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THE WATER QUALITY CHARACTERISTICS OF EFFLUENT GROUNDWATER FLOWING INTO THE RIVER IN SEOUL

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Abstract- To use effluent groundwater as stream maintenance water, it is important to evaluate the water quality compared to the nearby streams. Therefore, we examined the water quality characteristics and compared the results to nearby streams using continuous water quality inspection data generated from subway stations, electric power plants, communication ports, and buildings. The purpose of this study was to provide basic data to estimate the application potential and to derive a utilization plan for the effluent groundwater. Generally, precautions are needed for the aesthetic parameters including turbidity and color to use the effluent groundwater as stream maintenance water. Also, it is necessary to construct utilization plans that suit each facility such as separate classifications, processing, and uses tailored to each facility. As a result of the water quality comparisons it was found that the water quality of the effluent groundwater generated from each facility was better than that of the nearby stream for all parameters except for certain samples. Currently, the water quality is sufficient even if effluent groundwater is discharged to the nearby streams and the effluent groundwater is considered sufficient to utilize as stream maintenance water and to dilute nearby streams during water shortage periods.
Keywords – Effluent Groundwater, Underground Facilities, Stream Maintenance Water, Nearby Stream

1. INTRODUCTION

Until recently, large scale civil works such as subway stations, tunnels, and buildings have been carried out in major cities including Seoul to promote industrial development and land use. As such, side effects such as high quality groundwater continuously flowing into rivers and sewage treatment plants are also emerging. If we evaluate the occurrence of effluent groundwater in Seoul, the production of effluent groundwater is steadily increasing by about 66% from 229,621 m3/d in 2011 to 381,315 m3/d in 2018. The production of effluent groundwater is essentially influenced by the amount of precipitation, but the production of effluent groundwater is increased by artificial human activities such as underground development. According to “Management of effluent groundwater (Ministry of Land, Transport and Maritime Affairs)” [1], if groundwater leaks, its effects are not confined to facilities, but the disturbance extends to the groundwater and groundwater circulation systems in the region. Therefore, groundwater leakage should be prevented. However, in cases where groundwater leakage occurs, aggressively effluent groundwater should be used for alternative purposes. Effluent groundwater uses can be classified by the amount of effluent groundwater available. If effluent groundwater is used mainly on medium and small scales, effluent groundwater can be internal used for such applications as toilet washing, cleaning water, and heating and cooling energy sources, as well as other similar applications. Large scale effluent groundwater can be repurposed for external uses, such as for stream maintenance water, aquatic landscape design, and other applications according to the local conditions. In addition, according to the Groundwater Act [2] and the Groundwater Act Enforcement Regulation [3], for subway stations, electric power plants, and communication ports that discharged more than 300 tons of effluent groundwater per day, a building with a floor space of 100,000 m2 or more, and a building with 21 or more floors that discharged more than 30 tons of effluent groundwater per day, measures are required to the reduce effluent groundwater. In spite of these reduction measures, effluent groundwater use plans should be established when effluent groundwater is generated. Fortunately, in recent years, to prevent water shortages due to climate change, interest in water reuse and water circulation management has increased and the importance of using the effluent groundwater for the process of developing underground spaces such as subway station, electric power plants, communication ports, and buildings has been emphasized.
If we examine the usage status of effluent groundwater over eight years from 2011 to 2018, out of the total production of effluent groundwater amounts of 2,571,254 m3/d, 1,569,854 m3/d (61.1%) for stream maintenance, 79,903 m3/d (3.1%) for building water and 62,116 m3/d (2.4%) for park water were used. Also, effluent water was used for road cleaning, landscaping, and supplies to surrounding buildings. Besides, the remaining amount of effluent water was discharged to the sewer, and the sewage discharge amount was 709,449 m3/d (31.5%). In this way, effluent groundwater generated from

