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Study on users' recognition of and behavior toward water reuse

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ABSTRACT

The purpose of this study was to investigate users' recognition of a facility that supplies reused water for toilet flushing. A survey was conducted among 150 students at Sungkyunkwan University, where the water reuse facility is installed. The results were analyzed by the SPSS 18.0 statistical program. The survey's validity and reliability were analyzed using content validity, an exploratory factor analysis, and Cronbach's α, respectively. At the water reuse facility, the sewage effluent was treated through an advanced oxidation process and then supplied as toilet flushing water. From January to July 2017, 40,909 tons of gray water was reused. Moreover, the water quality thereof satisfied the water quality standards for cleaning and toilet water. Regarding users' recognition of the shortage and satisfaction in using reused water as toilet flushing water, most appreciated the urgency in finding a solution to the shortage. Likewise, 93.4% of users noticed no difference between the reused water and tap water. These results show that this positive recognition of water reuse will favorably impact the expansion of water reuse facility in the future.

Keywords: Gray water; Gray water system; Toilet flushing water; Water reuse recognition

1. Introduction

Incident of human water security has been found in 80% of the world's population and South Korea falls in the "high incident threat" category [1]. Likewise, South Korea experiences high water stress and has a low river drainage rate of 36%, which has created a vulnerable condition with respect to water usage during a drought. In addition, the existing water supply system in South Korea comprises a process of water intake, water purification, water supply and drainage, water supply, and water reception. Therefore, a large volume of energy is consumed in long-distance transportation, and greenhouse gas emissions are high. In such a situation, interest in using sewage-treated water, rainwater, and even gray water to replace existing water resources is increasing [2,3]. Furthermore, it is also considered a key strategy to prepare for upcoming droughts and disasters due to climate change [4,5].

In South Korea, plans and strategies to actively cope with water reuse projects to secure alternate resources have been implemented, such as the "Promotion of and Support for Water Reuse ACT (2010.6)," "Water Industry Development Strategy (2010)," and "Water Reuse Basic Plan [6,7–9]." The aim of the National Water Reuse Basic Plan is to increase

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rainwater usage to 49 million tons per year and gray water usage by 489 million tons per year by 2020. In 2015, 528 gray water facilities with a capacity of 1,202,000 tons, treated 843,000 tons per day. Moreover, there are 1,650 rainwater utilization facilities, and of the 4,563,000 tons of rainwater storage capacity, 7,024,000 tons of rainwater is used per year.

In order to promote water reuse, it is important to develop water treatment technology. Likewise, public's passive recognition and acceptance is important [10]. Yet, public recognition and acceptance of water recycling often lag behind [11–13]. In order to implement a water reuse policy plan, and secure policy continuity and stability for water reuse, it is necessary to improve public recognition of water reuse [14].

Therefore, this study was conducted to investigate the recognition of water reuse by water reuse facilities among students at Sungkyunkwan University in Suwon, Gyeonggi-do, South Korea. Currently, the water reuse facilities at Sungkyunkwan University reuse treated sewage water as toilet flushing water. As such, the survey was on student users' recognition of water reuse. The results of the survey are expected to serve as the basic data for the water reuse promotion policy and policymaking in the future.

2. Methodology

2.1. Research subject

This study investigated students' recognition of water reuse facility installed at the Sungkyunkwan University Natural Science Campus in Suwon, South Korea. The sewage discharged from the school moves to the wastewater treatment plant, where the process used is membrane bioreactor (Fig. 1). The process was operated with <4 d of sludge retention time and 2 h of hydraulic retention time (HRT). The effluent water treated at the plant is supplied to the medical college and second research complex center, where, too, water reuse facilities are installed and operating.

The water reuse facilities, which reuse treated wastewater, has been in operation since May 2016. Those produce and supply 632 ton/d for toilet flushing in each building. At the water reuse facility, after treatment through an advanced oxidation process (AOP), the water is reused directly as toilet flushing.

