【Original Article】

Study on water safety in Siem Reap, Cambodia -Surveys on drinking and daily life water quality at schools and their surrounding houses-

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Summary

We conducted a simplified water quality survey on contamination with general bacteria, *Escherichia coli* and arsenic contained in drinking and daily life water at schools and their surrounding houses in five districts in Siem Reap, Cambodia.

As a result, it was found that 23 out of 31 samples (74.2%) contained general bacteria exceeding the water quality standard. *E. coli* was also found in 16 samples (51.6%). Moreover, 9 out of 40 samples (22.5%) contained arsenic exceeding 5 μg/ℓ, and samples at some sites contained 50 μg/ℓ or more up to 100 μg/ℓ. Arsenic was also found in 2 out of 29 samples (6.9%) of well water; 7 out of 11 samples (63.6%) of filtered water by Ceramic Water Purifiers (CWPs). The highest level of arsenic was found in filtered water.

Though these CWPs are used to eliminate microorganisms, the survey indicated the necessity for their strict and appropriate controls and handling because *E. coli* was found in filtered water, too. In addition, since more arsenic was found in filtered water than in well water in Siem Reap, which is said to be less contaminated with arsenic, we assumed that arsenic contamination of the tested water in this survey may be associated with the CWPs.
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Key words: Surveys on water quality, Ceramic Water Purifiers, Bacterial contamination, Arsenic contamination, Siem Reap

Introduction

The Kingdom of Cambodia, one of the least developed among developing countries in Asia, is located in Southeast Asia. It is a hot country where, during the dry season, the temperature exceeds 40 deg C. As represented in its history in which many of the intelligentsia were massacred under Pol Pot's dictatorship during the 1960s and 70s, the country is still one of the poorest countries in Asia, the nation is economically depressed and the educational and medical environments have not been developed sufficiently[1,2]. Ingestion of safe water is important to support life under such natural and social environments. However, in Cambodia, while urban water supply is being promoted, it is not developed sufficiently in rural and suburban areas. The percentage of population with continuous access to improved

sanitation is 17% and that with continuous access to improved water sources is also as little as 41% (as of 2004)[3,4]. Since the coverage for water supply also correlates with the number of victims of water borne diseases and the infant mortality rate[5,6], water facility development is important to improve living environments in Cambodia. For this reason, the Japan International Cooperation Agency (JICA) and organizations in various other countries are proactively developing water supply and digging wells to supply safe water as a form of international aid. However, soils and groundwater in Phnom Penh, the capital of Cambodia, and the Mekong River basin are contaminated with arsenic[7], and chronic exposure to arsenic by residents in these regions has been reported[8,9], highlighting the problem of utilizing well water in the contaminated regions. Meanwhile, arsenic contamination levels in Cambodia differ among regions, and Siem Reap, which attracts many tourists, is reported to be less contaminated with arsenic[7], and actually, water quality tests such as well water served for drinking have rarely been reported.

In light of this fact, we conducted a simplified water quality test concerning contamination with general bacteria, *Escherichia coli* and arsenic contained in water used for drinking or daily use at elementary, junior high, and high schools and their surrounding houses in Siem Reap, Cambodia, to examine the safety.

Survey method

1. Period

The surveys were performed from February 16 through February 19, 2010 (4 days).

2. Regions

The subject of the surveys were 16 elementary, junior high, and high schools (Table 1) and their surrounding houses in 5 districts in Siem Reap (Fig. 1).

3. Surveyed water

Well water (unfiltered) and water filtered using

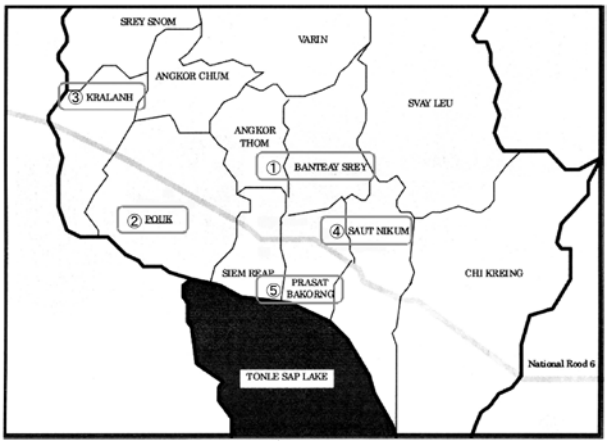

Fig. 1. Surveyed districts in Siem Reap

Table 1. Names of surveyed districts and schools in Siem Reap

(1) Banteay Srey district a. Banteay Srey Elementary School b. Banteay Srey High School c. Rum Chek Junior High School	(4) Saut Nikum district a. Damdek High School b. Kumrursrok Elementary School c. Khchas Elementary & Junior High School d. Samroang Junior High School
(2) Pouk district a. Sasar Sdom Junior High School b. Pouk Junior High & High School c. Tear Banh Elementary School	(5) Prasat Bakorng district a. Ror Lous Elementary & Junior High School b. Prasat Bakorng High School c. Sret Elementary & Junior High School
(3) Kralanh district a. Mohasamaki Elementary School b. Krolanch High School c. Kompong Tkov Elementary School	