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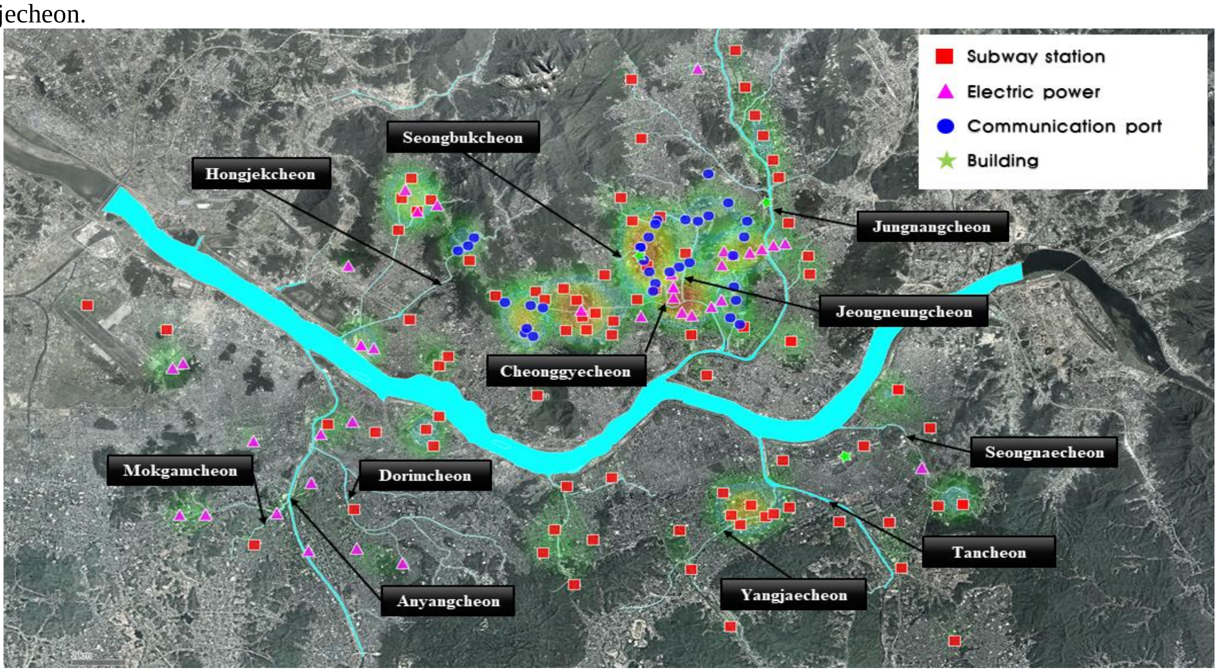
underground facilities is mainly used as stream maintenance water used to prevent stream drainage and for aquatic landscape designs. Especially, in cases of continuous drought such as a decrease in the average annual precipitation, it is desirable to utilize effluent groundwater as stream maintenance water to maintain minimum natural water levels. Considering the fact that alternative water resources need to be secured, if a portion of the effluent groundwater flows into the sewage treatment plant through the public sewer in addition to stream maintenance water, it may result in a deterioration of sewage treatment efficiency and economic loss [4]. Therefore, this problem should be improved in the future.

As effluent groundwater is mainly used as stream maintenance water, it is necessary to compare the water quality of the effluent groundwater with that of nearby streams. If the effluent groundwater quality does not conform to the nearby stream water quality level, it will affect the aquatic ecosystem by lowering the nearby stream water quality. Therefore, it should not be used as stream maintenance water, and it should be routed through water treatments plants for other purposes. However, most studies on effluent groundwater have highlighted aspects such as system construction, system improvement, and financial support for the activation of effluent groundwater utilization, while the fundamental research on the characteristics of effluent groundwater quality and the comparison of water quality with nearby streams is lacking. Therefore, in this study, we examined the water quality characteristics of effluent groundwater generated from subway stations, electric power plants, communication ports, and buildings that are being discharged to nearby streams in Seoul and compared the water quality with the nearby streams. Through these analyses, we will be able to provide the basic data needed to derive a utilization plan for the effluent groundwater such as discharge to nearby streams.

2. MATERIALS AND METHODS

2.1 Materials –

In this study, a total of 435 samples were collected from 167 effluent groundwater facilities, 229 samples from 85 subway stations, 101 samples from 44 electric powers, 95 samples from 34 communication ports, and 10 samples from 4 buildings that were used to investigate the water quality characteristics of effluent groundwater during three years from 2016 to 2018. The samples were collected from representative effluent groundwater wells in each facility. Also, to compare the quality of the effluent groundwater with that of nearby streams where the effluent groundwater is discharged, and to ascertain the feasibility of discharge to nearby stream, we used the “Water Environment Information System (http://water.nier.go.kr)” [5] to collect water quality data of nearby streams during three years from 2016 to 2018. In this study, effluent groundwater generated from each facility was discharged to nearby streams such as the Dorimcheon, Mokgamcheon, Seongnaecheon, Seongbukcheon, Anyangcheon, Yangjaecheon, Jeongneungcheon, Jungnangcheon, Cheonggyecheon, Tancheon, and Hongjecheon.



Location of the effluent groundwater discharge facilities

2.2 Analysis and methods –

Among the organic substances, nutrients, and microorganisms indicators, such as biological oxygen demand (BOD), total organic carbon (TOC), suspended solids (SS), total phosphorus (T-P), fecal coliform group, and total coliform group, 6 items were analyzed. In addition, for the statistical analyses, among the feces contamination and aesthetic indicators such as total nitrogen (T-N), nitrate nitrogen (NO3-N), color, turbidity, and chlorine ion (Cl-), 5 items were analyzed.

