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Correlations between Cleaning Frequency of Reservoir and Water Tower and Parameters of Water Quality

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Abstract**—**This study was investigated on sampling and analyzing water quality in water reservoir & water tower installed in two kind of residential buildings and school facilities. Data of water quality was collected for correlation analysis with frequency of sanitization of water reservoir through questioning managers of building about the inspection charts recorded on equipment for water reservoir. Statistical software packages (SPSS) were applied to the data of two groups (cleaning frequency and water quality) for regression analysis to determine the optimal cleaning frequency of sanitization. The correlation coefficient (R) in this paper represented the degree of correlation, with values of R ranging from +1 to -1.After investigating three categories of drinking water users; this study found that the frequency of sanitization of water reservoir significantly influenced the water quality of drinking water. A higher frequency of sanitization (more than four times per 1 year) implied a higher quality of drinking water. Results indicated that sanitizing water reservoir & water tower should at least twice annually for achieving the aim of safety of drinking water.

Keywords**—**cleaning frequency of sanitization, parameters of water quality, regression analysis, water reservoir & water tower

I. Introduction

THE quality and availability of drinking water are often indicative of the degree of modern nation. The news media in recent years have repeatedly reported incidents such as bacteria breeding in school water reservoir and pipeline terminals rupturing in water distribution systems. How to reduce public concerns and improve the safety of drinking water have become important issues to relevant government agencies.

Advanced water purification processes have been implemented in water treatment plants in Kaohsiung city, Taiwan. There are now four water treatment plants at Cheng-Ching Lake, Feng-shan, Kao-tan, and Weng-Gong-yuan to improve the quality of drinking water. Replacement of water distribution pipelines and proper maintenance of water storage facilities are even more vital to ensuring safe drinking water.

Researches from 2006 to 2008 [1,2,3] showed that the quality of drinking water in water tap from reservoir in Kaohsiung city significantly improved compared to previous years. The percentage of building residents using an indirect water supply from water reservoir had reached about 90% of the total residential population. While conducting installation interviews on the quality of water, researchers found that residents were exceptionally concerned about the safety of their drinking water in Kaohsiung city. These findings indicated the importance that residents placed on the safety of drinking water and regular sanitization of water reservoir.

Many scholars and experts studied the influence of hardness in drinking water on human health. Many overseas studies have demonstrated over the years that the level of hardness in water and the occurrence of disease in the human circulatory system had a strong negative correlation [4,5]. Drinking hardness water implied a lower risk of cardiovascular disease compared to drinking soft water. The mortality rate from stroke and myocardial ischemia among the population in areas primarily drinking soft water decreased following increase in the level of hardness of drinking water [6,7].

Rook [8] first confirmed in 1974 that chlorination of raw water could result in a variety of carcinogenic byproducts. According to a subsequent Keegan [9,10] report, trihalomethanes (THMs) contained liver and renal toxicity that were extremely carcinogenic. Apart from oral intake, carcinogenic substances could also be absorbed into the body through air or skin exposure during showering and swimming. As the most economical and effective method of eliminating potential pathogenic microorganisms in drinking water, chlorination is commonly used to disinfect water, despite the deficiencies of such a method due to THMs [11]. According to a survey conducted by Shin [12] in Korea, THMs represented the largest concentration of chlorination byproducts, at 60% of the total number of byproducts from chlorination, with halogenated acetic acid (HAAs) ranking second at 20%.The current methods of increasing the safety of drinking water are careful selection of water sources, improvement of water treatment system, continuous detection and reduce of THMs from treated water and regular sanitization of water reservoir.

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The purposes and content of this study mainly included (1) the results of tests of water parameters sampling from water reservoir installed in collective housing facilities with a minimum of 100 (inclusive) units, collective housing facilities with a maximum of 99 (inclusive) units, and various types of schools, in Kaohsiung. (2) Questioning building management administrators, the building management committee, or other persons in supervisory positions about the frequency of sanitization of water reservoir. Statistical software packages (SPSS) were used for regression analysis to generate the correlation coefficient (r) to determine the degree of correlation between cleaning frequency of sanitization and the results of water quality [13]. This study aimed to gain a clearer understanding of the quality of running water used in collective housing facilities and school buildings, and cleaning frequency of sanitization required to meet safety requirements for drinking water.

II. Equipment And Methods

The research methods in this study primarily targeted nine parameters of water quality: water temperature, hydrogen ion concentration index (pH), conductivity, free residual chlorine, hardness, THMs, total organic carbon (TOC), dissolved organic carbon (DOC), and UV254. According to the standards for the quality of drinking water (Environmental Protection Administration, Executive Yuan, R.O.C., 1998), the hardness of water is the element that most affects the drinkability of water and THMs is represented the most significant item on human health.

