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Investigation of Chemical and Bacterial Quality in Korean Public Bath Facilities

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Investigations of water quality concerning the occurrence of total coliform, heterotropic plate count and *Legionella* from taps, hot tubs and cold tubs were conducted at public bath facilities. The prevalence of total coliforms and heterotropic plate count were shown in tap water samples as well as tub water in bathing facilities. The results obtained showed a correlation (at the level of $p < 0.01$) between heterotropic plate count and turbidity in hot bath tubs. The spearman rank correlation results shows that the occurrence of total coliforms were related to the level of dissolved organic carbon. Present investigation has demonstrated that the suitable measures should be taken to more effectively assess bathing water quality and hygiene conditions in public bathing facilities.

Key Words: Public bath facility, Microbiological indicators, Heterotrophic bacteria, Total coliform, *Legionella*, Water supply.

INTRODUCTION

The management of microbial quality is important in public bathing facilities because it is associated with public health. Waterborne diseases can be transmitted by bathtub water. These days, the scale of the public bathing business is higher and has changed to the combined type linked with other business. Many Koreans traditionally enjoy bathing in public bathing facilities and they have become popular recreational as well as a bathing places.

There have been serious incidents of bathing water infection. In Hyuga, Japan, the deaths of 7 bathers from legionellosis were reported[1]. An outbreak of Pontiac fever in guests at a resort was reported by a *Legionella*-contaminated spa[2]. The occurrence of *Legionella pneumophila* were described in Taiwanese spring recreational areas and it was considered a potential public health threat[3]. Lumb *et al.*[4] demonstrated the persistence of a *Mycobacterium avium* complex in one spa pool for over 5 months and found it was related to cases of lung disorders by genotype investigation.

Bacterial growth in hot water supply systems seems to be related to problems such as skin allergies and bad odour. A higher level of heterotrophic bacteria in hot water has been observed compared to cold water[5,6]. Bagh *et al.*[5,6] declared that efforts need to deliberate on the release of bacteria from piping in the hot water system as well as hot water tanks to decrease the level of bacteria. The yield of higher numbers of bacteria seemed to increase due to the recirculation of hot water system in hot tubs, swimming pools and spa pools[7,8].

Selection of the best indicator to control the bathing water quality has been seriously considered in public bathing facilities in other to identify water deteriorations and to protect the public from the potential health risks[9,10]. Bacteria such as fecal coliform and *Enterococci* have been used conservatively as an indicator of fecal contamination. *Legionella pneumophila* has been offered as a parameter to judge of hygiene quality in swimming pools in Germany[11]. However, it has been suggested that the infection risk is more related to bacteria sourced from human skin and the mouths of bathers rather than from fecal derived microorganisms[9,12]. It has been suggested that more than two indicators should be considered concurrently to ensure bathing water safety[9]. The suitable indicator should inexpensive, simple to measure and efficient in identifying hygiene conditions in bathing water. The best indicator in bathing water is presently under discussion[13-15].

This research was performed to assess the hygiene conditions in public bath facilities in the C city, Korea and to evaluate the effective microbial indicator for public bathing water. In addition, how the level of bacteria is related to physico-chemical characteristics is studied.

EXPERIMENTAL

Sampling: Investigations were carried out in 80 water samples from taps, cold tubs and hot tubs in 27 public water bathing facilities in C city, Korea. Samples were collected between October 2007 and December 2007 from individual public water bathing facilities. The bathing water was collected at a depth of 20 cm. The tap water samples were obtained from the hot water side of the faucet. Water samples for *Legionella* were collected in sterilized 2 L sampling bags. The samples for heterotropic plate count and the total coliforms were collected in sterilized 50 mL polypropylene bottles. Samples were transported under refrigerated conditions to the laboratories and tested in 6 h for the microbial items after collection.

Chemical analysis: Residual chlorine was determined at the time of collection using the DPD procedure. The parameter of turbidity was measured using the Hach turbidity meter (Hach 2100A). Anion concentrations such as F^-, SO_4^{2-}, Cl^- were measured by A Dionex ion chromatograph (DX-500). The level of dissolved organic carbon was measured using a Shimadzu TOC-5000 analyzer after filtering using a 0.45 µm pore size. The metal concentrations were analyzed with an inductively coupled plasma spectroscopy (Labtem 8440). Four kinds of trihalomethane (chloroform, bromodichloromethane, dibromochloromethane and bromoform) were analyzed using the Environmental Protection Agency modification method 551.