The analysis was carried out according to the “Water Pollution Standard Method (Notice of National Institute of Environmental Research No. 2017-57)” [6] and “Quality Standard for Drinking (Water Notice of the National Institute of Environmental Research No. 2017-19)” [7]. Especially for the microbial analyses, to minimize contamination, samples were analyzed as soon as possible on the day of sample collection. In order to understand the water quality characteristics of the effluent groundwater, statistical analyses such as the correlation analysis and factor analysis by water quality item was conducted using open source language R 3.5.2 and the 2017 effluent groundwater data. In case of the factor analysis, the principle component analysis and VariMax methods were used for the factor analysis. Finally, in order to understand the concentration levels in the effluent groundwater, we compared with the values to nearby streams in terms of the living environment standard for the river in water quality and aquatic ecosystems in the Enforcement Decree of the Framework Act on the Environmental Policy [8] that is the national water quality standard applied to the current rivers.

3. RESULT AND DISCUSSION

3.1 Water quality characteristics of the effluent groundwater –

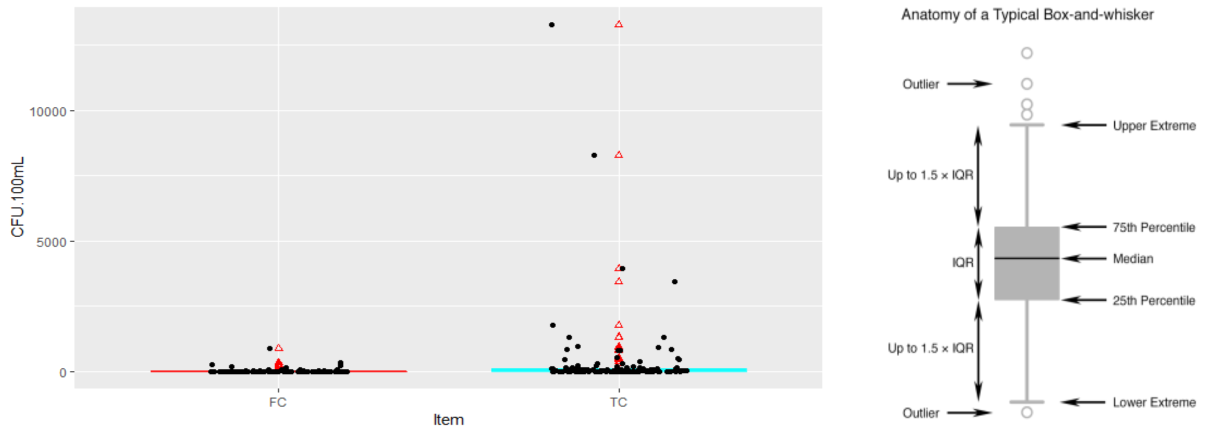
The water quality of the effluent groundwater was analyzed periodically for the last three years from 2016 to 2018, and the main results are shown in Table 1.

Table -1 Average water quality results for the effluent groundwater of Seoul (2016~2018)

Discharge facility	Number (n)	BOD (mg/L)	TOC (mg/L)	SS (mg/L)	T-P (mg/L)	Coliform group* (CFU/100 mL)	
						Fecal Coliform	Total coliform
Subway station	229	1.0 (0.0~6.8)	0.8 (0.0~6.3)	3.7 (0.2~74.1)	0.045 (0.001~0.457)	7 (0~893)	71 (0~13,286)
Electric power	101	0.6 (0.1~3.2)	0.8 (0.2~1.6)	1.7 (0.2~10.2)	0.029 (0.004~0.207)	2 (0~11)	19 (0~477)
Communication port	95	0.047 (0.0~0.6)	0.5 (0.3~1.1)	0.6 (0.3~2.4)	0.020 (0.007~0.210)	2 (0~7)	8 (3~20)
Building	10	0.3 (0.2~0.5)	0.7 (0.5~0.9)	0.7 (0.2~1.2)	0.015 (0.008~0.019)	1 (0~2)	5 (0~109)
Total	435	0.7 (0.0~6.8)	0.8 (0.0~6.3)	2.5 (0.2~74.1)	0.035 (0.001~0.457)	4 (0~893)	31 (0~13,286)

* For the coliform group, the mean value was obtained by the geometric mean

As shown in Table 1, most of the samples satisfied the BOD Ia grade (very good, 1 mg/L or less), TOC Ia grade (very good, 2 mg/L or less), T-P Ⅱ grade (slightly good, 0.1 mg/L or less), or the ~Ia grade (very good, 0.02 mg/L or less) of the living environment standards for the rivers in terms of water quality and aquatic ecosystems. In particular, effluent groundwater generated from electric power and communication ports were good (respectively, BOD 0.6 mg/L, 0.047 mg/L, TOC 0.8 mg/L, 0.5 mg/L, T-P 0.029 mg/L, 0.020 mg/L) in terms of water quality. Therefore, it was expected that it would be possible to use the water for not only stream maintenance, but also domestic water, cleaning water, and other clean water uses without complicated pre-treatments. This would aid plans for preparing the use of effluent groundwater in Seoul. On the other hand, in the case of the subway station, all the analytical results except the TOC were found to be higher than those of other facilities, namely, the 1.0 mg/L BOD, 3.7 mg/L SS, and the 0.045 mg/L T-P. This may be due to influences on the surrounding environment such as the nearby stream and soil, and the influence of pollution such as the influx of pollutants during construction, completion of construction, or subway movements due to overexposure of the collecting well, and insufficient washing. Also, Fig. 2 shows the distribution of the concentration values of the microorganisms using box and scatter-plots for the subway station. In particular, the total coliform group showed a large deviation (0~13,286 CFU/100 mL) at each point including the outliers (red mark). Therefore, it is important to prepare treatment measures such as ultraviolet sterilization and disinfection in advance to secure the safety of the effluent groundwater at the points where the fecal coliform group and total coliform group are high.