A. Sample Targets and Number of Water Samples

Fifty samples of water reservoir & water tower were taken from collective housing facilities with a maximum of 99 (inclusive) units and from collective housing facilities with a minimum of 100 (inclusive) units. Thirty samples of water reservoir & water tower were taken from various types of schools.

B. Analysis of Water Quality Items

Table 1 displays the compilation of methods of analysis for the nine parameters of water quality: water temperature, pH, conductivity, free residual chlorine, hardness, THMs, TOC, DOC, and UV254.

C. Procedures for Field Sampling

This study planned the on-site process of sampling based on methods for sampling the quality of drinking water, in specific relation to water systems (NIEA W101.54A), established by the Environmental Protection Administration (EPA).

The standard procedure for field sampling operations is as follows:

1) For pH measurements, the pH meter must first be correctly calibrated. Calibration should start with pH = 10 standard solution, then pH = 7, and finally finish with pH = 4.
2) To quantify elements of field inspection, immediately begin measurement of test elements such as pH, water temperature, and free residual chlorine, and simultaneously record all quantification results in the table sheet of field test results.
3) To detect THMs or other organic substances, sampling bottles should be filled to maximum capacity with water.

D. Regression analysis of clean frequency of sanitization and results of water quality from water reservoir & water tower

During sampling, cleaning frequency of sanitization was collected through questioning the building administrator or other persons in supervisory positions about the water reservoir & water tower. Sanitization cleaning frequencies and the test data on water quality were entered in statistical software packages (SPSS) for correlation analysis. The correlation coefficient (R) was used to determine the degree of correlation between cleaning frequency of sanitization and results of water quality. Values of R usually lie between +1 and -1($-1 \leqq r \leqq +1$).

TABLE I Compilation Of Methods Of Analysis For The Nine Parameters Of Water Quality

No	Test Element	Method of Analysis	Unit	Standards for Quality of Drinking Water
1	water temperature	NIEA W217.51A water temperature detection method	℃	-
2	pH	NIEA W424.51A electrode method	-	6.0 ~ 8.5
3	conductivity	NIEA W203.51B conductivity meter method	μs/cm	-
4	free residual chlorine	NIEA W408.51A Spectrophotometry	mg/L	0.2 ~ 1.0
5	hardness	NIEA W208.51AEDTA titration	mg $CaCO_3$/L	300
6	THMs	USEPA Standard Method 501.2	mg/L	0.08
7	TOC	NIEA W532.52C peroxide sulfur coke hydrochloric acid heating oxidation / Infrared detection method	mg/L	-
8	DOC			
9	UV_{254}	USEPA Standard Methods 501.2	1/cm	-

Note：1. NIEA (National Institute of Environmental Analysis) refers to the methods of testing published by the EPA, Executive Yuan.
2. USEPA Standard Methods are the standard testing methods of the U.S. EPA.

III. Results and Discussion

Table 2 shows the value of the correlation coefficient R and its meaning. An R-value of +1 signifies a strong positive linear relationship between two variables. An R-value of - 1 signifies a strong negative linear relationship; an R-value of 0 indicates that there is no linear relationship, and an R-value of 0 does not indicate that two variables are not related only that their relationship could be non-linear.

Table 3 shows the relations among the correlation coefficient, the level of significance, and the sample size. The value of R itself could not indicate a strong or weak correlation between two variables, as the values could have been a chance result. The number of samples (N) and the level of significance (α) were also considered. In general, a decrease in N resulted in an increase in the value of R, indicating the existence of a correlation between these two variables. In contrast, an increase in N did not result in an increase in the value of R, further indicating that the two variables were related.

TABLE II THE LEVEL OF STRENGTH OF THE CORRELATION COEFFICIENT R AND ITS MEANING

Correlation Coefficient (R)	Meaning
> 0.8	Extremely strong correlation
0.6 ~ 0.8	Strong correlation
0.4 ~ 0.6	Modest correlation
0.2 ~ 0.4	Weak correlation
< 0.2	Extremely weak correlation

TABLE III RELATIONS AMONG THE CORRELATION COEFFICIENT, LEVEL OF SIGNIFICANCE, AND SAMPLE SIZE

N	df	α=.05	α=.01
3	1	0.997	0.999
5	3	0.979	0.959
10	8	0.632	0.765
30	28	0.361	0.463
120	100	0.195	0.254

Table 4 shows the compilation of significant correlation between cleaning frequency of sanitization and the quality of water in collective housing facilities with a maximum of 99 (inclusive) units, collective housing facilities with a minimum of 100 (inclusive) units, and various types of schools in Kaohsiung city. The following conclusions were obtained from findings based on the correlation analysis of cleaning frequency of sanitization and various items of water quality:

A. Correlation analysis of water reservoir & water tower in collective housing facilities with a minimum of 100 (inclusive) units in Kaohsiung city:

Among the collective housing facilities with a minimum of 100 (inclusive) units sampled, one facility sanitized water reservoir only once annually, and correlation could not be established in that case. Cleaning frequency of 4 or more times annually was strongly correlated with TOC and DOC (R = 0.958, α = 0, significance level <0.01).The reduce efficiency on TOC and DOC is very high.