Microbiological analysis: Total coliform was analyzed using the membrane filtration procedure technique. Samples were filtered through a 0.45 µm pore size membrane. Sample volumes ranging from 25 and 100 mL were applied for each filtration and then the membrane was placed on a M-endo medium. Those were then incubated for 24 h at 35 ºC. Confirmation of typical colonies was performed as mentioned in the standard method[16].

Heterotrophic bacteria were enumerated by the spread plate method with R2A agar and 0.1 mL of each sample was inoculated on duplicate plates. The plates were incubated at 25 ºC for samples from cold bathtub water and 35 ºC for samples from hot bath tub water for 10 days before colony counting.

1000 mL of sample were concentrated to enumerate *Legionella* by filtration through 0.45 µm pore size filters. The membrane was swung at a shaker (TS-580, Yih Der) for 15 min in 20 mL of phosphate buffer solution to detach the bacteria. The concentrated samples were inoculated on buffered charcoal yeast extract agar and incubated at 35 ºC for 7 d. Typical colonies were counted and confirmed using buffered charcoal yeast extract without cysteine. Serogroup identification was performed using commercially available test kits (Oxide).

RESULTS AND DISCUSSION

Variation in water quality: The mean values of the chemical characteristics parameters of tap water, cold bathtub and hot bathtub water are given in Table-1. The average pH value for tap water, cold bathtub and hot bathtub water was 7.26, 7.40 and 7.73. The highest pH value was seen in hot bathtub. The Ministry of Health and Welfare (MOHW) in Korea stipulates levels should be between 5.8 and 8.6 for pH ranges for raw water in public bath[17]. The pH condition of all samples met the MOHW's regulation.

The mean level of turbidity was 0.26, 0.25 and 0.57 NTU for tap water, cold bathtub and hot bathtub water, which is below MOHW's standard (It stipulates under 1, 1.6 NTU for raw and tub water). The turbidity for hot tub was 2.2 times higher than that of tap water. Turbidity ranged between 0.10 and 0.77 NTU for tap water, 0.09 and 0.60 NTU for cold tub water and 0.15 and 1.79 NTU for hot tub water. The level of turbidity was not so high for bath water and tap water. The results obtained showed a correlation (at the level of $p < 0.01$) between heterotropic plate count and turbidity in hot tub water (Fig. 1).

No statistically significant correlations were observed between dissolved organic carbon and turbidity. The mean levels of dissolved organic carbon for tap water, cold bathtub and hot bathtub were 7.66, 7.24, 7.37 mg/L, respectively. This result indicated that a major source of high level of dissolved organic carbon might not be due to organics discharged from bathers in public bathing places. Dissolved organic carbon levels in bathing tub water did not show higher values than tap water. The highest dissolved organic carbon values from the selected tap, cold bathtub and hot bathtub water samples in public bathing places were 16.3, 15.8, 16.1 mg/L, respectively. Statistical analysis also showed that coliforms in tap water were correlated with dissolved organic carbon (at the level of $p < 0.05$).

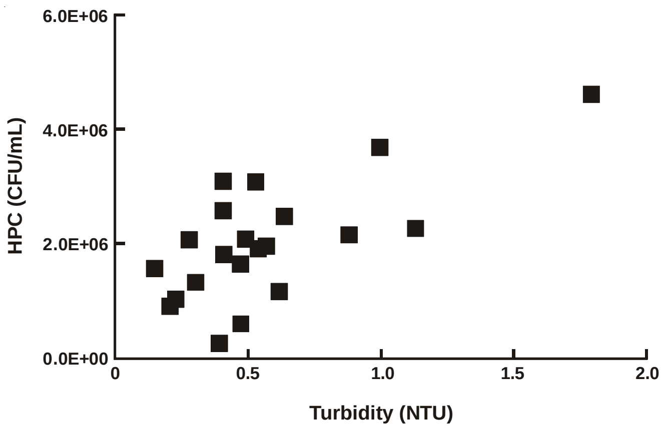

Fig. 1. Distribution of heterotropic plate count (HPC) and turbidity in hot tub water

There were no remarkable differences in the levels of anions such as F^-, Cl^-, SO_4^{2-} among the samples of tap, cold bathtub and hot bathtub water. The mean value of fluoride was 0.5 mg/L. But, the highest level of fluoride from a faucet was 2.16 mg/L. The recommended level for drinking water presented by the World Health Organization[18] is 1.5 mg/L. High levels of fluoride in water were related to outbreaks of mottled enamel[19].

The metal concentrations were not significantly high. The mean values of Zn and Cu concentrations detected were less than 100 µg/L in hot tub water. However, in one location, Zinc levels of 1.38, 0.82, 1.20 mg/L were shown for tap water, cold bathtub and hot bathtub water. Residual chlorines were not found among collected samples. This may contribute to the great multiplication of microorganism in bath waters. Formation of trihalomethanes was detected in 11 of the total 86 samples, however, it detected under 30 µg/L which was lower than standard of drinking water in Korea (< 100 µg/L).