The medical school comprises five buildings, and is supplied with ~483 tons of water per day. The second research complex center, which consists of two buildings, is supplied with ~149 tons of water per day. The total number of residents is 17,350 and 1,164 sanitary wares are supplied with reused water, which is around 623 ton/d. In addition to the water reuse facility, the IBS center also includes a rainwater utilization facility, which collects and reuses rainwater, thus integrating and linking various water resources (Fig. 2).

The water recycling process uses a micro-ozone bubble generator (HIO-600, Korea). The operating conditions are shown in Table 1. And water quality was measured in compliance with the water pollution process testing standards.

2.2. Investigation method

The survey of water reuse facilities was conducted among students who directly use the facility, and the data were collected in November 2016. Among the total number of students at Sungkyunkwan University Suwon Campus (30,840), 150 were randomly sampled. For the data collection, researchers explained the purpose of the study, content of the questionnaire, and distributed and collected the questionnaires. Respondents answered on a five-point Likert scale having the following options: "very well," "well," "normal," "no," and "not at all." The responses "very well" and "well" were considered positive, "normal" as neutral, and "no" and "not at all" as negative.

The data were analyzed using the SPSS/PC + Version 18.0. Questions on the general characteristics of the research participants and reused water were obtained according to frequency and percentage.

2.3. Validity and reliability

To verify the validity and reliability of this study, an exploratory factor analysis and Cronbach's alpha analysis were conducted. In the exploratory factor analysis, a principal component analysis was employed to extract factors. In this case, Varimax, an orthogonal rotation method, was applied [15]. Reliability refers to the degree to which consistent results are obtained when repeatedly applying a measurement tool to the same respondents, which is consistent

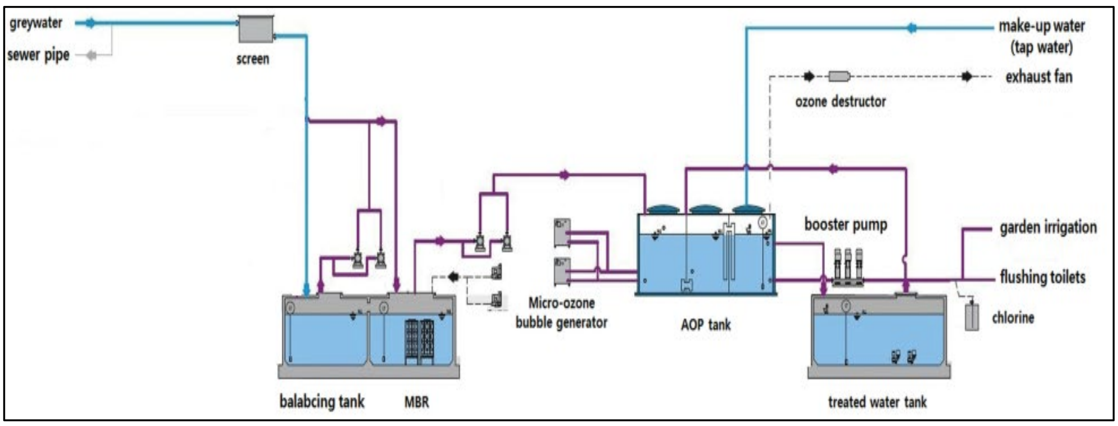


Fig. 1. Schematic diagram of the wastewater facility.

and predictable. In this study, reliability was measured by determining Cronbach's α coefficient for the four factors extracted in the factor analysis. When the value of Cronbach's α is 0.5–0.6, reliability is considered relatively high [16].