Cleaning frequency of two to three times annually was strongly correlated with TOC and DOC (R = 0.914, α = 0, significance level <0.01). The reduce efficiency on TOC and DOC is same as that cleaning frequency of 4 or more times annually.

TABLE IV COMPILATION OF SIGNIFICANT CORRELATION BETWEEN CLEANING FREQUENCY OF SANITIZATION AND ITEMS OF WATER QUALITY

Frequency of sanitization (occurrences/year)	100 unit collective housing facilities			99 unit collective housing facilities			Various types of schools		
	Number of samples	Group 1	Group 2	Number of samples	Group 1	Group 2	Number of samples	Group 1	Group 1
≧ 4	21	TOC DOC	conductivity hardness	14	TOC DOC	conductivity hardness	4	TOC DOC	conductivity hardness
		R=0.958**	R=0.839**		R=0.951**	R=0.892**		R=0.999	R=0.993
		α=0	α=0		α=0	α=0		α=0.001	α=0.007
2 ~ 3	28	TOC DOC	conductivity hardness	36	TOC DOC	conductivity hardness	18	TOC DOC	conductivity hardness
		R=0.914**	R=0.662**		R=0.953**	R=0.683**		R=0.777**	R=-0.601**
		α=0	α=0		α=3E-19	α=5E-06		α=0	α=0.008
≦ 1	1	TOC DOC	conductivity hardness	0	TOC DOC	conductivity hardness	8	TOC DOC	-
		-	-		-	-		R=0.842**	-
		-	-		-	-		α=0.0087	-

B. Correlation analysis of water reservoir & water tower in collective housing facilities with a maximum of 99 (inclusive) units in Kaohsiung city:

Collective housing facilities with a maximum of 99 (inclusive) units that had a cleaning frequency of less than once a year could not be obtained. Sanitization frequencies of either 4+ times or 2 to 3 times annually were strongly correlated with TOC and DOC (R-values were 0.951, α = 0 and 0.953, α = 3E-19; significance level <0.01), and with conductivity and level of hardness (R-values were 0.892, α = 0 and 0.683, α = 5E-06, respectively; significance level <0.01).

C. Correlation analysis of water reservoir & water tower in 30 schools in Kaohsiung city:

Analysis of cleaning frequencies of sanitization of water reservoir & water tower in schools demonstrated that frequency of sanitization, regardless the degree of frequency, was strongly correlated with TOC and DOC (R values were 0.999, α = 0.001, 0.777, α = 0 and 0.842, α = 0.0087; significance level <0.01).

D. Comprehensive analysis:

The above analysis results indicates that the higher cleaning frequency of sanitization, the greater the correlation coefficient. The correlation coefficient was more reliable when it had reached a level of significance of α <0.01 or α <0.05.

The cleaning frequency of sanitization of water reservoir & water tower and water quality items TOC/DOC were strongly correlated in all cases, indicating that regular sanitization of water reservoir & water tower could assist in removal of microorganisms from drinking water. Such purification is vital to preventing microbiological breeding. In addition, the quality of water in water reservoir & water tower in private households could also be evaluated according to the characteristics of conductivity in drinking water.

The percentage of cleaning frequency of sanitization of water reservoir & water tower are demonstrated that in collective housing with a minimum of 100 units, collective housing with a maximum of 99 units, and various types of schools, 56%, 72%, and 60%, sanitized water reservoir twice annually (i.e. once every six months); 42%, 28% and 13%, sanitized water reservoir four times annually (i.e. once every three months). Twenty-seven per cent (27%) of various types of schools sanitized water reservoir once annually.

This study confirmed that, for the above three categories of drinking water users, sanitizing water reservoir & water tower once every six months at least could ensure safe drinking water.

IV. Conclusion

This study found that the cleaning frequency of sanitization of water reservoir & water tower significantly affected quality of drinking water in all cases (collective housing facilities with a minimum of 100 (inclusive) units, collective housing facilities with a maximum of 99 (inclusive) units, and various types of schools at all levels). Higher frequency of sanitization (four or more times annually) increased quality of drinking water. Results showed that sanitizing water reservoir & water tower at least twice annually is sufficient to meet requirements for safe drinking water.

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