Occurrence of total coliforms: Total coliforms were monitored in the tap, cold tub and hot tub water from the public bathing facilities in the C city. The total coliforms results are presented in Figs. 2 and 3. Notable numbers of total coliforms were found in the samples from public bath facilities; not only in hot bathtub water but also in tap water. Total coliforms were detected in 64 of the 77 samples (83.1 %). 62.9, 92.0, 96.0 % of water samples for tap, hot tub and cold tub water in public baths.

The MOHW in Korea regulates the total coliforms in raw and bathtub water in other to supply safe public bathing water. No total coliforms should be detected per 100 mL of raw water and more than one total coliform per 1 mL for bathing tub water should not be detected[17]. A single standard was met in 52 samples. In the 27 tap water samples, 63.0 % of samples has total coliforms in excess of the standards for raw water. 28.0 % of hot bathtub samples exceeded the standards for bathtub waters.

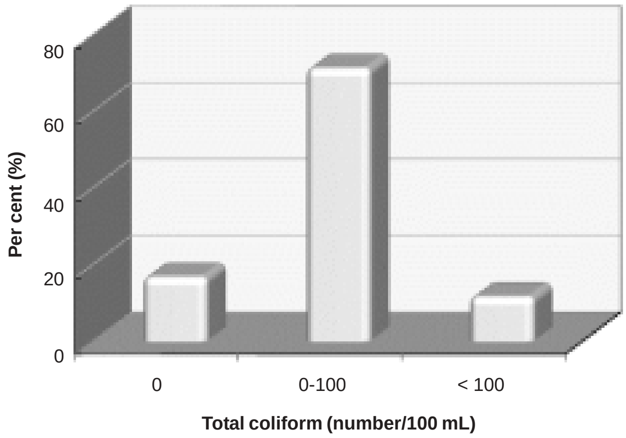

Fig. 2. Detection of total coliforms in public bath facilities

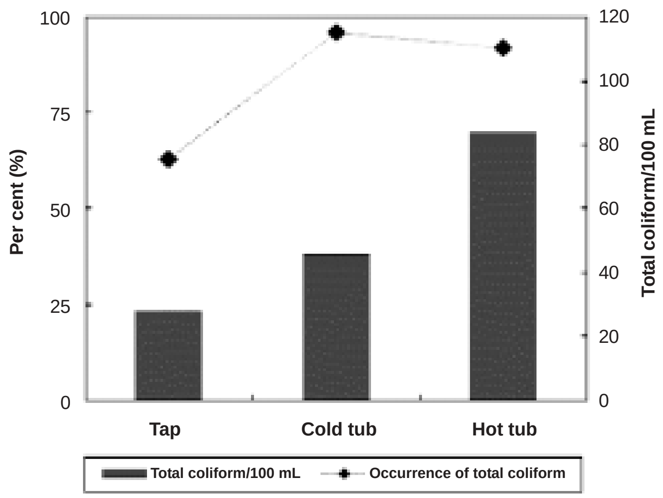

Fig. 3. Multiplication of total coliform in tap, cold tub and hot tub samples at public bath facilities

The results obtained in this study showed that bacterial pollution possibly originated from the heating process or the distribution system supplying hot water. In particularly, total coliforms were detected in all except two samples in the hot bathtub samples. Only one of the 25 collected cool bathtub water samples exceeded the MOHW standard. The number of total coliforms ranged between 0 and 106 number/100 mL in the cold bathtub water samples. 18 of the total 25 locations had a higher value of total coliforms in hot bathtub water compared to that from cold bathtubs. Only 6 public baths conformed to both microbiological levels recommended by MOHW.

The monitoring of microbiological water quality for tap water inside public bathing facilities should be performed looking for pollution sources related to the plumbing system, contaminated water heating system and the improper operation of the water re-using system inside the building, not just microorganism pollution derived from human's bathing. The variation of total coliforms in tap water was between 0 and 144 number/100 mL. Kim *et al.*[1] reported that 45 % of tap waters in 81 samples from public baths located in Seoul metropolitan city contained coliforms.

