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Article

Water Quality Study on the Hot and Cold Water Supply Systems at Vietnamese Hotels

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Abstract: This study was conducted as part of the Joint Crediting Mechanism (JCM) of the Japanese Ministry of Economy, Trade and Industry, and the Ministry of the Environment project's preparation in Vietnam. Samples were taken from hot and cold water supplies from guest rooms' faucets in 12 hotels in Hanoi city, Vietnam, and 13 hotels in Japan for comparison. A simple water quality measurement and determination of *Legionella* was carried out. The results showed that residual effective chlorine—which guarantees bactericidal properties—was not detected in tap water supplied in hotel rooms in Vietnam, and nitrite (an indicator of water pollution) was detected in 40% of buildings. In the hotels in Japan, the prescribed residual chlorine concentration met the prescribed levels, and nitrite was not detected. Additionally, while there was no *Legionella* detected in the Japanese cases, it was detected in most of the Vietnamese hotels, which were found to manage the hot water storage tank at low temperatures of 40–50 °C. It was found that there were deficiencies in cold and hot water supply quality, and that there was no effective system in place for building operation maintenance and management.

Keywords: water saving; water quality; *Legionella*; Vietnamese hotel

1. Introduction

The Sustainable Development Goals were adopted in 2016, following from the UN Millennium Development Goals, which had provided direction for sustainable global development. Water was recognized as an important issue for sustainable development, and global aims such as safe drinking water and use of sanitary facilities continued to be highlighted. Research was also initiated that investigated future scenarios for the relationship between water and energy [1].

Using examples from Japan and Vietnam [2,3], the authors show that one of the solutions for attaining sustainable development is the formation of water-saving societies. In Japan, it was shown that promoting such a water-saving society can contribute a reduction of 1% to the domestic CO_2 emissions (reference to 1990) by 2020. As a result, there is an accepted method of calculating CO_2 reduced by the spread of water-saving household equipment (e.g., water-saving toilets), in order to obtain domestic credits [4]. Water-saving projects for credit have already begun [4].

The CO_2 emissions reduction achieved by saving water is also adopted in the bilateral crediting scheme, the Joint Crediting Mechanism (hereafter referred to as JCM) managed by the Japanese Ministry of Economy, Trade and Industry, and the Ministry of the Environment. Vietnam is currently also preparing to launch a JCM project.

Vietnam experiences interruptions of water and electricity services, as the current system cannot cope with the increased water and power demands from rapid urbanization. In a study on JCM project feasibility, it was revealed that the water consumption reduction achieved by the proliferation of water-saving equipment could contribute to both a reduction of energy usage by the water and sewage systems, and the more efficient use of water resources. A 2500–4500 W electric water heater is used by Vietnamese households and small-scale hotels for showers. Their usage in the evening forms a peak in power use, and the spread of water-saving showers can contribute to lowering peak consumption [3]. As a result, both Japanese and Vietnamese government officials recognize that working towards a water-saving society is an effective and useful contribution to Vietnam's green growth goals. Thus, the JCM project is currently in the stage of developing the business environment for the spread of water-saving products. In this development stage, business models are being created for different market segments, such as hotels, office buildings, and housing, for the adoption of water-saving products.

This study reports on the issues and relevant strategies that have emerged in the process of preparing technical frameworks for possible JCM project sites (such as new hotel and office buildings), and contributes to the ongoing preparations for JCM projects in Vietnam.

When spreading water-saving products in Vietnam, it is important to ensure that the safety (i.e., the water quality) of hot and cold water supplies is maintained. Yet, the tap water is not even drinkable in five-star hotels in Vietnam. According to Vietnam's Water Supply and Sewerage Association, in Vietnam it is necessary to keep the water pressure of the water mains low because of the high leakage rate of water supply piping. The result of this is that water from the leaking pipes mixes with ground water, and it is said that this is what causes pollution of the water supply.