Concentration distribution of coliform group of effluent groundwater discharge facilities

3.2 Water quality characteristics of the effluent groundwater –

For the statistical analysis, the water quality analysis results of the effluent groundwater in 2017 using 5 parameters, namely, the total nitrogen (T-N), nitrate nitrogen (NO3-N), color, turbidity, and chlorine ion (Cl-) concentrations are shown in Tables 2 and 3.

Table -2 Average water quality results for the effluent groundwater of Seoul (2017)

Discharge facility	Number (n)	BOD (mg/L)	TOC (mg/L)	SS (mg/L)	T-P (mg/L)	Coliform group* (CFU/100 mL)	
						Fecal coliform	Total coliform
Subway station	85	1.2	1.3	7.1	0.075	13	154
Electric power	25	0.8	0.6	1.7	0.026	1	10
Communication port	31	0.039	0.5	0.5	0.018	1	5
Building	4	0.4	0.7	0.6	0.015	1	4
Total	145	0.8	1.0	4.6	0.052	5	42

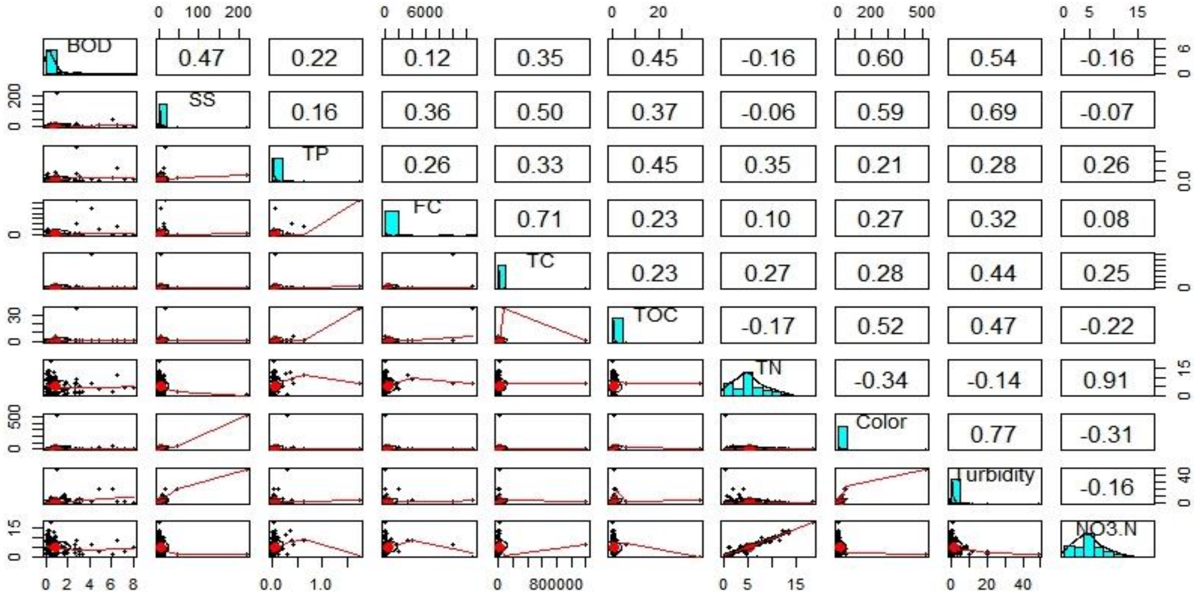
* For the coliform group, the mean value was obtained by the geometric mean

Table -3 Average water quality results for the effluent groundwater of Seoul (2017)

Discharge facility	Number (n)	T-N (mg/L)	NO3-N (mg/L)	Color (TCU)	Turbidity (NTU)	Cl- (mg/L)
Subway station	85	5.441	5.355	10	2.53	80.3
Electric power	25	5.852	5.461	2	0.88	75.7
Communication port	31	4.772	4.389	0	0.10	74.2
Building	4	5.646	5.893	2	0.49	75.4
Total	145	5.375	5.181	7	1.67	78.0

