Evaluation of Drinking Water Quality in Schools in a District Area in Hanoi, Vietnam

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Source: Environmental Health Insights, 14(1)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/1178630220959672

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Environmental Health Insights
Volume 14: 1–8

DOI: 10.1177/1178630220959672
SAGE

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ABSTRACT

BACKGROUND: Drinking water quality affects directly human health. Assessment and prevention of water-borne diseases are crucial for primary prevention, especially for children.

OBJECTIVE: The main aim of this study was to investigate the quality of drinking water from tap water in preschools and primary schools in a district area in Hanoi City, Vietnam.

METHODS: A cross-sectional study was performed from August to October 2019. Water samples from tap water of 154 schools in a district area of Hanoi were collected to determine the quality of drinking water. From each school, at least 2 bottles of water samples were collected on the basis of a standard operating procedure (SOP). Each water sample was analyzed for microbial and physicochemical parameters, including Color, Taste and Odor, Turbidity, pH, Nitrite, Nitrate, Ammonium, Total Iron, Permanganate, Chloride, Hardness, Total Manganese, Sulfate, Arsenic, *Coliform*, and *E.coli*, by analytical methods. The obtained values of each parameter were compared with the standard values set by WHO and National Technical Regulation on Domestic Water Quality of Vietnam.

RESULTS: All of the schools employed community water system as a main source for drinking water. The results showed that all tested samples were found to be within the standards for some physicochemical properties, including Color, Taste and Odor, Hardness, Chloride, Total Iron (Fe^{2+} và Fe^{3+}), Total Manganese (Mn), Nitrate (NO_3^-), Sulfate (SO_4^{2-}), and Total Arsenic (As). On the other hand, some samples did not meet the allowable limits of the national standard, due to pH (3.9%), Turbidity (0.6%), Nitrite (3.2%), Permanganate (6.5%), and Ammonium (5.8%). Furthermore, the microbial data revealed that the substandard water samples from municipal water systems were contaminated by *Coliform* (9.7%) and/or *E.coli (*7.8%).

CONCLUSIONS AND RECOMMENDATIONS: Contaminants such as bacterial and chemical agents in to drinking water could be occurred during transport, storage and handling before using by the consumer without regular surveillance. A periodic treatment procedure and monitoring system to keep the level of microbial and chemical contamination of drinking water in schools under control should be performed.

KEYWORDS: Drinking water, tap water, water quality, chemicals, microbial, Hanoi, Vietnam

RECEIVED: August 23, 2020. **ACCEPTED:** August 26, 2020.

TYPE: Original Research

FUNDING: The author(s) received no financial support for the research, authorship, and/or publication of this article.

DECLARATION OF CONFLICTING INTERESTS: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Introduction

Water plays a vital role for human life, and human should be assessed to clean water to sustain good health. According to the World Health Organization (WHO), tangible benefits to health can be obtained from access to safe drinking water.[1] Access to safe and affordable drinking water for all is among the first target of the Sustainable Development Goal 6 (SDG6) established by the United Nations General Assembly in 2015.[2] Poor drinking water quality impacts all of us, but children and infants are especially at risk of exposure to contaminated water. It has been hypothesized that exposure to fecal contamination due to living in poor water, sanitation, and hygiene (WaSH) conditions may play a fundamental role in the genesis and persistence of childhood undernutrition.[3,4] Theory and biological evidence suggest that alteration in the gut and immune system due to repeated exposure to pathogens related to poor WaSH is particularly important for chronic outcomes such linear growth faltering.[3,5,6] In addition, epidemiological evidence shows that the burden of childhood growth faltering is heavily concentrated in areas of deep poverty and poor WaSH; the prevalence of stuning is typically high across South Asia, Eastern and Southern Africa, and Western and Central Africa.[7] A systematic review, which assessed the impact of drinking water and sanitation on diarrhoeal disease in low- and middle-income settings published between 1970 and May 2013, showed that inadequate water and sanitation are associated with considerable risks of diarrhoeal disease, and that there are notable differences in illness reduction according to the type of improved water and sanitation implemented.[8] A study on the chemical analyses of 68 water samples and 213 biological samples (human hair and urine) of residents living in 4 districts, including Tu Liem, Dan Phuong, and Hoai Duc in Hanoi an Ly Nhan in Ha Nam, in the Red River Delta in Viet Nam showed that concentrations of arsenic in hair and urine increased significantly with increasing arsenic content in drinking water, indicating that drinking water is a significant source of arsenic exposure for these residents who had hair arsenic concentrations higher than 1 μg/g, which is a level that can cause skin lesions.[9]