To date, studies on water supply have found insufficient residual chlorine concentration in some water supplies [5]. Some studies have detected the presence of *Legionella* bacteria in hot water supply systems [6–9]. One study also found that there was *Legionella* bacteria in a filled tub in a Japanese bathing facility. However, there have been no studies on the occurrence of *Legionella* in operating Vietnamese hotels and the processes involved in hot water supply. Therefore, as part of the JCM project's business environment development, this study investigated the water quality of operating Vietnamese hotels. This included measuring the residual chlorine concentration of water from each room's faucet; the temperature of hot water from bathroom faucets; and basic measurement of *Legionella* bacteria. The study explores issues and measures related to a water-saving JCM project.

2. Method

2.1. Analyzing the Quality of Hotels' Hot and Cold Water Supply

The focus of the investigation was on 12 buildings, which were 3–5 star hotels and serviced apartments (henceforth "hotels") in Hanoi City, Vietnam. A water quality analysis was carried out using the residual active chlorine concentration as an indication of the bactericidal effect and the nitrite-nitrogen concentration as an indicator of pollution. For comparison, the same water quality analysis was also carried out at 13 Japanese hotels. Japanese business hotels that were located in urban areas such as Tokyo were targeted, and as "years in operation" was considered to have an impact on water quality, we chose a wide range from those that had been in operation for many years to only a few years. An outline of the hotels investigated, including number of rooms, construction year, and years of operation, is shown later in the paper with study results in Table 1. Analysts stayed at each of the hotels and took water samples from each room's taps in order to conduct a simple measurement of water quality.

Table 1. Analysis results showing hot and cold water supplies' water quality in hotel rooms in Vietnam and Japan.

NO.		Years of Operation	Approximate NO. of Rooms	Inspection Date	Hot Water Supply Type	Hot Water Supply Temperature (°C)	Residual Effective Chlorine Concentration (mg/L)	TH (mg/L)	Fe (mg/L)	NO_2 Concentration (mg/L)	pH	Legionella Detection in Hot Water Supply
①	Hanoi	11	300	5/10/2014	Centralised	47	ND	100	0.5	0.02	8	+
②	Hanoi	22	200	3/11/2014	Centralised	41.5	ND	100	0.3	0.02	7.5	+
③	Hanoi	20	80	4/11/2014	Centralised	40	ND	200	0.5	0.05	8.5	+
④	Hanoi	1	300	18/11/2014	Centralised	59.2	ND	100	ND	ND	7.5	−
⑤	Hanoi	2	100	19/11/2014	Centralised	43.5	0.1	100	ND	ND	8.5	+
⑥	Hanoi	6	40	19/11/2014	Centralised	29.8	ND	100	0.3	0.02	7.5	+
⑦	Hanoi	18	200	22/11/2014	Local electric	65.1	0.1	100	0.3	ND	7	−
⑧	Hanoi	16	400	29/11/2014	Central	46	ND	100	ND	ND	8.5	+
⑨	Hanoi	18	250	13/01/2015	Centralised	58.7	0.1	50	ND	ND	7	−
⑩	Hanoi	3	200	14/01/2015	Centralised	51.2	ND	50	ND	ND	7	−
⑪	Hanoi	6	300	25/01/2015	Centralised	41.8	0.1	100	ND	ND	7	+
⑫	Hanoi	16	250	26/01/2015	Centralised	62.5	ND	100	ND	ND	8.2	−
①	Tokyo	8	350	27/10/2014	Centralised	58.5	0.6	50	0.3	ND	7.5	
②	Tokyo	1	300	2/11/2014	Centralised	60.4	0.6	50	ND	ND	7.5	−
③	Tokyo	12	300	7/11/2014	Centralised	59.2	0.6	50	0.3	ND	8	−
④	Tokyo	21	3700	7/11/2014	Centralised	55.3	0.4	50	ND	ND	7.5	−
⑤	Tokyo	7	150	3/12/2014	Centralised	63.8	0.6	100	ND	ND	7.5	−
⑥	Tokyo	9	200	4/12/2014	Centralised	59.9	0.6	50	ND	ND	7.5	−
⑦	Tokyo	21	100	15/12/2014	Centralised	58.5	0.4	50	ND	ND	7.5	−
⑧	Kanazawa	21	10	18/12/2014	Centralised	66	0.6	20	ND	ND	7.5	−
⑨	Kanazawa	25	250	19/12/2014	Centralised	66.6	0.6	50	ND	ND	7	−
⑩	Fukuoka	43	250	26/12/2014	Centralised	60.3	0.8	20	ND	ND	7.5	−
⑪	Nagasaki	27	150	5/12/2014	Centralised	55.1	0.4	10	ND	ND	7	−
⑫	Tokyo	11	400	12/01/2015	Centralised	60.8	0.4	50	ND	ND	8	−
⑬	Chiba	6	200	21/01/2015	Centralised	64.5	0.6	20	ND	ND	7	−

Notes: ND: Not Detected; +: Detected; −: Not Detected.