Multiplication of heterotropic plate count: The heterotropic plate count in 26 tap waters samples was distributed with various ranges (Fig. 4). Only one bathtub sample contained a heterotropic plate count value of less than 100 CFU/mL. The distribution between 100 and 500 CFU/mL was highest. 50 % of heterotropic plate count in the water from faucets was found to be over 500 CFU/mL in collected tap water samples. Martins *et al.*[9] considered that the results of over 500 CFU/mL of heterotropic plate count presented risks for bathers. Therefore, 50 % of tap water supplies inside the public bathing facilities could not ensure bathers safety according to interpretation based on their report. The possible reason for the high multiplication of heterotropic plate count in tap water was explained by an improperly managed water recirculation system[1]. Another possible cause evaluated was the microbial pollution of the plumbing system, reservoir and inferiority of the facilities' cleaning condition. In Finnish study, the level of heterotropic plate count was associated with the source of the incoming cold water in hot water distribution systems[20]. Also, the number of heterotropic plate count was higher in the systems receiving surface water than those receiving ground water[20]. The bather load had a direct influence on the microbial contents[9].

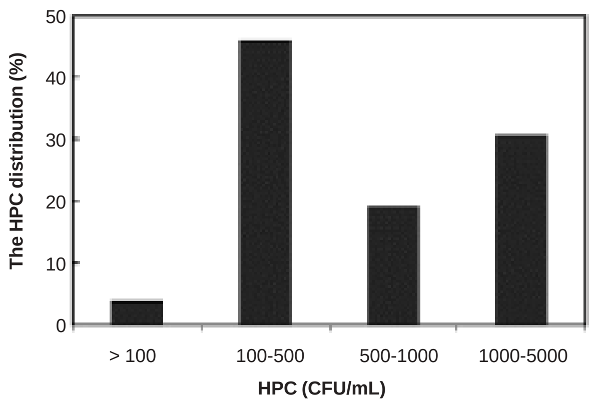

Fig. 4. Distribution of heterotropic plate count (HPC) bacterial densities in tap water at public bath facilities

A significant number of heterotropic plate count was considered to be a potential health risk[3]. Another study showed that the application of total coliform numbers in companies with heterotropic plate count is cost effective and can be used to assess the level of hygiene in swimming pools[9]. There are no guidelines for heterotropic plate count levels in public bath water in Korea. Of 10 tap water samples which did not contain total coliform, 4 samples had over 500 CFU/mL of heterotropic plate count.

The average level of heterotropic plate count in cold bathtub water was higher than that of tap water (Table-1). The heterotropic plate count level ranged between $3.8 \times 10^3 – 4.0 \times 10^5$ CFU/mL in cold tub water. The highest level of heterotropic plate count level in cold tub water was 835 times higher than tap water.

TABLE-1
MICROBIOLOGICAL AND CHEMICAL CHARACTERISTICS OF SAMPLES FOR TAP, COLD TUB AND HOT TUB WATER

Item	Tap			Cool tub			Hot tub		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
HPC (CFU/mL)	9.10×10^2	7.50×10^1	3.96×10^3	8.60×10^4	3.80×10^3	4.01×10^5	2.02×10^6	2.80×10^5	4.60×10^6
Total coliform (No./100 mL)	28	0	144	46	0	106	84	0	438
pH	7.26	6.83	8.09	7.40	6.66	7.95	7.73	6.87	8.52
DOC (mg/L)	7.66	3.53	16.3	7.24	3.57	15.8	7.37	3.68	16.1
Fluoride (mg/L)	0.53	0	4.36	0.55	0	4.70	0.56	0	4.94
Sulfate (mg/L)	45.9	13.3	94.1	45.9	14.1	92.6	46.5	13.6	101.6
Chloride (mg/L)	63.7	206	14.0	68.6	17.3	249	67.4	22.8	199.4
Turbidity (mg/L)	0.26	0.10	0.77	0.25	0.09	0.60	0.57	0.15	1.79
Free chlorine (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
THM (mg/L)	3.41	0	28.1	0.98	0	10.5	0.63	0	9.8
Iron (mg/L)	0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Copper (mg/L)	0.06	0.01	0.28	0.02	<0.01	0.05	0.06	0.01	0.21
Aluminum (mg/L)	<0.01	<0.01	0.05	<0.01	<0.01	0.11	<0.01	<0.01	0.03
Calcium (mg/L)	28.4	0.60	72.4	33.0	0.87	68.1	27.7	0.60	70.4
Potassium (mg/L)	0.14	0	2.4	0.13	0	1.98	0.17	0	2.38
Magnesium (mg/L)	6.22	0.08	12.8	7.13	0.25	16.0	6.13	0.14	12.4
Zinc (mg/L)	0.08	<0.01	1.38	0.04	<0.01	0.82	0.06	0	1.20

HPC: Heterotropic plate count; DOC: Dissolved organic carbon; THM: Trihalomethane

The high level of heterotropic plate count was measured in hot tub waters. Measurements of heterotropic plate count in hot water systems above 10^4 CFU/mL often been taken[5]. The mean value of heterotropic plate count of 21 selected hot tub water samples was 2.02×10^6 CFU/mL. The heterotropic plate count in hot tub water was shown to be 364-28,800 times higher compared to that in tap water. The reason for the high heterotropic plate count multiplication in hot tub waters may be due to the long cycle of tub-water exchange and biofilm formation in the basin. Previous studies have reported that *Legionella* detection was related to the density of heterotropic plate count[3].