Water distribution systems act on maintaining and delivering safe water to the public.[10] However, safe drinking water at the source does not necessarily guarantee its safety at the consumption point because of the possibility of recontamination of drinking water with organisms and/or chemicals between the source and the household.[11] Therefore, providing safe water from a reliable source and establishing a monitoring system to ensure that the water is safe for consumption for children are the main concern of water users. Regarding the quality of drinking water, microbiological contamination is a primary concern of developing countries. Contamination with bacteria may be due to leakage/discharge from septic tanks, lack of sewage and solid waste disposal systems which were the main threats to water resources.[1] In addition, chemical contaminants, concerning both health and aesthetic aspects, can be present in the water. Water supplies can be polluted due to chemical and microbiological contaminants and as a result of certain activities, such as inadequate treatment and disposal of waste from humans and livestock, industrial discharges, and over-use of limited water resources.[12-17] Heavy metal contamination with non-essential elements like arsenic in drinking water pose a serious threat to human health, since it is very toxic and can be carcinogenic.[18] This has raised public health concern as the organisms and chemicals identified can cause water-related diseases that have serious health effects, especially for susceptible individuals like children, pregnant women, the elderly and those who have chronic diseases.[12-18] According to a report from World Health Organization, there are 3.4 million deaths annually, mostly children due to water-related diseases, and the situation is much worse in the rural areas of developing countries.[19] Another study, which estimated infection risks and the global burden of diarrheal disease, showed that unsafe water supply is estimated to cause 17.2 million infections, including 4.52 million cases of diarrhea, 109 000 diarrheal DALYs (Disability-adjusted life-years), and 1560 deaths each year, especially in low and middle-income countries.[20]

Adequate quality of drinking water has to be available for users. Unfortunately, the supply of safe drinking water has been compromised by the absence of adequate sanitary infrastructure in some regions of developing countries like Vietnam, where this vital resource is vulnerable to pollution. A pilot study on the current quality of drinking and domestic water in Hanoi in 2014 showed that only 3.65% of 192 tested samples met the established water quality standards for chemical parameters, mainly due to free chlorine, ammonium, and arsenic concentrations. About 56.5% of tested water samples had *Coliforms*, and the high contamination of the bacteria could be due to the old water pipe systems in Hanoi and the low concentration of free chlorine, which was not enough to kill bacteria in water. Notably, none of the tested samples met the standards for chemical and microbial parameters.[21]

Therefore, the natural water analyses for microbial and physicochemical properties are very important for public health studies. The objectives of the study described in this paper are to assess some physicochemical and microbial parameters of drinking waters, to identify schools using unsafe water sources in a district of Hanoi in 2019 and to suggest possible solutions to reduce the problems of contamination.

Methods and materials

Study design

We employed a cross-sectional research design in this study. Drinking water from the tap of all public and private preschools and primary schools (154/154) in the studied areas was sampled.

Research area

The study was performed in Ha Dong District, Hanoi, Vietnam. Research on evalutaion of drinking water quality in districts in Hanoi, Vietnam is limited, and Ha Dong is the only district where drinking water samples from all schools were collected for testing at the same time through a monitoring program organized by the Ha Dong Department of Education. Ha Dong is an urban district of Ha Noi capital, the second highest of all districts in Ha Noi with a population of 352 002 reported in 2018, and covers a total area of 47.91 km^2. The district is located in the southwest of the city of Ha Noi, and covers a total area of 47.91 km^2. Administrative divisions consist of 17 wards, namely, Bien Giang, Dong Mai, Duong Noi, Ha Cau, Kien Hung, La Khe, Mo Lao, Nguyen Trai, Phu La, Phu Lam, Phu Luong, Phuc La, Quang Trung, Van Phuc, Van Quan, Yen Nghia, Yet Kieu (Figure 1).[22]