3. Results and discussion

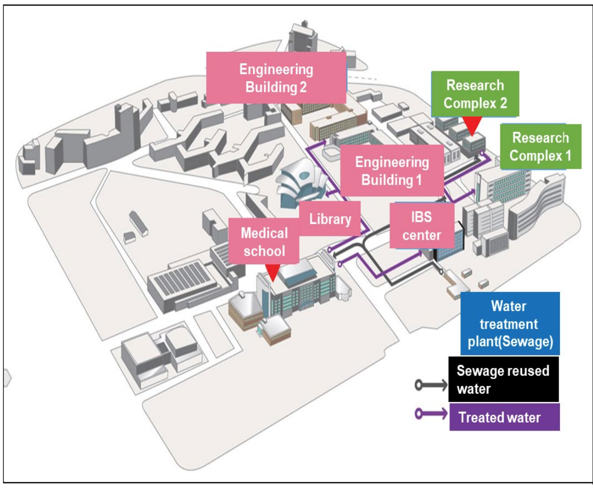
3.1. Water usage and water quality analysis

Table 2 provides the results of the monitoring of water use at the facility from January to July 2017. In all, 40,909 tons of water was reused, with a daily average of 194.8 tons. Because of changes to the population stemming from days off or vacation and weekend flow, less than the designed capacity of 632 tons was used per day.

The results of the water quality analysis are provided in Table 3. The inflow water was treated at the sewage treatment plant inside the school and supplied as toilet flushing water after AOP treatment at the water reuse facility in each building.

Table 1
AOP (10 µm ozone bubble) operating conditions

HRT	30
Ozone injection	2.5
I.D (mg/O_3)	0.37
K_c (10^{-3}/s)	1.32
Ozone-CT (mg/L s)	1,464.46



	Building	Population	Sanitary wares(EA)	Water Consumption(ton)
Medical School	IBS Center	1,000	159	35
	Library	4,100	112	150
	Medical School	2,600	172	93
	Engineering building 1	2,400	182	86
	Engineering building 2	3,250	260	116
	Subtotal	13,350	875	483
Research complex 2	Research complex 1	1,700	132	65
	Research complex 2	2,300	157	86
	Subtotal	4,000	289	149
Total		17,350	1,164	632

Fig. 2. Schematic diagram of the waste treatment water reuse facility at Sungkyunkwan University.

Table 2
Water reuse amount per buildings

	Total	Jan.	Feb.	Mar.	Apr.	May	June	July
Medical center	18,670	2,173	1,861	3,051	3,324	2,835	3,117	2,309
Research complex 2	22,239	3,904	3,736	4,024	3,001	1,053	2,104	6,726
Total	40,909	6,077	5,597	7,075	6,325	3,888	5,221	6,726

Table 3
Results of the water quality analysis

	BOD5 (mg/L)		CODcr (mg/L)		Color (degree)		Total Coliforms (CFU/100ml)		Turbidity (NTU)		Odor
	AVG[1]	SD[2]	AVG	SD	AVG	SD	AVG	SD	AVG	SD	–
	Min[3]	Max[4]	Min	Max	Min	Max	Min	Max	Min	Max	
Inflow	1.1	0.4	6.4	2.4	5.2	1.9	18	6	0.5	0.2	Offended
	0.4	1.6	2.8	10.1	2.1	7.3	6	26	0.2	0.8	
Outflow (AOP)	1.2	0.7	1.8	1.1	0.5	0.3	0	0	0.5	0.2	Not offended
	0.3	2.6	0.5	4	0.1	1.2	0	0	0.2	1	
Standard	5		–		20		0		2		Not offended

[1]Average, [2]Standard deviation, [3]Minimum, and [4]Maximum.

In the AOP, COD_{cr}, color, total coliform, and odor removal efficiencies were 71.9%, 90.4%, 100%, and 100%, respectively.

However, the treatment efficiency of BOD_5 and turbidity were considered low at –9% and 0%, respectively. The increase in BOD_5 in the AOP occurred due to the effect of ozone, leading to the conversion of degradable materials into biodegradable ones. It is often considered that the phenomenon is caused by the conversion of COD_{cr} into BOD_5 components [17]. The quality of the final treated water from the water reuse facility satisfied the water quality standards for cleaning and toilet water among the criteria for the use of gray water. Furthermore, its stable supply as toilet flushing water was demonstrated.