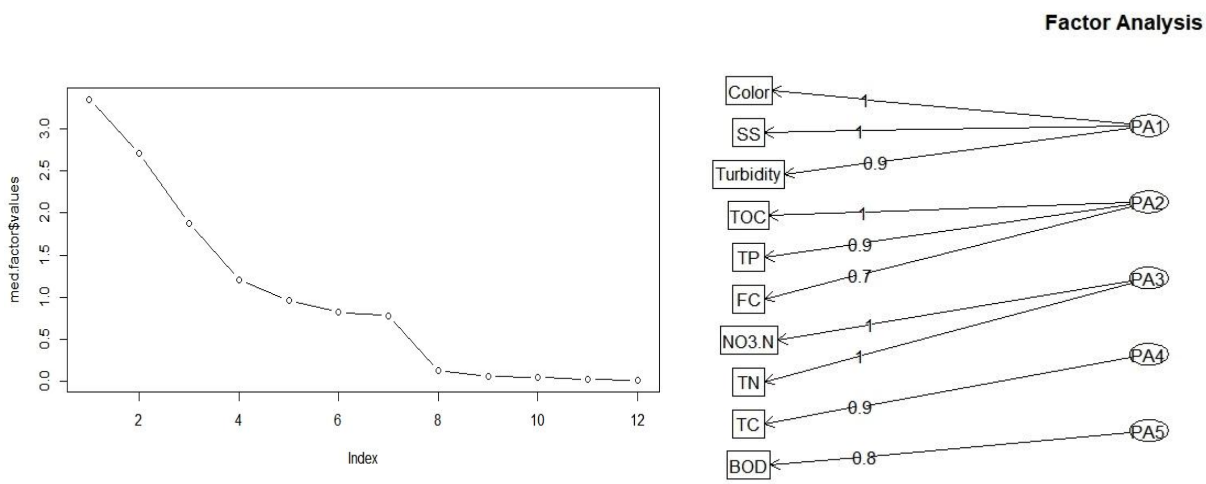
The average water quality of the effluent groundwater in 2017 had BOD values of 0.8 mg/L, TOC of 1.0 mg/L, SS of 4.6 mg/L, T-P of 0.052 mg/L, fecal coliform group 5 CFU/100 mL, and total coliform group 42 of CFU/100 mL. As such, this results correspond to BOD Ia grade (very good, 1 mg/L or less), TOC Ia grade (very good, 2 mg/L or less), T-P Ⅱ grade (slightly good, 0.1 mg/L or less), and ~Ia grade (very good, 0.02 mg/L or less) of the living environmental standards for rivers for water quality and aquatic ecosystems.

These results were worse than the average water quality concentrations for the last three years from 2016 to 2018. Correlation analysis and factor analysis by water quality parameter were conducted using 2017 effluent groundwater data (n = 145). The results are shown in Figs. 3 and 4.



Spearman correlation analysis by water quality parameter (2017)

The correlation analysis results showed a high positive(+) correlation between the aesthetic parameters such as SS, color, and turbidity, and showed that the correlation coefficient between SS and color was 0.59 ($p<0.01$), the correlation coefficient between SS and turbidity was 0.69 ($p< 0.01$), and the correlation coefficient between color and turbidity was 0.77 ($p<0.01$). In addition, the correlation between the fecal coliform group and the total coliform group ($r = 0.71$), the correlation between the T-N and NO3-N ($r = 0.91$), and the correlation between the BOD and color ($r = 0.71$) were high. In order to confirm the suitability of the factor analysis, KMO (Kaiser-Meyer-Olkin) verification and Bartlett tests were conducted. The measurement of the KMO (Kaiser-Meyer-Olkin) was 0.60 and the Bartlett test result was $p<0.01$. Five factors were extracted as a result of the factor analysis. As shown in Fig. 4, the first factor was SS, followed by color and turbidity.



Factor analysis using the principal component method (2017)

As shown in Figs. 3 and 4, when using the effluent groundwater, important parameters to consider are the aesthetic items such SS, color, and turbidity. When using surface waters such as rivers as a main water source, such as in Seoul, one of the water quality parameters that should be considered important in the river water quality is turbidity. This is because the turbidity influences water treatment processes such as filtration and disinfection [9]. Therefore, in cases where high turbidity effluent groundwater flows into nearby streams, turbidity reduction measures (preliminary treatment such as screen filtration, sedimentation, periodic cleaning of collecting well, and others) are needed. In addition, it is also important to control the color that is a typical aesthetic parameter when using the effluent groundwater. In particular, because color is directly recognized by the naked eye, it is necessary to reduce it with turbidity because it can cause civil problems such as aesthetic discomfort and lowered water quality reliability of the river. In general, one of the representative materials causing color in the water relates to iron. Iron is a substance that can be easily exposed to the surrounding environment in natural waters, especially groundwater. Iron in effluent groundwater is known to occur mainly from soil and underground facilities construction processes, such as grouting materials for ground reinforcement, urethane materials such as urethane used to prevent sudden groundwater leaks, and shotcrete that is sprayed on the outer walls of tunnels after excavation [10]. Iron is not included as a living environment standard for rivers in the water quality and aquatic ecosystems guidelines, but when discharging into a river, dissolved bivalent iron in the groundwater reacts with oxygen in the air to become trivalent iron and a red precipitate is formed that adversely affects parameters such as suspended solids, color, and turbidity. Therefore, precautions against iron should also be considered.