Water sample collection and processing

The study was implemented from August to October 2019 through the monitoring program for drinking water of schools in the studied area. Water samples were collected using new plastic sampling bottles (2 litters). Care must be taken not to contaminate the bottle or cap. At the water sampling site, a cold water faucet, which is clean and free of sources of contamination, was selected and water suply was thoroughly flushed from 3 to 5 minutes. Bottles were then rinsed 3 times with sampled water before it was finally filled to within one to two inches from the top, capped, labeled, and placed in a cool

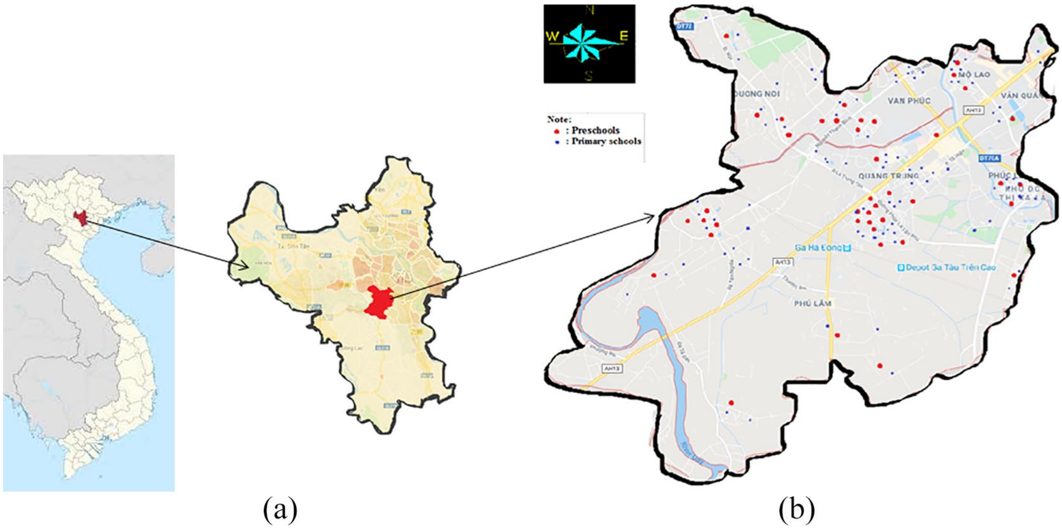

Figure 1. (a) Map of location of Ha Dong district. (b) Map of water sample collection points.

box. The samples were then transported to Laboratory Center, Hanoi University of Public Health for analysis of microbial and physicochemical parameters of daily collected samples.

Analysis items and methods

The items analyzed for each water sample were Color, Taste and Odor, Turbidity, pH, Hardness, Chloride, Total Iron, Total Manganese, Nitrate, Nitrite, Permanganate, Sulfate, Ammoniac, Total Arsenic, *Coliform* and *E. coli*, based on standard procedures.[23]

In the Laboratory, *E coli* and *Coliform* were determined using the most probable number method (MPN). Water to be tested is diluted serially and inoculated in lactose broth, coliforms if present in water utilize the lactose present in the medium to produce acid and gas. The presence of acid is confirmed by the medium color change, and gas bubbles collected in the inverted durham tube present in the medium indicated the presence of gas. The number of total coliforms is determined by counting the number of tubes giving positive reaction (ie, both color change and gas production) and comparing the pattern of positive results (the number of tubes showing growth at each dilution) with standard statistical tables. pH was measured using digital pH meter (HACH). Turbidity Meter (HACH) was used for Turbidity measurement. Other chemical parameters were evaluated by titration methods and UV-VIS spectrometer (Perkin Elmer) on the basis of standard procedures. Traces elements were determined by PinAAcle 900T Atomic Absorption Spectrometer (Perkin Elmer). All measurements were completed in triplicate. Table 1 shows these items and the analytical methods used.