ceramic water purifiers (CWPs) (Fig. 2-a to 2-c) used as drinking water at each sampling point were surveyed. The survey used 31 samples for bacteria tests for general bacteria and *E. coli* and 40 samples for arsenic. The surveyed CWPs are those mainly used to eliminate microorganisms contained in well water by filtering it, and are regularly used at schools and their surrounding houses in the surveyed areas.

4. Analysis method

Approximately 150 ml of tested water was collected in a sterile polyethylene bottle (Nalgene), and kept in a cooling bag with ice packs inside or in a refrigerator until tested. A sheet medium for simplified identification "Sanita-kun (Sun Co., Ltd.)" was used to detect general bacteria and *E. coli*. The water was diluted 10-fold with sterile Phosphate Buffered Saline, cultivated at 37 deg C for 48 hours, and then the viable count (colony forming unit: cfu) per ml was measured. Arsenic was semi-quantitatively measured using Merckoquant® arsenic test strips [ultrasensitive type] (Merck Japan Co., Ltd.). The survey results were assessed in accordance with the water quality standards of Japan/WHO[5] and Cambodia[11].

Results

1. Survey status

The weather when tested water was collected was good on all the days during the survey period, with an average temperature of 31.8 ± 2.4 deg C; an average humidity of 59.8 ± 8.6%; and an average tested water temperature of 29.0 ± 1.6 deg C. According to interviews with school principals etc., most schools instructed their students not to drink well water directly. However, we saw some students drinking well water directly. Some schools served well water as drinking water after boiling it, but most schools explained that they mainly ingested filtered well water.

At Pouk Junior High & High School (Table 1. (2)-b), one of the surveyed schools in the Pouk district, well water at school was not used as drinking water, and both teachers and students brought their own water in a plastic bottle from home; therefore, they were excluded from the survey targets.

2. Bacteriological contamination status (Table 2)

General bacteria were found in all of the 31 samples of the bacteria tests. Only 5 out of 22 samples (22.7%) of well water (unfiltered) and 3 out of 9 samples (33.3%) of filtered water satisfied the water quality standard (100 cfu/ml or below) for general bacteria in Japan. The well water sample at Sret Elementary & Junior High School ((5)-c) contained the smallest number of general bacteria (5 cfu/ml). In contrast, the filtered water sample at Khchas Elementary & Junior High School ((4)-c) contained the largest number (1.4×10^5 cfu/ml).

E. coli was found in 16 out of 31 samples (51.6%), and about a half of the samples satisfied the Japanese or WHO's water quality standard

Fig. 2-a. Filtration device

Fig. 2-b. Ceramic Water Purifiers (CWPs)

Fig. 2-c. Injection of well water into the filtration device

Table 2. Average number of general bacteria and *E. coli* detected in unfiltered and filtered water (cfu/ml)

Name of surveyed district and school	Detected bacteria	Well water (unfiltered)	Filtered water (filtered)
(1) Banteay Srey district			
a. Banteay Srey Elementary School	General bacteria	1.2×10^{2}	$6.5 \times 10^{*}$
	E. coli	-	-
b. Banteay Srey High School	General bacteria	$5.7 \times 10^{2*}$	$2.0 \times 10^{3*}$
	E. coli	$3.2 \times 10^{*}$	3^{*}
c. Rum Chek Junior High School	General bacteria	$4.4 \times 10^{2**}$	NA
	E. coli	$-^{**}$	NA
(2) Pouk district			
a. Sasar Sdom Junior High School	General bacteria	NA	7.5×10^{3}
	E. coli	NA	1.3×10^{3}
c.Tear Banh Elementary School	General bacteria	1.5×10^{2}	NA
	E. coli	-	NA
(3) Kralanh district			
a. Mohasamaki Elementary School	General bacteria	$9.9 \times 10^{*}$	NA
	E. coli	8^{*}	NA
b. Krolanch High School	General bacteria	6.8×10^{3}	NA
	E. coli	1.4×10^{3}	NA
c. Kompong Tkov Elementary School	General bacteria	1.7×10^{3}	NA
	E. coli	1.7×10^{3}	NA
(4) Saut Nikum district			
a. Damdek High School	General bacteria	$4.2 \times 10^{3**}$	NA
	E. coli	$2.9 \times 10^{2**}$	NA
b. Kumrursrok Elementary School	General bacteria	$1.4 \times 10^{4*}$	NA
	E. coli	$1.7 \times 10^{3*}$	NA
c. Khchas Elementary & Junior High School	General bacteria	9.7×10^{2}	1.4×10^{5}
	E. coli	2	7.0×10
d. Samroang Junior High School	General bacteria	$2.3 \times 10^{3*}$	NA
	E. coli	$1.9 \times 10^{2**}$	NA
(5) Prasat Bakorng district			
a. Ror Lous Elementary & Junior High School	General bacteria	1.4×10	NA
	E. coli	-	NA
b. Prasat Bakorng High School	General bacteria	NA	$7.5 \times 10^{*}$
	E. coli	NA	$-^{*}$
c. Sret Elementary & Junior High School	General bacteria	$1.0 \times 10^{*}$	2.4×10^{2}
	E. coli	$-^{*}$	-