Vietnam's tap water quality is regulated by the "Decision on standards of drinking water applying to food and beverage: Decision 1329/2002/BYT/QD". Similar to developed countries, a safe water supply is free from metal ions, organic matter contamination, and microbial contamination, which are health concerns. Typical tap water quality items and reference values are shown in Table 2. To compare, these are shown alongside the Japanese water quality standards. With regard to nitrite nitrogen, the drinking water quality guidelines of the WHO (World Health Organization) determined that the influence on the human body is uncertain, and so include a provisional value. However, in Japan, the value was officially determined in 2014, and even in Vietnam the standard values are defined (as shown in Table 2). Therefore, it was analyzed in this study. In tap water quality analysis, a Shibata Science simple water quality test kit was used. The analysis principles and measurement range is shown in Table 3.

Table 2. Comparison of Vietnam and Japan's water supply water quality standard values.

Item	Unit	Vietnam's Standard * (Maximum Value)	Japan's Standard ** (Maximum Value)
Residual chlorine	mg/L	0.5	1
Chromaticity	TCU	15	5
Turbidity	NTU	2	2
Odor	–	No abnormality	No abnormality
pH	–	6.5–8.5	5.8–8.6
Nitrate nitrogen	mg/L	50	10
Nitrite nitrogen	mg/L	3	0.04
Iron	mg/L	0.5	0.3
Coliform group	–	0	0

Notes: * Water quality standard values were determined by Vietnam's Decision 1329/2002/BYT/QD; ** Tap water quality standard value stipulated by "Ministerial Order on Water Quality Standards" based on Article 4 of the Waterworks Act of Japan.

Table 3. Tap water quality analysis [10,11].

Item	Measurement Principle	Range (mg/L)
Free residual chlorine	Diethyl-p-phenylenediamine ammonium method	0.1–5.0
Nitrite nitrogen	Sulfanilamide-naphthylethylenediamine method	0.02–1.00
Iron	o-Phenanthroline method	0.3–10.0
Total hardness	Phthalein Complexone method	0–200
pH	Bromothymol blue method	5.8–8.0

Moreover, in JCM project feasibility studies to date, it has been confirmed that a number of Vietnamese hotels supply hot water at lower than optimum temperatures, and therefore the possibility of contamination of the water by microorganisms was also analyzed. Regarding the microorganism risk of the hot water supply, this risk includes *Legionella* bacteria, which can cause *Legionella* pneumonia if breathed in from hot water vapor from showering, etc.

Legionella is a bacterium that can be found in natural soil and fresh water sources. As it lives and grows inside protozoans such as amoebas that occupy 20–50 °C habitats, it can be found growing in biofilms where protozoans are present. Possible environments where the water may stay within this temperature range for long periods of time include buildings' cooling towers, ornamental ponds, circulation-type bathtubs, and hot water supply systems. People who inhale water vapor that contains *Legionella* bacteria may develop Legionnaires' disease. Those with weakened or compromised cellular immunity are at a greater risk, and thus infection occurs more often in elderly people. The term Legionnaires' disease was discovered following a pneumonia outbreak that occurred in service members of the American Legion in Philadelphia, United States, in 1976.

Cases caused by the *Legionella* bacteria have been reported in countries around the world, including Japan and the United States. Therefore, a simple analysis was carried out on each bathroom faucet's hot water to determine the presence of *Legionella* bacteria in Vietnamese hotels' hot water supply, using Legio Search technology of Yuki Chemical Co., Ltd., Niigata, Japan. The method is a simple analysis method based on antigen–antibody reaction to the *Legionella pneumophila* group 1, with samples under 50 CFP/100 mL being defined as negative. Legio Search was used because it was necessary to transport analytical instruments from Japan and bring them to the rooms of each hotel in Vietnam. It is lightweight and easy to handle. Measuring with the maximum hot water temperature, X-ray photoelectron spectroscopic analysis of the hot water supply 20 L (ϕ47 mm glass fibre microfiltration membrane) was also performed. The reason why X-ray photoelectron spectroscopy (XPS) was carried out was to observe the particulate matter contained in tap water.