Quality control and quality assurance

All intrusments used for analysis of microbiological and physicochemical parameters of samples were calibrated and validated anually by a certified measurement service organization. Regarding bacteria evaluation, we used a negative control (sterile water) and a positive control strain (ATTC 25922 Lot No.59301741). Regarding physicochemical parameters, internal quality control was also performed in a batch of test samples to monitor compliance with acceptance criteria on the basis of standard guidelines. For chemical parameters evaluated by titration, a blank sample (deionized water) and a standard sample at a known concentration were also analyzed. For chemical parameters analyzed by UV or AAS method, specificity was conducted by a blank sample (deionized water). Linearity and working range were perfomed and a high correlation coefficient was obtained. Recovery experiments were also made by using a spiked sample at a known concentration. In addittion, repeatability and and reproducibility were also performed for quality control of all measurement.

Data analysis

Descriptive statistics was used to described the element concentrations, which was compared with the maximum values recommended by WHO and established standard for drinking water in Vietnam (QCVN01) that provides guidelines for controlling and monitoring the quality of drinking water for human consumption in Vietnam.[24,25]

Results

A total of 154 water samples were collected from the tap of schools and analyzed in the laboratory for microbial and physicochemical parameters. The values, including mean, minimum, and maximum values for microbial and physicochemical parameters of drinking water, are shown in Table 2. The obtained values of each parameter were compared with the standard values set by WHO and QCVN01.[25,26]

Overall, the results showed that all tested samples are within the standard of WHO and QCVN01 for physicochemical parameters, including Color, Taste and Odor, Hardness,

Table 1. Analytical methods.

NO	CHARACTERISTIC	TEST METHOD	UNIT
1	Color	Perceptible	–
2	Taste and odor	Perceptible	–
3	Turbidity	TCVN 6184-1996	NTU
4	pH	TCVN 6492:2011	pH
5	Hardness, calculated by $CaCO_3$	TCVN 6224:1996	mg/L
6	Chloride	TCVN 6194:1996	mg/L
7	Total Iron (Fe^{2+} và Fe^{3+})	SMEWW 3111B:2012	mg/L
8	Total Manganese (Mn)	SMEWW 3111B:2012	mg/L
9	Nitrate (NO_3^-)	TCVN 6180:1996	mg/L
10	Nitrite (NO_2^-)	TCVN 6178:1996	mg/L
11	Permanganate	TCVN 6186:1996	mg/L
12	Sulfate (SO_4^{2-})	SMEWW 4500SO_4^{2-}E:2012	mg/L
13	Ammoniac (NH_4^+)	TCVN 6179-1:1996	mg/L
13	Total Arsenic (As)	SMEWW 3113B:2012	mg/L
15	Total *Coliform*	TCVN 6187-2:1996	MPN/100 mL
16	*E. coli*	TCVN 6187-2:1996	MPN/100 mL

Table 2. General results of microbial and physicochemical parameters.

NO	PARAMETERS	UNIT	MEAN	MINIMUM	MAXIMUM	QCVN01 REGULAR LIMIT	WHO LIMIT
1	Color	–	None	None	None	None	–
2	Taste and odor	–	None	None	None	None	–
3	Turbidity	NTU	0.45	0.2	4.33	2	<1
4	pH	pH	7.73	6.45	8.79	6.5-8.5	<8
5	Hardness, calculated by $CaCO_3$	mg/L	67.58	0	220	300	–
6	Chloride	mg/L	14.94	1.28	78.49	250	<250
7	Total Iron (Fe^{2+} và Fe^{3+})	mg/L	0.14	0.1	0.25	0.3	<0.3
8	Total Manganese (Mn)	mg/L	0.13	0.1	0.28	0.3	0.3
9	Nitrate (NO_3^-)	mg/L	3.98	0.1	40.4	50	50
10	Nitrite (NO_2^-)	mg/L	2.1	0.03	17.7	3	3
11	Permanganate	mg/L	1.33	0.82	14.4	2	–
12	Sulfate (SO_4^{2-})	mg/L	9.45	1.3	27.1	250	250
13	Ammonium (NH_4^+)	mg/L	1.57	0.04	7.16	3	<3
14	Total Arsenic (As)	mg/L	0.003	0.002	0.004	0.01	0.01
15	Total *Coliform*	MPN/100 mL	–	0	$2.4.10^3$	0	0
16	*E. coli*	MPN/100 mL	–	0	$2.4.10^3$	0	0

Table 3. Results of samples exceeded limits for physicochemical parameters.