3.3 Comparison of the water quality of the effluent groundwater and nearby stream –

Tables 4 and 5 show the results of the comparison of the water quality of the nearby streams where effluent groundwater is introduced. The main points were selected considering the discharge rate (average 847.68 m3/d) of the effluent groundwater and the location of each facility (same administrative area as the nearby stream). The nearby streams that effluent groundwater flows into as stream maintenance water are the Anyangcheon, Jungnangcheon, Cheonggyecheon, and others. The average water quality values for these streams were a BOD of 2.3 mg/L(0.6~6.1), TOC of 2.9 mg/L(1.1~6.4), SS of 5.2 mg/L(1.8~12.6), T-P of 0.085 mg/L(0.012~0.206), fecal coliform group of 2,575 CFU/100 mL(28~54,059), and a total coliform group of 18,801 CFU/100 mL(197~227,587). The water quality levels of the nearby rivers excluding microbial parameters was grade Ⅲ (normal) ~ Ib grade (good) when applied to the living environment standards for rivers for water quality and aquatic ecosystems.

Table -4 Average water quality results for nearby streams with flowing effluent groundwater (2016~2018)(1)

Nearby stream	Classification	Discharge rate (m3/d)	BOD (mg/L)	TOC (mg/L)	SS (mg/L)	T-P (mg/L)	Coliform group (CFU/100 mL)	
							Fecal coliform	Total coliform
Dorimcheon	Stream	-	1.5	2.2	2.0	0.052	1,535	15,630
	Daerim	1,625.00	1.0	0.7	3.5	0.012	0	2
Mokgamcheon	Stream	-	2.6	4.1	7.4	0.148	5,726	75,305
	Onsu S/S	163.46	0.1	0.2	1.0	0.007	0	17
Seongnaecheon	Stream	-	2.7	2.5	10.4	0.092	3,938	23,488
	Geoyeo	701.33	2.0	0.6	7.1	0.041	24	151
	Macheon	679.67	1.4	0.3	10.0	0.021	13	46
	Mongchontoseong	342.33	1.6	0.7	3.3	0.008	2	3
	Geoyeo Shaft	43.00	1.0	1.6	0.6	0.158	11	90
Seongbukcheon	Stream	-	1.4	1.5	3.3	0.038	1,490	15,026
	Donam Kookmin Bank	142.67	0.0	0.5	0.7	0.011	2	6
	Donam Post Office	146.33	0.0	0.5	0.7	0.012	3	8
	Bomun Market	373.00	0.0	0.5	0.5	0.011	2	4
	Hansung Univ.	138.67	0.1	0.5	0.3	0.012	3	8
	Seongbukgu Office	252.67	0.3	0.5	1.2	0.016	2	109
Anyangcheon_4	Stream	-	4.8	6.4	12.6	0.178	54,059	131,673
	Gugong S/S	524.12	0.3	0.8	1.9	0.015	1	7
	Guro Tool Town	421.68	0.2	1.1	0.9	0.013	0	0
	Siheung IC	84.88	0.2	0.6	0.9	0.013	1	23
Anyangcheon_5	Stream	-	3.6	4.7	8.3	0.100	3,194	25,139
	Yangpyeong	2,498.67	1.3	1.1	3.8	0.028	5	493
	Yeongdeungpo S/S	151.44	1.2	1.0	5.1	0.020	1	79
Yangjaecheon	Stream	-	1.5	2.4	4.5	0.078	3,003	25,873
	Daecheong	91.67	1.0	0.9	6.5	0.015	26	814
	Daechi	1,259.67	2.3	1.3	20.6	0.066	2	367
	Dogok	353.45	0.4	0.6	6.0	0.242	54	323

Jeongneungcheon	Stream	-	0.9	1.1	2.0	0.064	2,274	12,620
	Gileum	835.67	0.1	0.8	1.1	0.037	6	68
	Miasageori	356.33	0.0	0.5	0.5	0.013	1	7
	Unam Building	373.67	0.0	0.5	0.4	0.032	1	3
	Wolgok Nonghyup	197.00	0.0	0.5	0.7	0.019	2	6
	Wolgok	137.67	0.0	0.5	0.3	0.013	1	17

Table -4 Average water quality results for nearby streams with flowing effluent groundwater (2016~2018)(2).