2.2. Interviews and On-Site Investigations

In October 2014–January 2015, water quality analysis of the hot and cold water supply systems for four hotel facilities (①②③⑩ in Table 1) was carried out. The researchers observed the rear area of the hotel and confirmed the installation conditions of water supply tanks, hot water supply boilers, hot water storage tanks, water supply/hot water supply pipes in rooms and circulation pumps, which were installed in machine rooms and on rooftops. Regarding the operation, maintenance, and management situation, we conducted an interview survey with the hotel's managing technician. In the interview, questions were asked such as: "What is the water supply system of the hotel?/Do you measure the water supply quality of the building?/At what temperature is the hot water storage tank managed?/Is there cross connection in the water/hot water supply pipes?" The sample of hotels selected included those that were built and operated using Vietnamese capital, and those that were built and operated using American and Singaporean capital.

Additionally, interviews were carried out with Japanese building companies that were undertaking large-scale building design in Vietnam. This provided an overview of the design and construction of large-scale buildings such as hotels.

3. Results and Discussion

3.1. Analysis of Hotels' Water Supply Quality

In Vietnam, to maintain the water quality values shown in Table 2, the water supply system functions in the same way as developed countries, with water supplied after treatment with rapid filtration and chlorine disinfection. Following that, the tap water passes through the building's internal water supply system and is distributed to users. All water supply systems of the hotels investigated in this study used an elevated water tank system. According to the interviews with design businesses, the majority utilize the elevated water tank system.

The results of water quality analysis of the water supplied to each hotel room in Vietnam and Japan are shown in Table 1 and Figure 1. In the water supplied to Vietnamese hotel rooms, residual active chlorine that maintains bactericidal properties was not detected. Further, nitrite was present in 40% of buildings—an indicator of water pollution. Additionally, the film from 20 L of filtered tap water is shown in Figure 1. It was revealed that in almost all of the facilities—including five-star hotels that had been constructed in the past year—particulate matter supplemented by the microfiltration membrane was mixed with the water supply, and chlorine that had been added at the water treatment facility was being consumed. Therefore, it is possible that the contamination of the tap water occurred prior to being supplied to the building's water supply system.

As outlined above, according to Vietnam's Water Supply and Sewerage Association, in Vietnam, the deterioration of water supply piping has caused widespread leakage (the leakage rate is 30%). As there are many leaks, it is impossible to raise the pressure of the water pipes. Since the water pipes are buried underground, if the pressure of the water pipe is low, groundwater, etc. is likely to become mixed with tap water through cracked parts of the pipes. Therefore, there is a high probability that the source of pollution is ground water that has mixed in with tap water in underground pipes.

Additionally, it was confirmed in interviews with building managers that maintenance to protect hotel water quality was not carried out. Moreover, it was determined that water contaminated from leaking parts of underground buried piping was supplied to guest rooms in that state. In an interview with a hotel's manager (technician), it was revealed that there was no cross-connection between the hot/cold water supply piping and other lines in the hotel building. However, we cannot completely exclude the possibility that the cause of contamination is a cross-connection, because it was not possible to investigate the existence of cross-connection in this survey.

To compare, the same analysis was carried out in Japanese hotels. The results are displayed in Table 1 and Figure 1. According to legislation on water systems in Japan, the residual active chlorine concentration of water supplied from the faucet is required to be above 0.1 mg/L. Accordingly, in all of the hotels in the study, levels over 0.4 mg/L were detected. Additionally, there was no contamination of the particulate components supplementing the membrane filters. To date, the researchers have investigated the water supply system of Vietnam and found that its water quality has been maintained at the same level as Japan [12]. Therefore, as stated above, contamination of the tap water is likely to be caused by groundwater entering the underground water supply pipe. Additionally, even if contaminated water is supplied to the building, no counter-measures have been taken by the building's management, such as the addition of residual chlorine. As such, it may be concluded that the absence of building maintenance operations in Vietnam is an issue. In Japan, there are established systems that give maintenance personnel a management education, and the *Act on Maintenance of Sanitation in Buildings* obliges maintenance managers of buildings' water supply systems to acquire national qualifications on maintenance and obliges them to attend classes on a regular basis. Conversely, interviews with relevant managers in Vietnam revealed that similar regulations and education systems for managers were undeveloped.