CHARACTERISTIC	BELOW LIMITS		ABOVE LIMITS		REGULAR LIMIT
	N	%	N	%	
pH	148/154	96.1	6/154	3.9	6.5-8.5
Ammonium (NH_4^+)	145/154	94.2	9/154	5.8	⩽3 mg/L
Permanganate	144/154	93.5	10/154	6.5	⩽2 mg/L
Nitrite (NO_2^-)	149/154	96.8	5/154	3.2	⩽3 mg/L
Turbidity	153/154	99.4	1/154	0.6	⩽2 NTU

Table 4. Results of samples exceeded limits for microbial parameters.

C CHARACTERISTIC	BELOW LIMITS		ABOVE LIMITS		REGULAR LIMIT MPN/ 100 ML
	N	%	N	%	
Coliform	139/154	90.3	15/154	9.7	0
E.coli	142/154	92.2	12/154	7.8	0

Chloride, Total Iron (Fe^{2+} và Fe^{3+}), Total Manganese (Mn), Nitrate (NO_3^-), Sulfate (SO_4^{2-}), Total Arsenic (As). However, several samples did not meet the recommended acceptable range by WHO and QCVN01 for some physicochemical and microbial parameters, including pH (6/154, 3.9%), Turbidity (1/154, 0.6%), Nitrite (5/154, 3.2%), Permanganate (10/154, 6.5%), Ammonium (9/154, 5.8%), Total *Coliform* (15/154, 9.7%), *and E. coli* (12/154, 7.8%) as shown in Tables 3 and 4. Considering the percentage of samples that meet the WHO/QCVN01 guidelines for all parameters, it was found that 71% (110/154) of the tested samples meet the drinking water quality standards of the WHO/QCVN01.

Discussions

Physicochemical parameters

pH is classed as one of the most important water quality parameters because it can affect the disinfection process.[26-29] The data in Table 1 showed that pH of the water ranged from 6.45 to 8.79 (mean: 7.73). pH is a value to show the concentration of the hydrogen ion in water. The pH of a neutral solution is 7, the pH of an alkaline solution is greater than 7, and the pH of an acidic solution is less than 7. The pH range of safe drinking water mentioned in the National Technical Regulation on Domestic Water Quality of Vietnam (QCVN01) is between 6.5 and 8.5, and the desirable limits of WHO for pH is below 8.[24,25] Among the tested samples, the pH of 148 samples (96.1%) was in accordance with the level of WHO and QCVN01, and 6 samples (3.9%) crossed the permissible guideline values (Table 3). The pH of drinking water has no immediate direct effects on human health but has some indirect health effects by changing other water quality parameters, such as metal solubility and survival of pathogens. Acidic water can lead to corrosion of metal pipes and plumbing system. Meanwhile, alkaline water shows disinfection in water.[26-29]

Turbidity is another key parameter in drinking water analysis. It is the cloudiness of water caused by a variety of particles. It is also related to the content of diseases-causing organisms in water, which may come from soil runoff.[24,30] The standard recommended maximum turbidity limit, set by WHO and QCVN 01, for drinking water is less than 1 and 2 nephelometric turbidity units (NTU), respectively, since the appearance of water with a turbidity of less than this value is usually acceptable to water users.[24,25] It does not have a health based-guideline; nevertheless, microorganisms (bacteria, viruses and protozoa) are typically attached to particulates. As a consequence, contamination with bacteria in turbid waters can be occurred and indirectly effects human health. Moreover, microorganisms can be protected from the effects of disinfection due to high levels of turbidity, giving rise to a significant demand for chlorine and reducing the effectiveness of some disinfection treatments. Therefore, turbidity could be the value to estimate the microbiological quality and disinfection of water. Low turbidity value due is often observed in tap water thanks to the good filtration system, which is used to remove undesired solids and organisms from turbid water.[24,30] Out of the tested samples, only one sample (0.6%) did not meet the standard of WHO or QCVN with turbidity value of 4.33 NTU (Table 1 and 3).