3.2. General characteristics of the study subjects

Gender distribution of the study respondents was 74% male and 26% female. In terms of departments, 74.7% were from engineering, 16.7% from natural science, 2% from physical education, 2% from medical science, and 4.7% from other fields. Last, 96.7% of the students were pursuing their bachelor's degree, 2% their master's degree, and 1.3% their doctoral degree. The students surveyed the toilets utilizing the reused water for flushing (Table 4).

3.3. Technical statistics

A statistical analysis was performed to determine the mean, standard deviation, minimum value, and maximum value of each variable used in this study. In addition, the substantiality of each variable was examined by calculating the skewness and kurtosis values. The results are provided in Table 5. The assumption of normality of measured variables is not significantly violated if the absolute value of skewness is 3 and that of kurtosis <10 [18]. The analysis indicated that all parameters were within normal limits.

3.4. Reliability analysis

Reliability of each variable used in this study was measured. The results are provided in Table 6. The most reliable sub-factor was Cronbach's α of 0.762, namely the recognition of the water reuse facility, which was measured based on four items. In contrast, Cronbach's α for the recognition of water supply was 0.605, confirming that its reliability was the lowest. In general, if Cronbach's α is 0.6 or higher, reliability is considered high [19]. The Cronbach's α of all scale items in this study was higher than 0.6, indicating high reliability.

3.5. Exploratory factor analysis

To determine that the data collected was appropriate for factor analysis, a Kaiser-Meyer-Olkin (KMO) sample appropriateness test and Bartlett's sphere formation test were conducted. According to Kaiser [19], the KMO measurement value should be at least 0.7, and if 0.7 or more, a factor analysis should be performed, meaning it is at a normal level. The KMO measure for this study was 0.737, and therefore considered suitable for a factor analysis. In addition, the Bartlett test verifies the correlation coefficient matrix used in the factor analysis. The Bartlett sphere test value for this study was 397.618 (df = 66) and the significance level 0.000. The exploratory factor analysis procedure resulted in finally extracting 13 Variables from the four factors. The factor matrix and load per item are shown in Table 7.

3.6. Analysis of users' recognition of water reuse facility

3.6.1. Water shortage recognition

When asked whether they believe a water shortage could occur in the future, 70.7% of respondents answered positively, 12.7% were neutral, and 23% answered negatively. When asked whether they believe saving water is important for the protection of the environment, 82% responses were positive, 12.7% neutral, and 5.3% negative. Furthermore, on high water consumption in South Korea, 71.3% responses were positive, 22.7% neutral, and 6% negative. In response to

Table 4
General characteristics of the study subjects

Classification		Distribution	
		Person	%
Gender	Male	111	74
	Female	39	26
Department	Engineering	112	74.7
	Natural science	25	16.7
	Physical education	3	2
	Medicine	3	2
	Others	7	4.7
Degree	Bachelor	145	96.7
	Master	3	2
	Doctoral	2	1.3

Table 5
Key variable technical statistics

(N = 150)

Variable	Average	Standard deviation	Minimum value	Maximum value	Skewness	Kurtosis
Appropriateness of water reuse	4.0250	0.55695	2.00	5.00	–0.567	1.288
Environmental protection	3.9133	0.56013	2.25	5.00	–0.606	0.312
Recognition of water reuse	2.8300	0.52827	1.00	4.50	–0.416	1.657
Water service satisfaction	2.4833	0.66407	1.00	4.00	–0.060	0.295

Table 6
Reliability of the scale

Sub-factor	No. of questions	Cronbach's α	Eigenvalue	Variance description (%)	Cumulative description (%)
Recognition of water shortage	4	0.629	2.118	16.293	36.318
Recognition of water supply	2	0.605	1.495	11.498	60.585
Recognition of water reuse facility	4	0.762	2.603	20.025	20.025
Recognition of water reuse	3	0.612	1.660	12.769	49.087