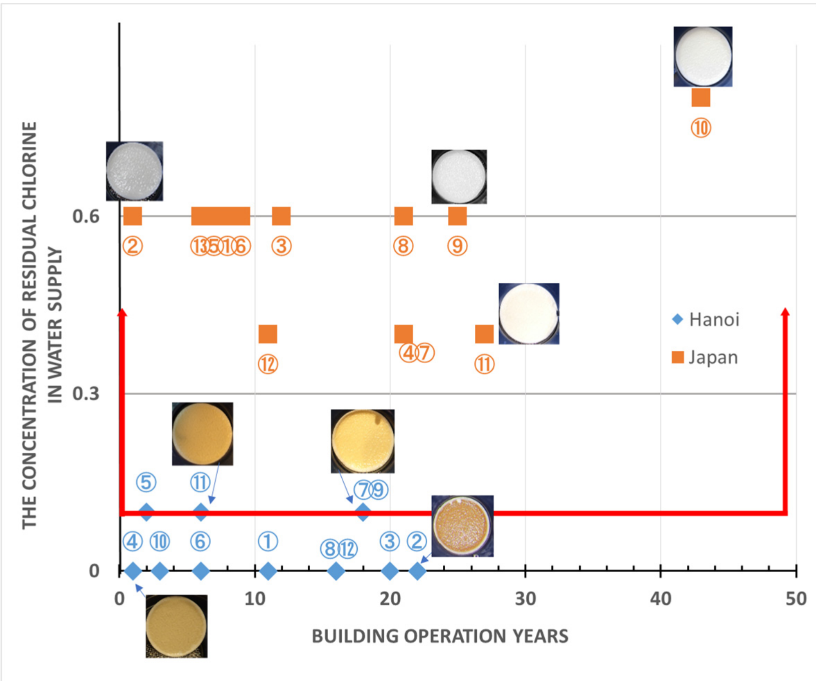

Figure 1. Residual effective chlorine concentration in tap water supplied in hotel rooms.

3.2. *Legionella Study of Hotels' Hot Water Supply*

In Japan, measures against *Legionella* are taken at both the design and construction stage and the maintenance stage, and the aim is to reduce the risk of disease from *Legionella* for the whole of society. In 1994, the building management education center issued Legionnaires' disease prevention guidelines as measures for the building maintenance stage. In 2006, the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan enacted regulations to prevent *Legionella* at the design and construction phase of buildings aimed at bathing facilities. *Legionella* bacteria cannot grow in temperatures above 55 °C. Therefore, buildings' hot water supply systems in Japan are designed and maintained so that the hot water is circulated constantly and maintained at a temperature of over 55 °C. However, corrosion of piping and energy loss can occur, so temperature is controlled by the circulation flow rate to maintain a hot water storage temperature of 60 °C and recirculation temperature of 55 °C. Accordingly, all measurements of hot water supply temperatures in Japanese hotels were above 55 °C, and no *Legionella* was detected.

The results of the analysis are shown in Table 1 and Figure 2. Figure 3 shows an electron micrograph of the film surface supplemented with 20 L hot water with glass fiber microfiltration membrane of ϕ47 mm. However, no significant particulate contamination of the hot water was observed.