The presence of high concentration of heavy metals in drinking water can lead to an increased risk of many diseases. Thus, the measurement of heavy metals in drinking water is an important parameter, and evaluation of heavy metals in drinking water is performed in most studies.[19,30-37] Chronic exposure to arsenic has been shown to cause dermal lesions, neuropathies, cancers of the skin, bladder and lung and peripheral vascular disease. Iron and manganese may occur naturally at low levels in the water and may be responsible for taste and staining problems with the water.[36] Manganese is an important trace mineral that is needed by human body in little amounts for the production of digestive enzymes, absorption of nutrients, wound healing, bone development and immune-system defenses.[36] Negative health effects can be caused by insufficient or excessive intake of manganese. Human exposure to higher amount of manganese can result in severe disorders in nervous system, and long term of exposure in its worst condition can cause permanent neurological effects with symptoms characterized by Parkinson's disease.[36] Iron (Fe) is an essential element for human health that performs various function in our body, the most well-known of them is production of protein hemoglobin, which carry oxygen from lungs to transfer it throughout the body. Insufficient or excess levels of iron can have negative effect on body functions. An excess iron in vital organs, increases the risk for liver disease (cirrhosis, cancer), heart failure, diabetes mellitus, depression, osteoarthritis, osteoporosis, infertility, hypothyroidism, abdominal pain, hypogonadism, numerous symptoms and in some cases it becomes cause of premature death.[36] In the present study, the values of analysis of heavy metals such as Fe, As, Mn were also compared with the safe limits set by WHO and QCVN01.[24,25] The concentrations of total iron, manganese, total arsenic measured in drinking water samples met with the regular limit of WHO and QCVN01guidelines.

Chloride is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), Na_2CO_3 and added through industrial waste, sewage, sea water etc. Surface water bodies often have low concentration of chlorides as compared to ground water.[38] According to WHO and QCVN01, concentration of chloride for drinking water should not exceed 250 mg/L. In this study, chloride ranged from 1.3 to 78.5 mg/L with an average value of 14.94 mg/L. Thus, low concentration of chloride was observed in the tested samples (Table 1). Sulfate concentration in natural water ranges from a few to a several hundred mg/L, but no major negative impact of sulfate on human health is reported. Sulfate concentration ranged from 1.3 to 27.1 mg/L with an average value of 9.45 mg/L. Sulfate drinking water standards of QCVN01 and WHO have established 250 and 500 mg/L, respectively. Therefore, all water samples met the permissible limits.

The water hardness ($CaCO_3$) is dependent on some major anions and cations, such as bicarbonate, sulfate, chloride, calcium and magnesium. Water with $CaCO_3$ concentration range from 0 to 75 mg/L $CaCO_3$ is considered as soft; range from 75 to 150 mg/L, moderately hard; range from 150 to 300mg/L, hard; and greater than 300 mg/L, very hard water. It is known that the water hardness induces no effects in human health, but high hardness can cause problems for daily human uses.[39] The total hardness values ($CaCO_3$) of the tested samples ranged from 0 to 220 mg/L and a mean value of 67.6 mg/L, which met the regular limit of QCVN01 ($<$300 mg/L $CaCO_3$).

Nitrate (NO_3) and nitrite (NO_2) are ions found in the environment. Both are products of the oxidation of nitrogen, as part of the cycle required by all living systems for the production of complex organic molecules, such as enzymes and other proteins. Nitrate is the stable form of oxidized nitrogen. However, under anaerobic conditions and in the presence of a carbon source, microbial action can reduce nitrate to nitrite, which is relatively unstable and moderately reactive. Water supplies contaminated with nitrate is often due to agricultural activities that involve the use of fertilizers. The health effects of nitrate and nitrite come from its ability to cause methaemoglobinaemia in humans, especially in children fed with milk or water containing high concentrations of this chemicals.[40-42] This study showed that the nitrate level in all the samples, which ranged from 0.1 to 40 mg/L with an average value of 3.9 mg/L, was lower than the maximum recommended limit (50 mg/L) of WHO and QCVN01. However, 5 samples (3.2%) exceeded the regular limit of nitrite in drinking water ($\leqslant$3 mg/L) as shown in Table 3.

