http://dx.doi.org/10.14400/JDC.2014.12.8.283

Influence of Underground Water Quality Adjacent to Landfill Site on Hydrogeologic Characteristics of LPG Storage Cavern

Won-Gyu Choi

Department of New Energy·Mining Engineering, SangJi University

매립장 인근 지하수질이 LPG 저장 공동의 수리지질학적 특성에 미치는 영향

최원규

상지대학교 이공과대학 신에너지.자원공학과

Abstract The underground water quality of petroleum products storage cavern is influenced by that of dumping and landfill sites adjacent to cavern. From the chemical analysis of underground water sampled from landfill site, insignificant amounts of As, Cu and Pb were detected in a half of test samples while Cd, Hg, Cr^{6+}, CN^-, TCE, PCE and Phenol were not detected in all samples. All measurements of COD^{Mn} were below 8.0㎎/ℓ that can be negligible for the contamination by organic matters. The total bacteria counted from 1st and 2nd microbiological analysis were $94.84x10^4$cells/㎖ and $146.26x10^{-4}$cells/㎖, respectively, and all counts of the sulfate reducing bacteria were less than 2cells/㎖. It can be suggested that the water quality adjacent to storage cavern can also be studied to improve the reliability of hydrogeologic stability of storage cavern.

Key words : Groundwater Quality, Storage cavern, Bacteria, Landfill, Contamination

요 약 석유 제품 지하 저장 공동의 지하수 수질은 공동 인근 매립지 수질의 영향을 받는다. 매립지 주변의 지하수 수질 분석 결과, 시료의 반 정도에서 지하공동 수질에 영향이 미미한 농도의 As, Cu 및 Pb가 검출되었으며, Cd, Hg, Cr^{6+}, CN^-, TCE, PCE 및 Pheno은 검출되지 않았다. COD^{Mn}의 농도는 모든 시료에서 8.0㎎/ℓ 이하로 유기물질에 의한 지하수 오염은 거의 없는 것으로 분석되었다. 1차, 2차 미생물 분석결과 총박테리아는 각각 $94.84x10^4$cells/㎖과 $146.26x10^{-4}$cells/㎖이고 황산환원 박테리아는 2cells/㎖이하로 분석되어 지하공동의 수질에 영향이 미미할 것으로 분석되었다. 저장 공동 인근 지역의 지하수 수질 분석은 공동의 수리 지질의 안정성을 향상시키기 위하여 지속적인 조사와 관리가 필요할 것으로 판단된다.

주제어 : 지하수 수질, 저장 공동, 박테리아, 매립지, 오염

1. INTRODUCTION

The underground water quality of dumping and/or landfill sites adjacent to the cavern can affect the hydrogeologic characteristics of petroleum products

Received 26 May 2014, Revised 30 June 2014
Accepted 20 August 2014
Corresponding Author: Won-Gyu Choi(Sangji University)
Email: wgchoi@sangji.ac.kr

ISSN: 1738-1916

storage cavern. In this study, the hydrogeologic interrelationship between landfill and cavern areas can be inferred by analyzing groundwater quality of landfill. And the chemical and microbiological changes in porous spaces around the cavern can vary the amount of solid content in channels that may cause clogging, and can also damage underground facilities due to corrosion(Lim, 2001). Dissolved oxygen(DO), pH, electrical conductivity(EC), and oxidation-reduction potential(Eh) of groundwater those affecting the chemical environment of subsurface were measured at the sampling sites, and the other chemical and biological factors were analyzed in the laboratory. Total dissolved solid(TDS) was analyzed to determine concentration and extent of contamination. Chemical oxygen demand(COD_{Mn}) analysis was also carried out to investigate groundwater contamination by organic matters. Microorganism in the groundwater affects the permeability that is closely related to water tightness of rockmass(SK Engineering & Construction, 2002). And the total, aerobic, anaerobic, slime forming and sulfate reducing bacteria were counted to identify hydrobiological environment.

2. EXPERIMENTS

The groundwater sampling was carried out near storage cavern adjacent to landfill located in southern part of Woolsan. Sampling was done from 15 observation wells at the depth of 15m by Waterra Pump. And water samples were collected 2 times with the interval of 6 months, and 15 samples were collected each time.

pH, EC, Eh and DO were measured at field according to Experimental Standards of Water Pollutants(Ministry of Environment, 2001), and COD was determined using the same method with potassium permanganate($KMnO_4$) as an oxidizing agent.