Table 7
Factor matrix table

Contents	Factor 1	Factor 2	Factor 3	Factor 4
Will there be water shortage in the future?	0.720			
Water conservation is important for environmental protection	0.656			
South Korea uses a lot of water	0.641			
Water reuse is necessary in case of water shortage	0.534			
The current water fee rate is expensive		0.782		
I am satisfied with the current water supply facility.		0.752		
Reused water is appropriate for use as toilet flushing water			0.831	
There is an intention to use reused water as toilet flushing water in homes			0.809	
There is agreement in terms of using reused water as toilet flushing water			0.766	
It is necessary to expand the installation of water reuse facilities to solve the water shortage			0.610	
There is an interest in water management				0.796
It is necessary to develop alternate water resources				0.656
The differences between reused water and water from the water supply facility were noticeable				0.574

the water shortage situation, 83.3% of respondents answered positively to the necessity of water reuse, 14.7% were neutral, and 2% answered negatively. This indicated that respondents recognize the necessity of water reuse in preparation of water shortage in the future.

3.6.2. Water supply recognition

When asked about their satisfaction with the use of tap water, 70.3% of respondents answered positively, 24% were neutral, and 12.3% answered negatively. In terms of satisfaction with water supply in general, 17.3% answered positively, 50.7% were neutral, and 32% answered negatively. Furthermore, the results indicated that respondents were generally satisfied with the current water rate.

3.6.3. Recognition of the water reuse facility

When asked about the suitability of reused water as toilet flushing water, 84.6% answered positively, 12% were neutral, and 3.3% answered negatively. Regarding respondents' intention to apply reused water to their residential space as toilet flushing water, 74.7% answered positively, 17.3% were neutral, and 8% answered negatively. In response to the opinion that water reuse facility should be expanded to solve the water shortage problem, 89.3% answered positively, and the remaining 10.7% were neutral. Furthermore, regarding the recognition of reusing sewage water as toilet flushing water, 86% of respondents were positive, 10.7% neutral, and 3.3% negative. Facility users answered positively to the use of reused water as toilet flushing and appeared to show little resistance in doing so.

3.6.4. Recognition of water reuse

The rate of interest in water management among facility users was 22.7% positive, 53.5% neutral, and 24% negative. Regarding the necessity of developing alternate water resources, 75.3% answered positively, 22% were neutral, and 2.6% answered negatively. When asked whether the difference between the reused water and tap water as toilet flushing water was significant, 93.4% answered positively, 1.3% were neutral, and 4.7% answered negatively. The results indicated that 93.4% of respondents did not notice any difference between the reused water and tap water when using the toilet; those who did were asked more questions to clarify the difference. Three respondents answered that the water smelled different, and the remaining seven said the water's transparency differed. This indicated that users are sensitive to the odor and color of reused water.

4. Conclusion

This study was conducted to survey recognition of users who use reused water for toilet flushing, and investigate the effect of experience to influence the recognition of using reused water.

Regarding the recognition of water shortage, 71.3% of respondents reported feeling that South Koreans use an excessive amount of water, while 70.7% said South Korea would run out of water in the future. Further, 83.7% believed that water should be reused. Meanwhile, 70% of respondents were mostly satisfied with the water supply, including the fees thereof.

In terms of water reuse facilities, 84.6% of respondents demonstrated a positive recognition of using reused water as toilet flushing water, and 74.7% indicated that they would implement the idea in their own living spaces to reuse water. To solve the water shortage problem in the future, 89.5% of respondents believed that water reuse facilities should be expanded. Furthermore, when using water from the water reuse facility, 93.4% of respondents reported not noticing any difference between the reused water and tap water. As such, they were generally satisfied with the reused water. On the other hand, users who did notice a difference reported that the odor and color of the reused water differed.

Based on the analysis of users' recognition of water reuse facilities, satisfaction with the reused water as toilet flushing water was very high, and these experiences were helpful in driving positive recognition of water reuse.

Therefore, in order to vitalize water reuse, it is important to not only come up with a water reuse policy but also let users know that they are using recycled water. Experiences of using reused water will make them overcome the prejudice associated with it. In addition, it is considered that the stability of water quality should be strengthened to improve the reliability of the reuse water quality.

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