The permanganate index is a conventional measure of the contamination by organic and oxidizable inorganic matter in a water sample.[24,25] The permanganate index of water samples ranged from 0.8 to 14.4 mg/L. An index of less than 2 mg/L is accepted by the standard of QCVN01. The data showed that 10 samples (6.5%) crossed the permissible guideline values as shown in Table 3, suggesting possible contamination by organic matter in the samples. Ammonia in water exists either in the form of un-ionized ammonia or the ammonium ion. The reported value in studies is usually the sum of both forms and reported as total ammonia or simply-ammonia. pH value strongly effects the relative proportion of the two forms present in water. When pH is high, un-ionized ammonia is the toxic form and predominates. On the other hand, when pH is low, the NH_4^+ion is relatively non-toxic and predominates. In general, when pH is less than 8.0 pH units less than 10% of ammonia is in the toxic form, and this proportion increases dramatically as pH increases.[24,25]

Microbiological quality

Bacteria are present naturally in the environment, and the presence of total bacteria is considered as an indication for the existence of pathogens in water although it is harmless to human health. Water may be contaminated by human and/or animal wastes and may cause water-related illnesses, such as intestinal infections, dysentery, hepatitis, typhoid fever, cholera and other illnesses, due to the presence of *Coliform* and *E. coli*.[43] Table 1 shows the min and max values of *Coliform* and *E.coli* in drinking water collected from the study area. All drinking water samples were analyzed for *Coliform* and *E.coli*. *Coliform* bacteria ranged from 0 to 2.4×10^3 per 100 mL, and *E.coli* bacteria also ranged from 0 to 2.4×10^3 per 100 mL. Out of 154 water samples collected from different schools, 15 samples

(9.7%) tested positive for *Coliform*, and 12 samples (7.8%) tested positive for *E.coli*, which exceeded the permissible limit (0 per 100 mL) set by QCVN01 and WHO.[24,25] Although, *Coliform* bacteria by itself may not cause illness but their presence indicates that the water is vulnerable to contamination and may include other organisms (pathogens) harmful for human health after drinking. The presence of *E.coli* may indicate the presence of other disease-causing bacteria. In addition, leakage/discharge from septic tanks, lack of sewage and solid waste disposal systems which were the main threats to water resource can be the main cause of contamination of household drinking water by total *Coilform* and *E.coli*.[42]

Considering the percentage of samples that meet the WHO/QCVN01 guidelines for all parameters, it was found that 71% (110/154) of the tested samples meet the drinking water quality standards of the WHO/QCVN01, whereas 29% (44/154) failed to pass the WHO/QCVN01 guidelines due to exceed limit for at least one physicochemical parameter and/or one microbial parameter. Compared to a previous study which reported that none of the tested samples (0/192) in Hanoi in 2014 met the standards for all chemical and microbial parameters,[21] the tested samples in the present study have higher number of compliance with WHO/QCVN01 guideline levels. The different results between the prensent study and the previous one may be due to the different water sources used for testing. In the present study, all water samples were collected from tap water; on the other hand, other water sources (eg, storage water) with usually less maintenance or cleaning compared to tap water were probably collected in both urban and suburban of Hanoi Citity for testing in the previous study.[21]

Conclusion and recommendation

The study showed that water samples contaminated with bacteria from several schools is more concern than the chemical contamination. Unhygienic conditions of the water reservoirs, corrosion of water supply network, and poor condition of water storage facilities can be the main cause of bacterial contamination. Therefore, the study revealed that proper maintenance of water storage facilities at schools, which may be a source of microbiological contamination, plays an important role for primary prevention of water-related diseases. In addition, regular monitoring of drinking water quality in public schools to control the level of microbial and chemical contamination is recommended to avoid human health hazards.

Acknowledgements

We thank on Zhi Xiang Kelvin, Bizzoni Jessica Wan Lin and Darishini D/O Dashnamoorthy for their assistance during preparation of the first draft of the manuscript.

Authors' contributions

DTH, CML, VTBP, DTTD, VTC, NVL, NTHT, NPT, DTTC, TMH conceived and designed the experiments, collected and analyzed the data, jointly developed the structure and arguments for the paper, wrote the manuscript, made critical revisions, and agreed on the final version of the manuscript. The final manuscript was reviewed and approved by all authors before submission.

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