Groundwater samples for cation and anion analysis were filtered in-situ using 0.45㎛ membrane filter, and HNO_3 was added to maintain pH below 2 for cation analysis. According to SW-846 6010A(EPA) and Standard Methods 4110(AWWA, 18th Ed., 1992), ions were analyzed ICP-OES(Vista-MPX, Varian) and IC(761, Metrohm), respectively. Total organic carbon(TOC) was determined using UV-Persulfate TOC Analyzer(Dohrmann, Phoenix 8000) according to Standard Methods 5310c(AWWA, 18th Ed., 1992). Alkalinity was determined under the regulation of Standard Methods 2320(AWWA, 18th Ed., 1992).

Total number of bacteria including viable and inviable microorganism, was counted by taking 2㎖ of filtered sample by paper(Whatman, PC 0.2㎛) which was submerged in Sudan Black B and air-dried in advance using Universal Fluorescent Microscope(Karl Zeiss, Axioskop). The samples for aerobic bacteria analysis were cultured using plate count ager in incubator for 5 days at 25℃. FTM ager was used for counting anaerobic bacteria and cultivated in anaerobic chamber for 5 days at 35℃. Three culture media were used for the analysis of slime forming bacteria, those are 1) K_2HPO_2 25% 1㎖, 2) casitone 2.5g in D.W. 200㎖, and 3) fructose 1g, sucrose 1g, soluble starch 5g, $MgSO_4$ 7H2O 0.5g and ag K215g in D.W. 800㎖, and cultured in incubator for 5 days at 25℃. Following reagents are used for analysis of sulfate reducing bacteria; Solution 1) sodium lactate 3.5g, $MgSO_4$ $7H_2O$ 2.0g, Na_2SO_4 1.0g, $CaCl_2$ $2H_2O$ 0.1g, yeastucxtract 1.0g, NH_4Cl 1.0g and K_2HPO_4 0.5g in D.W. 1ℓ, Solution 2) $FeSO_4$ $7H_2O$ 5.0g in D.W. 100㎖, and Solution 3) ascorbic acid 1.0g and sodium thioglycollate 1.0g in D.W. 100㎖ were used for culture media. 0.1㎖ of both solutions 2) and 3) was added to Solution 1), and substituted head space of H_2:CO_2(15:85). 1㎖ of sample was inoculated dilution medium, and counted after culturing for 10 days at 25℃.

3. RESULTS AND DISCUSSION

3.1 In-situ measurement

Measurements of pH, EC, Eh and DO of groundwater can provide principal hydrochemical environment of subsurface. As shown in Table 1, noticeable changes in values were not identified. This implies that underground water environment presumed to be stable.

〈Table 1〉 Results of in situ measurement

No	Water Temp(℃)		pH		Ec (㎲/㎝)		Eh(㎷)		DO (㎎/ℓ)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1	14.1	13.8	9.58	9.05	221	121	-85	-149	2.71	3.03
2	14.0	13.3	8.08	7.15	167	234	-20	-82	1.77	2.62
3	14.0	13.8	10.00	10.01	177	169	-116	-100	2.35	2.85
4	14.6	13.7	7.80	7.80	305	223	34	-14	2.33	2.30
5	14.7	14.1	8.39	7.60	253	206	36	-41	1.55	2.97
6	14.0	14.1	7.79	7.77	294	279	21	-5	1.45	2.68
7	14.0	13.3	7.59	7.87	282	248	-72	77	9.14	2.56
8	14.3	14.4	6.66	6.76	1,025	928	-77	-132	2.71	3.59
9	14.4	14.2	6.56	6.94	279	295	96	24	2.59	3.37
10	15.1	13.2	7.69	6.07	128	179	-88	-74	2.79	4.34
11	15.2	13.6	7.65	8.18	131	201	-85	-71	2.90	10.01
12	13.9	13.8	11.06	11.12	1,490	350	-162	-288	2.99	3.42
13	15.0	13.6	11.15	11.04	867	925	-169	-220	3.21	6.52
14	13.9	13.7	6.50	6.29	197	190	1	-29	1.89	3.72
15	14.0	14.7	7.93	8.22	244	234	-179	-99	1.94	2.64

3.2 Chemical analysis

The results of chemical analysis are summarized in Table 2. It is noted that noticeable changes in TOC and TDS values were not identified from 1st and 2nd analyses. The value ranges of TOC and TDS from 1st analysis were 0.43~5.17㎎/ℓ and 95~475㎎/ℓ, and those of 2nd analysis were 0.16~5.16㎎/ℓ and 138~385 ㎎/ℓ, respectively. It can be supposed that there were no significant effect of TOC and TDS on hydrogeologic circumstances.