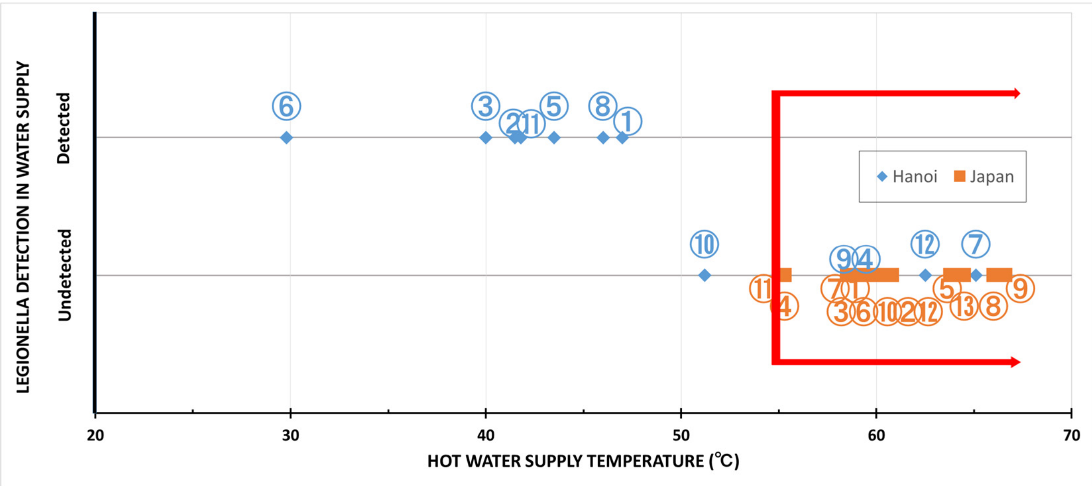

Figure 2. The supplied hot water temperature at hotels and the result of *Legionella* bacteria detection.

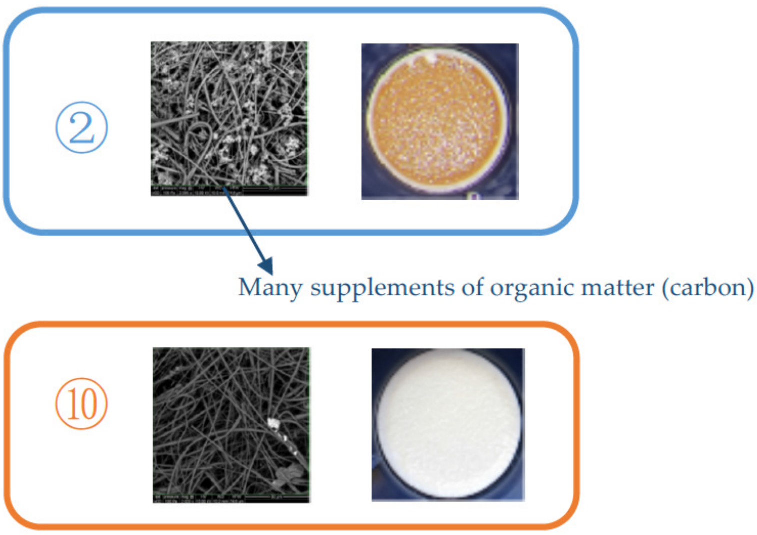

Figure 3. Filtration membranes and electron micrographs of hot water from the guest room faucets on site ② and ⑩.

Conversely, in the analysis of hotels' hot water supply systems in Vietnam, the majority were 55 °C or less, creating the conditions for *Legionella* bacteria proliferation, and *Legionella* was detected.

The measurement of *Legionella* levels could not be confirmed because a simple measurement kit was used; however, as shown in Figure 2, it is considered that there is a clear correlation between hot water supply temperature and presence or absence of *Legionella*. Even in the hot water supply membrane filtration supplement, many micro particles were observed. These were identified as organic matter (carbon) in the XPS analysis. In the Vietnamese hotels examined, the bactericidal properties of the tap water were being lost, leading to a high risk of microbial contamination of the hot water supply that could transform the tap water into raw water. Further, since the maintained temperature of the hot water supply is low, this indicates that biofilms which cause *Legionella* growth have formed in the hot water supply. In addition, there are small-scale hotels and serviced apartments in Vietnam which have a small electric hot water tank in each room. An example of a small storage-type electric water heater is shown in Figure 4. The compact storage-type electric water heater's hot water storage temperature is set to above 60 °C, and as such, *Legionella* was not even detected with raw water contamination (⑦ in Figure 3).

Figure 4. Example of an electrical water heater used for the shower.