Occurrence of *Legionella*: *Legionella* was monitored in tap and hot tub water. The results of the *Legionella* occurrence are given in Table-2. *Legionella* was tested for 1 of the 26 hot tub water samples and 3 of the 23 tap water samples. In this experiment, only 8.2 % of the 49 samples were positive for *Legionella*. The occurrence rate of *Legionella* was not high in this experiment. However, the sampling was performed mostly in the winter time in this experiment. One species was also identified to *L. pneumophila* in tap water samples[20].

TABLE-2
DISTRIBUTION OF *Legionella* IN PUBLIC BATH FACILITIES

Sampling site type	Total no. of samples	No. of *Legionella*-positive samples (*Legionella* positivity)
Hot tub	26	1 (3.8 %)
Tap	23	3 (13.0 %)
Total	49	4 (8.2 %)

The detection of *Legionella* from faucets inside bathing facilities was an important reminder of the possibility of public infection from hot water distribution systems. Wadowsky *et al.*[21] confirmed that hot water tanks in plumbing systems are a source of *Legionella* contamination. If a hot water distribution system is contaminated, *Legionella* can be detected at each point such as tap water, shower heads and tub water, *etc*.

Kim *et al.*[1] found all *Legionella* positive samples for hot tub water had a high level of heterotropic plate count over 10^4 CFU/mL. In this research, the presence of *Legionella* did not always coincide with the level of heterotropic plate count (Table-3). *Legionella* are generally classified as non-fecally derived bacteria. However, *Legionella* positivity in tap water was collated with the presence of total coliform in this result ($p < 0.05$).

TABLE-3
RELATIONSHIP BETWEEN THE OCCURRENCES OF *Legionella* AND WATER QUALITY

Sampling site	HPC (CFU/mL)	Total coliform (No./100 mL)	DOC (mg/L)	pH	Turbidity (NTU)
A	3.6×10^2	18	4.70	7.5	0.10
B	1.5×10^3	74	15.9	7.6	0.19
C	1.3×10^3	59	7.30	8.1	0.62
D	1.7×10^6	14	4.54	8.3	0.47

HPC = Heterotropic plate count.

A number of studies evaluating influential factors on *Legionella* growth have been performed. The density of *Legionella* related positively with the level of total organic carbon, sulfate, calcium and nitrate and microbial biomass[20]. States *et al.*[22] reported that a high concentration of metal is toxic to *Legionella*. The optimal pH for *Legionella* survival was found[23] to be between 6 and 8. In present study, the level of copper, zinc and iron was not high and the dissolved organic matter was high (7.36 mg/L). The pH was in the optimal range between 6 and 8 in most samples.

In present study, 83.1 % of collected samples were positive for total colifoms. A high number of heterotropic plate count was detected and in 4 cases samples tested were *Legionella* positive. This result shows that decontamination of facilities, disinfection application and effective indicator evaluation with strict enforcement of guideline should be carefully considered to protect from a potential health threat from public bath facility.

Conclusion

This research was performed to assess the microbiological and chemical pollution in public bathing facilities in South Korea and to investigate a better approach for the management of related public recreational facilities such as spring spas and swimming pools. The 80 samples in this study were taken from hot tub, cold tub and tap water from inside the public bath facility. The following conclusions were drawn from the presented study.

Present investigation has shown the high level of total coliforms in public bath facilities. Total coliforms are currently the only microbiological guideline item for the management of public bath facilities in Korea and were detected in 83 % of samples. The occurrence of total coliform was correlated with the level of dissolved organic carbon. The level of dissolved organic carbon was not significantly different between tap water and tub water. Metal leaching was not serious in bath tub and tap water. Serious levels of trihalomethanes were not be detected in any of the samples.

The level of heterotropic plate count was related to turbidity in hot tub water. The presence of total coliforms and the high level of heterotropic plate count in tap water indicate possible problems of water distribution.

A low positivity of *Legionella* (8.2 %) was shown in this research. However, considering the structural space characteristics of public bath facilities and the high concentration of nutrition discharged by bathers, suitable control measures should be considered to prevent future public infection risks.

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