From the hazardous heavy metal analysis, As concentrations were determined 3 out of 15 samples in 1st test, and 6 out of those in 2nd test with the ranges of 0.007~0.017㎎/ℓ and 0.001~0.041㎎/ℓ, respectively. And Cu were detected 1 sample in 1st test and 3 samples in 2nd test. Pb were detected from 2 samples in 1st test, but not detected in 2nd test. The other heavy metals elements Cd, Hg, Cr^{6+} and CN^-, and TCE, PCE and Phenol were not detected in all samples.

To investigate groundwater contamination by organic materials, COD_{Mn} was measured using potassium permanganate as an oxidizing agent. The determined value ranges of COD_{Mn} from 1st and 2nd tests were 0.2~7.8㎎/ℓ and 0.6~8.0㎎ /ℓ, and the average values were 2.98㎎/ℓ and 2.88㎎/ℓ, respectively. It is presumed that groundwater contamination by organic materials can be insignificant.

From the results of the chemical analysis, some variations in measurements were notified, but the noticeable and significant changes and trends were not found. This can be supposed that the chemical environment groundwater of the site is relatively stable and may have a little effects on groundwater adjacent to the test site.

〈Table 2〉 Results of chemical analysis (Unit: ㎎/ℓ)

No	TOC		TDS		As		Cu	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1	2.79	2.12	165	146	N.D.	N.D.	N.D.	N.D.
2	4.75	2.76	110	294	N.D.	N.D.	N.D.	N.D.
3	4.55	1.83	115	298	N.D.	0.001	N.D.	N.D.
4	0.95	0.16	200	320	0.014	0.003	N.D.	N.D.
5	0.91	0.19	180	258	0.007	N.D.	N.D.	N.D.
6	0.43	0.45	235	324	N.D.	0.005	N.D.	N.D.
7	0.52	1.19	185	322	N.D.	0.041	N.D.	N.D.
8	5.29	4.72	335	314	0.017	0.008	0.007	0.002
9	2.39	3.28	190	386	N.D.	N.D.	N.D.	N.D.
10	4.60	2.27	110	138	N.D.	N.D.	N.D.	0.001
11	5.17	3.83	95	144	N.D.	N.D.	N.D.	0.004
12	3.72	5.16	475	210	N.D.	N.D.	N.D.	N.D.
13	3.91	1.78	355	262	N.D.	0.012	N.D.	N.D.
14	2.53	1.93	180	292	N.D.	N.D.	N.D.	N.D.
15	1.66	1.33	180	208	N.D.	N.D.	N.D.	N.D.

〈Table 2〉 Results of chemical analysis (Unit: ㎎/ℓ)

No	TOC		TDS		As		Cu	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1	2.79	2.12	165	146	N.D.	N.D.	N.D.	N.D.
2	4.75	2.76	110	294	N.D.	N.D.	N.D.	N.D.
3	4.55	1.83	115	298	N.D.	0.001	N.D.	N.D.
4	0.95	0.16	200	320	0.014	0.003	N.D.	N.D.
5	0.91	0.19	180	258	0.007	N.D.	N.D.	N.D.
6	0.43	0.45	235	324	N.D.	0.005	N.D.	N.D.
7	0.52	1.19	185	322	N.D.	0.041	N.D.	N.D.
8	5.29	4.72	335	314	0.017	0.008	0.007	0.002
9	2.39	3.28	190	386	N.D.	N.D.	N.D.	N.D.
10	4.60	2.27	110	138	N.D.	N.D.	N.D.	0.001
11	5.17	3.83	95	144	N.D.	N.D.	N.D.	0.004
12	3.72	5.16	475	210	N.D.	N.D.	N.D.	N.D.
13	3.91	1.78	355	262	N.D.	0.012	N.D.	N.D.
14	2.53	1.93	180	292	N.D.	N.D.	N.D.	N.D.
15	1.66	1.33	180	208	N.D.	N.D.	N.D.	N.D.