※ －：Detection limit or below

※ NA：Not collectable or analyzable

※ When there is more than one sample, the average value is shown (*：n = 2, **：n = 3).

(which does not allow the detection of *E. coli*). For well water, the sample collected at Kumrursrok Elementary School ((4)-b) contained the largest number of *E. coli* (3.3×10^3 cfu/ml). For filtered water, the sample collected at Sasar Sdom Junior High School ((2)-a) contained the largest number (1.3×10^3 cfu/ml). The original purpose of the CWPs is to filter bacteria, but *E. coli* was found in 3 out of 9 samples (33.3%) of filtered water in this survey.

The water quality standards for both general bacteria and *E. coli* were satisfied in 8 out of 31 samples (25.8%) – 5 out of 22 samples (4.5%) of unfiltered water; 3 out of 9 samples (33.3%) of filtered water.

3. Arsenic detection status (Table 3)

Arsenic of 5 to 50 μg or more up to 100 μg / ℓ was found in 9 out of 40 samples in total (22.5%) in the surveyed five districts in Siem Reap. It was found in 2 out of 29 samples (6.9%) of unfiltered well water and 7 out of 11 samples (63.6%) of filtered water.

Japan and the WHO set the water quality standard for arsenic and arsenic compounds at 10 μg/ ℓ or below, while Cambodia sets it at 50 μg/ ℓ or below. While 5 samples had a level equivalent to or higher than the Japanese and the WHO's water quality standards, only 1 sample had such a level against the Cambodian standard.

The sample of filtered water installed at Sret Elementary & Junior High School ((5)-c) exceeded both standards, in which arsenic from 50 μg/ ℓ to 100 μg/ ℓ was found. Then, the water was collected and tested again, but the result was the same. The school explained that its well water was filtered before serving as drinking water, but arsenic was not found in unfiltered well water. Water used at the homes of the school principal and the teachers who lived near the school was also tested, but again, no arsenic was found. The result was the same for 2 samples of the well water shared among the surrounding houses. That is, while arsenic was not found in the well water at Sret Elementary & Junior High School ((5)-c) and its surrounding houses, filtered well water containing arsenic exceeding the standards was found.

For well water, arsenic of 5 μg/ ℓ to 10 μg/ ℓ was found in each sample at Mohasamaki Elementary School ((3)-a) and Damdek High School ((4)-a). For filtered water, arsenic of 5 μg/ ℓ to 25 μg/ ℓ was found in 6 samples in total; each sample at Banteay Sreg High School ((1) -b), Sasar Sdom Junior High School ((2)-a), a house near Kompong Tkov Elementary School ((3)-c), and Prasat Bakorng High School ((5)-b); and 2 samples at Khchas Elementary & Junior High School ((4)-c).

Considerations

1. General bacteria and E. coli

CWPs are used to filter bacteria which may cause diarrhea, and are said to be effective for reducing its incidence if they can remove 99.0% or more of *E. coli* [11-13]. However, in this survey, only 8 out of the 31 samples of the bacteria tests satisfied the water quality standards for both general bacteria and *E. coli*, which indicates fecal contamination. Moreover, one of the well water samples contained the smallest number of general bacteria, while one of the filtered water samples contained the largest number. *E. coli* was found in filtered samples (3 out of 9 samples). Through the observation of the CWPs condition by the naked eye while collecting water samples, we saw a type of oil film floating on the surface of water inside the CWPs or the attachment of algae or fungus-like organisms, from which it was found that CWPs were not managed hygienically. For this reason, while filtered water is generally considered to be clean, improper hygiene management of the CWPs conversely may cause contamination with general bacteria or *E. coli*, resulting in health

damages such as waterborne diseases. To prevent such diseases, it would be important to provide thorough education on the proper management and handling of CWPs before using these CWPs to suppress bacterial growth.