Nearby stream	Classification	Discharge rate (m3/d)	BOD (mg/L)	TOC (mg/L)	SS (mg/L)	T-P (mg/L)	Coliform group (CFU/100 mL)	
							Fecal coliform	Total coliform
Jungnangcheon_2	Stream	-	2.2	3.3	6.0	0.095	4,956	39,193
	Gongneung	1,621.33	1.8	1.0	12.6	0.011	11	147
	Hagye	316.67	6.8	1.1	7.5	0.021	65	452
Jungnangcheon_3	Stream	-	1.9	2.8	4.4	0.065	3,079	26,412
	Janghanpyeong	1645.67	1.0	1.1	0.5	0.022	167	3,447
	Junghwa	985.00	0.2	0.8	2.0	0.006	10	42
Jungnangcheon_4	Stream	-	6.1	4.3	6.9	0.206	29,095	227,587
	Wangsimni	103.00	0.5	0.4	3.0	0.003	20	3,300
Cheonggyecheon_1	Stream	-	0.6	1.4	1.8	0.012	28	197
	Gyeongbokgung	893.83	0.1	0.5	0.3	0.191	3	91
	Gwanghwamun	546.00	0.5	0.8	0.5	0.074	4	68
	Dongnimmun	164.70	0.1	0.9	1.5	0.041	5	171
	Dongmyo	1,612.00	1.0	0.8	1.7	0.057	2	18
	Jongno 3-ga	447.28	0.9	0.7	1.1	0.067	9	85
Cheonggyecheon_2	Stream	-	0.8	1.4	2.0	0.016	609	4,780
	Korea Univ.	2,395.00	1.3	0.8	1.6	0.015	14	927
	Bomun	614.23	0.3	0.8	1.2	0.033	1	4
	Majang S/S	634.00	0.5	0.7	1.0	0.031	0	9
	Seongdong	356.80	0.9	1.4	2.5	0.030	3	38
Cheonggyecheon_3	Stream	-	1.5	1.7	3.2	0.043	1,058	5,606
	Sindap	465.80	3.2	1.2	5.6	0.207	2	122
Tancheon_5	Stream	-	3.3	4.3	4.4	0.126	6,992	39,576
	Daemosan	5,096.40	0.4	0.7	2.8	0.001	1	20
	Bokjeong	1,642.38	0.5	1.0	74.1	0.104	14	127
	Sports Complex	5,659.67	1.0	0.5	0.7	0.011	3	122
	Suseo S/S	291.00	0.5	0.9	1.5	0.019	11	17
	Family Apt	178.67	0.5	0.9	0.8	0.019	8	23
Hongjecheon	Stream	-	2.2	1.9	3.9	0.052	1,106	11,002
	Hongje	1,288.47	0.1	0.7	0.9	0.100	2	26
	Shopping Center	141.33	0.1	0.5	0.4	0.009	3	17

Overall, it was found that the water quality of the effluent groundwater generated from each facility was better than that of the nearby streams for all parameters. In particular, microbial parameters concerned with the water quality of the effluent groundwater were significantly lower than those of the nearby streams. Therefore, it is currently considered that the water quality problem is insignificant even if the effluent groundwater is discharged to nearby streams without being used for various purposes such as building water and cleaning water. Therefore, the effluent groundwater is considered to be sufficient to utilize stream maintenance water and to dilute nearby streams during periods of water shortage. However, in the case of effluent groundwater discharged to some streams such as the Yangjaecheon and Cheonggyecheon, the maximum BOD 3.2 mg/L(Sindap), SS 20.6 mg/L(Daechi), and T-P 0.191 mg/L(Gyeongbokgung), BOD, SS, and T-P values were higher than those of nearby streams. This is because the concentration of organic matter increased suddenly due to the outflow of effluent groundwater along with the soil and irregular washing of the collecting well. In addition, since Yangjaecheon and Cheonggyecheon have effluent groundwater flows that are mainly located in commercial and densely populated areas where there is a high possibility that the collecting well is exposed to pollutants from the surrounding area. For such high concentration facilities, it is necessary to maintain a clean collection well to prevent the inflow of soil and to continuously monitor the effluent groundwater quality to determine whether the high concentration phenomenon is temporary or continuous. Furthermore, if the phenomenon is continuous, it is necessary to first compare the water quality of the effluent groundwater with that of nearby streams where the effluent groundwater is discharged as before for stream maintenance water. Also, it is necessary to construct utilization plans that are suitable for each facility such as separately classifying the excess facilities and then processing and using the effluent groundwater according to each facility.

Stream maintenance water is used to maintain the original function of the river and meet the normal functions of the river, such as maintaining the minimum natural water level, protection of the river ecosystem, and conservation of the river landscape apart from water used by humans. Also stream maintenance water flow rates must be considered in the management of the river quantity [11]. Currently, effluent groundwater for each facility is mainly utilized as stream maintenance water. As effluent groundwater is discharged to a river, not only the cost of sewage treatment is reduced, but also maintenance water for the urban river can be secured, and the river environment is improved. It can also be used for water amenity space composition. Therefore, firstly it is important to examine the feasibility of discharging to the river by comparing the water quality of the effluent groundwater with that of nearby streams where the effluent groundwater will flow because the effluent groundwater generated from each facility is utilized as stream maintenance water.