No	Pb		Cd		Hg	
	1st	2nd	1st	2nd	1st	2nd
1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
3	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
4	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
5	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
6	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
7	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
8	0.006	N.D.	N.D.	N.D.	N.D.	N.D.
9	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
10	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
11	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
12	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
13	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
14	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
15	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

No	Cr^{6+}		CN^-		TCE		PCE	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
3	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
4	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
5	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
6	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
7	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
8	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
9	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
10	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
11	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
12	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
13	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
14	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
15	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

No	Phenol		COD_{Mn}	
	1st	2nd	1st	2nd
1	N.D.	N.D.	1.8	2.2
2	N.D.	N.D.	6.0	3.4
3	N.D.	N.D.	4.8	2.6
4	N.D.	N.D.	2.2	0.6
5	N.D.	N.D.	1.8	1.2
6	N.D.	N.D.	0.2	1.6
7	N.D.	N.D.	0.4	0.8
8	N.D.	N.D.	2.5	3.0
9	N.D.	N.D.	1.0	4.0
10	N.D.	N.D.	6.8	3.8
11	N.D.	N.D.	7.8	3.8
12	N.D.	N.D.	2.8	8.0
13	N.D.	N.D.	3.2	2.4
14	N.D.	N.D.	2.2	3.4
15	N.D.	N.D.	1.2	2.4

(N.D.: Non-Detected)

3.3 Biological analysis

The permeability of porous medium in underground can be influenced by microorganism in the groundwater. Total, aerobic, anaerobic, slime forming and sulfate reducing bacteria were counted to analyze the hydrobiological characteristics that can affects the watertightness of cavern.

The test results are summarized in Table 3. Aerobic, anaerobic and slime forming bacteria counted from 1st and 2nd experiments were 46.78×10^4cells/㎖ and 59.60×10^4cells/㎖, 15.93×10^4cells/㎖ and 34.60×10^4cells/㎖, and 32.11×10^4cells/㎖ and 52.06×10^4cells/㎖, respectively. And all counts of the sulfate reducing bacteria were less than 2cells/㎖. It is noted that sulfate reducing bacteria is considered to be an indicator of change in biological environment and corrosion. In this analysis, less than 2 cells/㎖ of sulfate reducing bacteria implies that is hardly influence underground water environment and corrosion of metal equipment and facilities. All types of bacteria counted from 2nd test, excluding sulfate reducing bacteria, have higher values than those of 1st test. Total bacteria of 2nd test was approximately 1.5 times grater than that of 1st test, and the values were 94.84×10^4cells/㎖ and 146.27×10^4cells/㎖, respectively. It can be presumed that

the reason for increase in counts is the changes in atmospheric temperature rather than other circumstances. Total number of bacteria, that is inclusive of viable and inviable microorganism, is mainly affected by bacterial multiplication environment such as temperature and quality of ambient water and nutrient salts.

In this microbiological analysis, the hydrogeology of rockmass adjacent to the cavern is not noticeably influenced by the biological environment of underground water(Choi, 2005). Although the bacteria can have little influence on hydrogelogy of rockmass in this study, but continuous analysis and monitoring will be advised for future reference.

〈Table 3〉 Results of biological analysis (Unit: x104cells/㎖)

No	Aerobic			Anaerobic		
	1st	2nd	Ave.	1st	2nd	Ave.
1	2.90	2.03	2.47	0.07	5.51	2.79
2	5.68	9.95	7.82	3.76	6.64	5.20
3	0.51	1.92	1.22	0.21	1.14	0.68
4	17.18	10.43	13.81	1.03	3.13	2.08
5	3.00	0.31	1.66	1.90	0.96	1.43
6	0.85	1.31	1.08	1.22	1.17	1.20
7	3.79	0.23	2.01	2.31	0.85	1.58
8	0.08	0.71	0.40	0.07	0.95	0.51
9	2.49	0.44	1.47	0.82	1.71	1.26
10	2.83	1.72	2.28	0.87	2.23	1.55
11	3.70	15.72	9.71	3.13	0.35	1.74
12	0.16	3.79	1.98	0.10	0.63	0.37
13	0.05	6.70	3.38	0.00	0.05	0.03
14	1.83	1.15	1.49	0.50	7.05	3.78
15	1.77	3.20	2.49	1.54	2.81	2.17

4. CONCLUSIONS

The chemical and microbiological analysis of groundwater in the vicinity of cavern was carried out to study the influence of chemical elements and microorganism on hydrogeologic environment of the cavern. From the hazardous heavy metal analysis, As concentrations were determined 9 out of 30 samples, and Cu and Pb were detected from 6 samples