3.3. *Results from Water Supply Facility Investigations*

To further explore reasons behind the prevalence of low temperature hot water supply in Vietnam's hotels, site inspections and interviews with facility management officers were carried out in addition to water quality analysis. The four facilities had hot water circulation systems yet, regarding the systems' management, the operation method was left to the individual discretion of the operations manager. For example, a timer stop valve was added to the return piping and intermittent circulation may be performed every hour. The operation methods in Table 4 show an example of the hot water supply temperature in Figure 2. It was found that the purpose of complete circulation of hot water at a lower temperature was to save on operating costs and that there was no awareness of measures against *Legionella*.

Table 4. Overview of hot water facilities investigated in Vietnamese hotels.

No *	Heat Source	Hot Water Circulation	Hot Water Tank Storage Capacity (1 Unit)	Hot Water Tank Number	Hot Water Tank Temperature
①	Heat pump	Constant	6000 L	two units	40–50 °C
②	Hot water boiler (heavy oil)	Constant	Outer circumference = 5.4 m, height = 2.8 m, volume = 6.4 m^3	two units	50 °C
③	Electric heater type	Timer-controlled Intermittent circulation	Outer circumference = 6.6 m, height = 2 m, volume = 6.9 m^3	three units	42 °C
⑩	Steam boiler (heavy oil)	Timer-controlled Intermittent circulation	Outer circumference = 0.7 m, height = 1.6 m, volume = 0.6 m^3	four units	50 °C

Note: * The numbers correspond with Table 1.

Regarding the construction of urban infrastructure around the world, the designs of large-scale buildings are often decided by a competitive global market. As such, building designs are becoming standardized globally. Even in Vietnam, major Japanese architectural design and building companies are expanding, and advanced designs and building techniques have been adopted. However, maintenance and management of the buildings is left in local hands on-site.

The JCM project conducted by the Japanese government is a project aiming to contribute to the sustainable development of developing countries by providing them with the most advanced environmental Japanese technologies available. For this to be successful, it is necessary that the partner country accepts and utilizes the technology for an extended period of time. The authors posit that to support the establishment of a water-saving society, building quality must be ensured (specifically safety and security), so that buildings with water-saving products will be in long-term operation and use.

Japan has already instituted an education system for specialists in the procedures and standards of every aspect of maintenance from the building stage onward. It is important to teach the skills necessary for building maintenance, as well as providing the necessary environmental technologies, in order to contribute to sustainable development within the JCM project for water conservation.

4. Conclusions

This study was conducted as part of the JCM project's preparation in Vietnam. Samples were taken from the hot and cold water supplies from guest rooms' faucets in 12 hotels in Hanoi city, Vietnam, and 13 hotels in Japan for comparison. A simple water quality measurement and determination of *Legionella* was carried out. As a result, residual effective chlorine—which guarantees bactericidal properties—was not detected in tap water supplied in hotel rooms in Vietnam, and nitrite as an indicator of water pollution was detected in 40% of buildings. In the hotels in Japan, the prescribed residual chlorine concentration met the prescribed levels, and nitrite was not detected. Therefore, contamination of the tap water is likely to be caused by groundwater entering the underground water supply pipe. Additionally, even if contaminated water is supplied to the building, no counter-measures were taken by the building's management, such as the addition of residual chlorine. Further, while there was no *Legionella* detected in the Japanese cases, it was detected in most of the Vietnamese hotels, which were found to manage the hot water storage tank at low temperatures of 40–50 °C. It seems that the cause of this is the absence of an established education system for maintenance managers in Vietnam, and as such, building maintenance was not properly carried out. Regarding *Legionella* detection, since a simple measurement kit was used, more detailed analysis of the target sites is necessary in the future.

In order to utilize the JCM scheme promoted by the Japanese government and contribute to Vietnam's green growth, water-saving products must be spread in conjunction with securing the basic quality and safety of buildings. For this, it is necessary to develop a system for the operational management of buildings.

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Author Contributions: Yasutoshi Shimizu designed the experiments; Kanako Toyosada performed the experiments; Kanako Toyosada, Takayuki Otani analyzed the data; Shunsuke Managi checked the analyzed data; Kanako Toyosada and Takayuki Otani wrote the paper.

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