3.4 Discussion

Recently, the development of alternative water resources has been required to solve the water shortage problem and improve the utility of water resources, and the utilization of effluent groundwater along with rainwater has been emphasized. In particular, the demand for a more comfortable living and natural environment compared to an artificial living environment has increased due to income levels and public awareness. Therefore, the demand for the creation of water amenity spaces composition is increasing. Therefore, the use of effluent groundwater can be expected to have positive effects on the redistribution and securing of limited resources, replacement of the unnecessary use of tap water as cleaning water, and the reduction of sewage treatment costs by preventing good quality effluent groundwater from the inflowing sewage treatment plants [11].

If we examine the case of using effluent groundwater from abroad, as in the case of Japan, parks, green tracts, and waterways are being built to generate waterside landscapes using effluent groundwater [12]. In France, water is being used for such applications as car washes, after treating the effluent groundwater generated from subway stations [11]. In Korea, there are increasing cases where effluent groundwater generated from underground facilities in major cities such as Seoul, Busan, Daegu, Daejeon and Gwangju is being utilized as stream maintenance water, cleaning water, fire water, as a heating and cooling energy source, and other applications. However, in order to continuously supply stable water resources, specific utilization plans and policies for effluent groundwater should be prepared so that it can be used for various purposes besides stream maintenance water. In order to do this, as in this study, it is important to preferentially evaluate the status and water quality of the effluent groundwater.

4. CONCLUSION

In this study, we examined the water quality characteristics of effluent groundwater generated from subway stations, electric power plants, communication ports, and buildings in Seoul and compared the water quality with nearby streams to provide basic data for the use of groundwater in the future. As such, the following conclusions were drawn from the results.

1) From 2016 to 2018, as a result of the water quality analysis of the effluent groundwater, the overall water quality of the effluent groundwater satisfied a BOD Ia grade (very good, 1 mg/L or less), TOC Ia grade (very good, 2 mg/L or less), T-P Ⅱ grade (slightly good, 0.1 mg/L or less)~Ia grade (very good, 0.02 mg/L or less) for the living environment standards for rivers in terms of water quality and aquatic ecosystems. On the other hand, for the subway station, all the analytical parameters except the TOC were found to be higher than those of other facilities such as the electric power plant, communication port, and building.

2) The statistical analysis results using the 2017 effluent groundwater data (n = 145) showed a high positive(+) correlation between the aesthetic parameters such as SS, color, and turbidity. The correlation coefficient between the SS and color was 0.59 ($p<0.01$), the correlation coefficient between the SS and turbidity was 0.69 ($p< 0.01$), and the correlation coefficient between color and turbidity was 0.77 ($p<0.01$). Also, as a result of factor analysis, the first factor was SS, followed by color and turbidity.

3) Generally, it is necessary to take precautions for aesthetic parameters such as turbidity and color in order to utilize the effluent groundwater for stream maintenance water. For this purpose, aesthetic parameter reduction measures (preliminary treatment such as screen filtration, sedimentation, and periodic cleaning of the collection well) are needed.
4) In the case of facilities with continuously high concentrations of water pollutants, it is necessary to compare the water quality of the effluent groundwater with that of nearby streams where the effluent groundwater has been previously discharged for stream maintenance water. Also, it is necessary to construct utilization plans that are suitable for each facility such as separately classifying the excess facilities and then processing and using the effluent groundwater according to each facility.
5) The water quality of effluent groundwater generated from each facility was better than that of the nearby streams for all parameters. Currently, the water quality is considered sufficient. The effluent groundwater is considered sufficient to utilize as stream maintenance water and to dilute nearby streams during water shortage periods

5. REFERENCE

[1] Ministry of Land, Transport and Maritime Affairs: Management of effluent groundwater, Korea, 2009.
[2] Ministry of Environment: Groundwater Act, Korea, 2017.
[3] Ministry of Environment: Groundwater Act Enforcement Regulation, Korea, 2018.
[4] Incheon Development Institute: Strategies for improving the utilization of effluent groundwater from Incheon subway, Korea, 2009.
[5] Ministry of Environment: Water Environment Information System, Korea, 2018. http://water.nier.go.kr [accessed in March, 2019]
[6] National Institute of Environmental Research: Water Pollution Standard Method, Korea, 2017.
[7] National Institute of Environmental Research: Quality Standard for Drinking Water, Korea, 2017.
[8] Ministry of Environment: The Enforcement Decree of the Framework Act on Environmental Policy, Korea, 2015.
[9] National Institute of Environmental Research: Water Treatment Criteria Guide, Korea, 2013.
[10] C. Sangyong, " Groundwater Obstructions and Countermeasures for Groundwater Discharge from Subway in Seoul", Journal of the Geological Society of Korea, Vol. 46, No. 1, pp.61 – 72, 2010.
[11] Ministry of Construction and Transportation: Study on Utilization of Outflowing Groundwater Resource in the Large-scale Facilities, Korea, 2002.
[12] Seoul Institute: A Study on the improvement of Underground Water Leakage Utilization in Seoul, Korea, 2018.