No	Slime forming			Total		Sulfate reducing	
	1st	2nd	Ave.	1st	2nd	1st	2nd
1	0.23	3.59	2.00	3.21	11.12	<2	<2
2	7.83	10.50	2.00	17.30	27.09	<2	<2
3	0.62	1.86	2.00	1.33	4.92	<2	<2
4	8.02	3.65	2.00	26.22	17.21	<2	<2
5	7.40	2.36	2.00	12.30	3.63	<2	<2
6	1.44	3.80	2.00	2.41	6.28	<2	<2
7	2.73	3.32	2.00	8.83	4.39	<2	<2
8	0.09	5.69	2.00	0.24	7.34	<2	<2
9	1.18	2.56	2.00	4.49	4.70	<2	<2
10	0.04	0.73	2.00	3.73	4.68	<2	<2
11	2.01	0.72	2.00	8.84	16.80	<2	<2
12	0.03	7.15	2.00	0.20	11.01	<2	<2
13	0.04	1.22	2.00	0.09	7.96	<2	<2
14	0.39	4.18	2.00	2.72	12.38	<2	<2
15	0.06	0.77	2.00	2.98	6.77	<2	<2

throughout the tests. The other heavy metals elements Cd, Hg, Cr^{6+} and CN^-, and TCE, PCE and Phenol were not detected in all samples. The all measurements of CODMn were below 8.0㎎/ℓ that can imply insignificant water contamination by organic matters. The results of chemical analysis shows some variations in measurements, but the notable changes and trends were not found.

Aerobic, anaerobic and slime forming bacteria counted from 1st and 2nd experiments were $46.78x10^4$cells/㎖ and $59.60x10^4$cells/㎖, $15.93x10^4$cells/㎖ and $34.60x10^4$cells/㎖, and $32.11x10^4$cells/㎖ and $52.06x10^4$cells/㎖, respectively. The total bacteria counted from 1st and 2nd were $94.84x10^4$cells/ ㎖ and $146.27x10^4$cells/㎖, respectively. All counts of sulfate reducing bacteria were less than 2cells/㎖ that can have little effect on the groundwater environment and corrosion of equipment and facilities.

It is found that the groundwater quality adjacent to cavern is relatively stable that can imply insignificant effect on the hydrogeologic stability of cavern. It can be advisable that the water quality adjacent to storage cavern can be studied to improve the reliability of hydrogeology of cavern.

REFERENCES

[1] American Public Health Association, Washington, U.S., 1992, "Standard Methods for the Examination of Water and Waste Water", AWWA, 18th Ed.

[2] Choi W.G., 2005, "Influence of Underground Water Quality on Hydrogeologic Characteristics of LPG Storage Cavern", J. of Korean Society of Geosystem Engineering, Vol 42, No. 4, pp. 371-377.

[3] Chon, H.T., Lee, J.U., and Oh, S.Y., 1999, "Groundwater Chemistry and Water-Rock Interactions at Hydrocarbon Storage Cavern Sites in Korea" J. of Geosystem Engineering, Vol. 36, No. 3, pp. 13-25.

[4] Dreyer W. 1982, "Underground Storage of Oil and Gas in Salt Deposits and Other Non-Hard Rocks", Halsted Press, New York, pp. 17-19.

[5] Kansas Department of Health and Environment, U.S., 2002, "Regulations of Underground Natural Gas Storage Wells", Article 28-451-15.

[6] Kim, S.G. 2001, The Hydrogeochemical Characteristics of Groundwater in the Underground LPG Storage Cavern, Yosu, Korea, MS Thesis, Seoul National University, Seoul, pp. 13-18.

[7] Lim, J.S. 2001, "A Study on Efficient Management for Underground LPG Storage Cavern, Yosu, Korea", MS Thesis, Seoul National University, Seoul, pp. 40-41.

[8] Ministry of Environment, 2001, "Experimental Standards of Water Pollutants" SK Engineering & Construction, 2002, "SK Gas Hydro-geologic Motoring Report", Seoul, pp. 37-59.

최 원 규(Choi, Won Gyu)

- 1983년 2월 : 인하대학교 자원공학과 공학사
- 1985년 2월 : 인하대학교 자원공학과 공학석사
- 1989년 7월 : 뉴캐쓸대학교(영국) 광산과 공학박사
- 1994년 3월 ~ 현재 : 상지대학교 신에너지. 자원공학과 부교수
- 관심분야 : 수질, 토양 오염
- E-Mail : wgchoi@sangji.ac.kr