use water from a variety of sources. Most used treated water such as the water supply of the local administration, water supply from deep water wells and filtered water. The statistically analyzed result in this study confirmed that the treated water had significantly lower quality parameter problems than those of the

untreated water. Unfortunately, many hospitals had to use untreated water from rain, shallow wells and deep wells as alternative choices. This was due to the high water use demand and/or the local administration affording insufficient water demand volume. This situation presents a risk to population health especially in areas where urbanization is increasing faster than the public infrastructure services.

A research report investigated untreated water quality used in a hospital. Prasertsin *et al*. (2017) studied water supply qualities from a mountain water supply in Chiang Rai Province in northern Thailand. It found the mountain water supply was operated by pump water from small waterways, transferred using PVC pipe, stored in tanks, and directly distribute to be used in hospital units. The water quality problems included turbidity ( $3.13 \pm 1.83$ - $8.32 \pm 9.75$  NTU), manganese ( $0.50 \pm 0.27$  -  $0.80 \pm 0.42$  mg/L), coliform bacteria ( $2.2$  -  $>23$  MPN/100 mL) and fecal coliform bacteria ( $1.1$  -  $>23$  MPN/100 mL). The conclusion created concerns that no water samples passed the drinking water supply standard requirement of the Department of Health B.E. 2553.

The record of water quality during ten years (2010 to 2019) confirmed all types of water use in hospitals still encountered quality problems. These included pH, turbidity and contamination by coliform bacteria especially fecal coliform bacteria. Some water samples were contaminated with highly toxic heavy metals such as cadmium, mercury and lead. A similar situation can be found in Bangladesh, a South Asian country, as reported by Houque *et al*. (2006). Up to 85% of Bangladeshis could access clean water services but more than 35 million individuals still experienced frequent water borne diseases. Total coliform bacteria and fecal coliform were major constituents found in the water samples. Some people experienced the impact from arsenic poisoning because arsenic contamination in water reached up to 0.05 mg/L.

Regarding the research by Hanwarodom and Chansung (2016) concerning water supply quality improvement of 115 hospitals under the Clean Water Project of the Ministry of Public Health, Thailand, only 31.30% of water

use in these hospitals met the standard criteria. Problems from these parameters occurred in this ranked order: total coliform bacteria 55.65%, fecal coliform bacteria 46.09%, pH 17.39%, turbidity and color 3.48%, chloride 5.23%, sulfate 4.35%, total dissolved solids 3.48%, hardness 1.74% and manganese 0.87%. A study by Rakkamon *et al.* (2012) explained that most hospitals in Thailand have installed water filtered systems including the resin and/or reverse osmosis filter systems. Nevertheless, contamination by lead, coliform and fecal coliform bacteria was still found in these water samples. They reflected the course of problems stemmed from raw water quality, filtering system, and maintenance.

This study found a close relationship among five chemical parameters: turbidity, chloride, hardness, nitrate and pH with total and fecal coliform bacteria. The highest predominant parameter was turbidity exhibiting an occurrence probability of exceeded water quality parameters 3.7 to 4.3 fold. Most turbidity in water samples resulted from all kinds of solid constituents and was mediated by microbial cells. Therefore, increased concentrations of some chemical compounds in water can influence the appearance and growth of microbiologic populations. Some studies confirmed the relationship of these bacterial indicators with chemical water parameters. A study of Habuda-Stanić *et al.* (2013) investigated the microbiologic quality of drinking water in 25 public and municipal water supply systems in the area of Osijek-Baranja County in eastern Croatia. They found a positive correlation between turbidity and appearance of total coliform bacteria, Enterococci and *Escherichia coli* populations (the higher the turbidity, the higher appearance of microbiological populations). Aram *et al.* (2021) also assessed the relationship between coliform bacteria and water geochemistry in surface and ground water systems in the Tarkwa mining area in the Western Region of Ghana, West Africa, using logistic regression models. They found higher values of electrical conductivity (OR = 1.097,  $p < 0.05$ ), nitrates (OR = 1.191,  $p < 0.05$ ) and total suspended solids (OR = 1.023,  $p < 0.05$ ) associated with higher odds of fecal coliform contamination

of groundwater sources. Moreover, higher values of total suspended solids (OR = 1.054,  $p < 0.05$ ) and nitrates (OR = 1.069,  $p < 0.05$ ) implied the contamination by total coliform in ground water sources.

In addition to the influence from the presence of microbial populations on chemical water quality, the disinfectant dosage also plays an important role. All plants in Thailand use chlorine as the disinfectant in their water treatment process. Improper water chlorination, means lowered disinfection efficiency, and creates similar risks as those in untreated water. Investigating the source of microbial contamination and improving disinfection efficacy should be considered. Habuda-Stanić *et al.* (2013) confirmed a negative correlation was observed between appearance of microbiologic populations and concentrations of free residual chlorine. The limited sanitary facilities of centralized treatment systems and distribution networks should determine the practical point-of-use (POU) for water chlorination. Clayton *et al.* (2021) suggested selecting hypochlorous acid as an appropriate alternative to chlorine-based disinfectants for POU drinking water applications because it provided better antimicrobial and anti-biofilm activity than other chlorine-based disinfectants.

#### 4. Conclusion

The conclusion of this study revealed that water use quality in hospitals under the Ministry of Public Health, Thailand undergoing risky situations over a long time. Its chemical and biological water quality primarily resulted from water origin, treatment process, and handling management. Local Administrations and Village Water Supply Committees, in charge of 99.6% of water treatment plants all over the country, should pay more attention to enhancing better water quality. They can use the significant chemical parameters such as turbidity, chloride, hardness, nitrate and pH as a rapid tool to estimate the situation of microbial indicators. Similarly, hospitals should choose only clean water use. When selection is limited, further onsite water treatment and disinfection are recommended. Because low water

quality is one of the means through which many infectious agents can be transmitted to humans causing waterborne diseases, constant and frequent monitoring of its quality are needed.

A further feasibility study for evaluating the effectiveness of removing turbidity and Coliform bacteria from various water sources of the hospital using primary treatment system (settling techniques) followed by chlorination should be carried out in comparison with those of the full-scale conventional treatment system. The results of this study could be applied to some of the hospitals having limited budgets and/or water sources.

## Acknowledgement

This research work is supported in part by the grant from Center of Excellence on Environmental Health and Toxicology (EHT), OPS, Ministry of Higher Education, Science, Research and Innovation.

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