2. Arsenic

As a result of attempts to detect arsenic in well water (unfiltered) and filtered water, it was found that 9 out of 40 samples contained arsenic, but those exceeding the Japanese and the WHO's water quality standards were not found in well water. Though the arsenic level is said to be connected to the excavation depth of the well[5], it is difficult to examine such a correlation because the arsenic level detected in well water in this survey was below the standards and the detected quantity was not sufficiently high. However, the result of this survey is considered to reflect a land characteristic of Siem Reap, which is generally said to be less contaminated with arsenic in Cambodia[7]. Meanwhile, more arsenic was found in filtered water than in well water, and the highest level of arsenic was also found in one of the filtered water samples. In Cambodia, wells are typically dug and groundwater is pumped for drinking water in suburban and rural areas, except major cities such as Phnom Penh, the capital[14]. Therefore, CWPs which can be used inexpensively and conveniently are recommended to mainly eliminate microorganisms for extracting clean water, and they are widely used in rural and suburban

Table 3. Arsenic detection status in unfiltered and filtered water (μg/l)

Name of surveyed district and school	Well water (unfiltered)	Filtered water (filtered)
(1) Banteay Srey district		
a. Banteay Srey Elementary School	0	0
b. Banteay Srey High School	0	5
c. Rum Chek Junior High School	0	0
(2) Pouk district		
a. Sasar Sdom Junior High School	NA	5
c. Tear Banh Elementary School	0	NA
(3) Kralanh district		
a. Mohasamaki Elementary School	5	NA
b. Krolanch High School	0	NA
c.Kompong Tkov Elementary School	0	10
(4) Saut Nikum district		
a. Damdek High School	5	0
b. Kumrursrok Elementary School	0	NA
c. Khchas Elementary & Junior High School	0	10 ～ 25*
d. Samroang Junior High School	0	NA
(5) Prasat Bakorng district		
a. Ror Lous Elementary & Junior High School	0	NA
b. Prasat Bakorng High School	0	10
c. Sret Elementary & Junior High School	0	50 ～ 100

※ NA: Not collectable or analyzable

※ When there is more than one sample, the range value is shown (*: n = 2).

areas[11,13]. On the other hand, these CWPs do not work sufficiently for filtering chemical substances contained in water such as arsenic, hence their use for well water which contains a high level of arsenic is not recommended[11]. Therefore, it is not surprising that arsenic was also found in filtered water if the well water was contaminated with arsenic, but this survey also revealed a mixture of arsenic in drinking water due to the use of the CWPs per se. This also led to an assumption that well water may be more exposed to arsenic by the use of CWPs than it is directly drunk in a land which is said to have less arsenic contamination of soils, such as Siem Reap. From local interviews about the CWPs conducted based on the arsenic detection results, it was found that three companies manufactured those CWPs in Cambodia but further information such as their manufacturing locations or materials was not obtained. Since it's apparent that groundwater is contaminated with arsenic in specific regions of Cambodia, including Phnom Penh, the capital, and the Mekong River basin[7-9], it would be necessary to identify the regions where soils used as ingredients of the CWPs are collected in further studies and confirm whether or not the CWPs are contaminated with arsenic during their manufacturing processes.

Some principals at the surveyed schools explained that they instructed their students to bring water boiled at their home or mineral water in a plastic bottle to school or drink water filtered with a CWP placed in each classroom. Nevertheless, we saw some students drinking well water directly, and found that those instructions were not fully observed. It is necessary to disseminate health education so that people in Cambodia can use safe water, and also to recommend strict hygiene management of the CWPs. In addition, the correlation between the CWPs and detection of arsenic would also need to be solved.

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カンボジア シェムリアップ州内における水の安全性についての検討
ー学校および周辺民家の飲用および生活用水の水質調査ー

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要　旨

カンボジア シェムリアップ州内 5 地区にある学校とその周辺民家において、飲用水と生活用水の一般細菌、大腸菌およびヒ素による汚染状況について簡易水質調査を行った。

その結果、水質基準以上の一般細菌は 31 検体中 23 検体（74.2%）、大腸菌は 16 検体（51.6%）が検出された。さらにヒ素は 40 検体中 9 検体（22.5%）から 5 μg/ ℓ を超え、50 μg/ ℓ 以上 100 μg/ ℓ 以下に達した地点もあった。また最も高濃度のヒ素は素焼濾過器による濾過後の水から検出された。

素焼濾過器は微生物除去の目的で使用されるが、フィルタリング後の水からも大腸菌が検出されたため、素焼濾過器の適切な管理、取り扱いを徹底する必要性が示唆された。またシェムリアップ州はヒ素汚染の少ない地域であるが、井戸水に比べフィルタリング後の水からヒ素が多く検出されたことから、本調査における被検水のヒ素汚染は素焼濾過器と関連性があることが推察された。

キーワード：水質調査、素焼濾過器、細菌汚染、ヒ素汚染、シェムリアップ

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