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The Hydrogeological Evaluation of Groundwater Degradation at Kimpo Metropolitan Landfill Site

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首都圈 埋立地 地下水 汚染의 水理地質學的 評價

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국 문 초 록

埋立地에서 發生하는 浸出水는 代表的인 地下水 汚染源인데, 이를 防止하기 위해서는 埋立地 自體의 水理地質學的 特性이 決定的인 役割을 한다. 首都圈 쓰레기를 最終處分하기 위해 金浦郡 黔丹面에 建設한 "首都圈 埋立地"의 水理地質學的 特性을 把握하기 위하여 1段階 埋立地에 回轉試錐裝備를 利用하여 10개의 試錐孔을 掘鑿하고, 그 試錐孔을 slug實驗用 測定孔으로 同時에 活用하여 水理傳導度, 地下水位, 地質構造 및 土壤特性 등의 資料를 구하였다. 測定된 資料를 利用하여 埋立地의 地下水 汚染可能性을 水理地質學的 次元에서 數値化하여 評價하는 모델인 DRASTIC과 NRS에 適用한 結果는 DRASTIC 方法에서는 125~130 사이의 點數를 나타내어 "良好(good)"하다는 評價를 얻었고, NRS 方法에서는 16~19點을 얻어 "良好" 및 "좋지도 나쁘지도 않음(fair)"이라는 判定을 내릴 수 있었다.

Keywords : Groundwater degradation, DRASTIC, NRS, hydrogeological suitability.

Introduction

In Korea, the quality of surface water has been deteriorated by the lack of sufficient prevention measures of pollution as well as the rapid industrialization. Correspondingly, the relative role of groundwater as drinking water has increased gradually.[1~4)]

Nevertheless, contamination of groundwater has been spread over nationwide in Korea. The main causes of groundwater contamination are septic tanks, underground storage tanks, pesticides in farms, accidental leaks and spills, industrial wastes and landfill leachate.

Landfill site should be located in accordance with planning criteria which incorporate safety, environmental, social, political and technical constraints. Consistent with the overall planning process, the goals of site selection are to minimize health risks, to maximize public acceptability, and to minimize environmental impacts and costs.[5~7)]

The polluted leachate from the landfilled waste appears shortly after disposal of the waste. In most cases, the heavily polluted leachate cause extensive contamination of surface water and groundwater through subsurface migration. Groundwater pollution is the major environmental concern at sanitary landfills demanding extensive controlling measures, such as liners, drainage collection, treatment of leachate and groundwater quality control monitoring.[8~10)]

In this thesis, the potential of groundwater pollution caused by landfill leachate was analyzed for the purpose of validating evaluation techniques of landfill site. The scope of this study is restricted to the evaluation of hydrogeological factors, in "Kimpo Metropolitan Landfill Site", which influence critically the phenoimena of mobility of contamination solutes.[11~13,15,16)]

Table 1. Ranges and ratings for DRASTIC features

Feature	Weight
Depth to water	5
Net recharge	4
Aquifer media	3
Soil media	2
Topography	1
Impact of the vadose zone media	5
Hydraulic conductivity of the aquifer	3

Table 2. Ranges and ratings for depth to water

Depth to water (feet)	
Range	Rating (weight: 5)
0~ 5	10
5~ 15	9
15~ 30	7
30~ 50	5
50~ 75	3
75~100	2
>100	1

Table 3. Ranges and ratings for net recharge

Net recharge (in/year)	
Range	Rating (weight: 4)
0~ 2	1
2~ 4	3
4~ 7	6
7~10	8
>10	9

Table 4. Ranges and ratings for aquifer media

Aquifer media		
Range	Rating (weight: 3)	Typical rating
Massive shale	1~3	2
Metamorphic/igneous	2~ 5	3
Weathered metamorphic/igneous	3~ 5	4
Glacial till	4~ 6	5
Bedded sandstone, limestone and shale sequences	5~ 9	6
Massive sandstone	4~ 9	6
Massive limestone	4~ 9	6
Sand and gravel	4~ 9	8
Basalt	2~10	9
Karst limestone	9~10	10

Table 5. Ranges and ratings for soil media

Soil media	
Range	Rating (weight: 2)
Thin or absent (<0.25 m)	10
Gravel	10
Sand	9
Peat	8
Shrinking and/or aggregated clay	7
Sandy loam	6
Loam	5
Silty loam	4
Clay loam	3
Muck	2
Nonshrinking and nonaggregated clay	1

Materials and Methods

Monitoring wells were constructed to verify geological distribution, core sampling, water table and aquifer conditions. The number of monitoring wells are 10. Boring method is mud rotary rigs which drills through marine sediments to bedrock. In marine sediments as fragile stratum, which is developed below the water table, core samples were collected as 2 per a borehole in process. As a sampling method, the thin-wall tube method which is specified in KSF-2317 was applied. Core samples extracted by the method of thin-wall tube were sealed by wax and then transported to laboratory for analyzing soil properties. After completion of boring, 50 mm diameter PVC pipe for well was equipped to utilize as slug test and the measurement of water table.[16,17]

And then, applying hydrogeological data surveyed by the above methods to DRASTIC and NRS (Numerical Rating System)[19] which are developed for evaluating the possibility of groundwater contamination in landfill sites with a view to corroborating the security risk of "Kimpo Metropolitan Landfill Site".

1. DRASTIC

DRASTIC, the evaluation method of landfill site, can be applied according to the following methods. The hydrogeological parameters of "Kimpo Met-

Table 6. Ranges and ratings for topography

Topography (% slope)	
Range	Rating (weight: 1)
0~ 2	10
2~ 6	9
6~12	5
12~18	3
>18	1

Table 7. Ranges and ratings for impact of the vadose zone media

Impact of the vadose zone media		
Range	Rating (weight: 5)	Typical rating
Confining layer	1	1
Silt/clay	2~ 6	3
Shale	2~ 5	3
Limestone	2~ 7	6
Sandstone	4~ 8	6
Bedded limestone, sandstone, shale	4~ 8	6
Sand and gravel with significant silt & clay	4~ 8	6
Metamorphic/igneous	2~ 8	4
Sand and gravel	6~ 9	8
Basalt	2~10	9
Karst limestone	8~10	10

ropolitan Landfill Site" also can be evaluated according to the following tables.

On the basis of above tables, "pollution potential" can be integrated as the following method;

$$Sum = D_rD_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_rI_w + C_rC_W \quad (1)$$

where,

D_r : Rating for Depth to Water
D_w : Weight for Depth to Water
R_r : Rating for Net Recharge
R_w : Weight for Net Recharge
A_r : Rating for Aquifer Media
A_w : Weight for Aquifer Media
S_r : Rating for Soil Media
S_w : Weight for Soil Media
T_r : Rating for Depth to Topography
T_w : Weight for Depth to Topography

Table 8. Ranges & ratings for hydraulic conductivity

Hydeaulic conductivity	
1~ 100	1
100~ 300	2
300~ 700	4
700~1000	6
1000~2000	8
>2000	10

*Unit : GPD/FT^2.

Table 9. Generalized site grade based on DRASTIC

Grade	DRASTIC
Best	< 79
Excellent	80~ 99
Very good	100~119
Good	120~139
Fair	140~159
Poor	160~179
Bad	180~199
Worst	>200

I_r : Rating for Impact of the Vadose Zone Media
I_w : Weight for Impact of the Vadose Zone Media
C_r : Rating for Hydraulic Conductivity
C_w : Weight for Hydraulic Conductivity

Then these DRASTIC values should be compared with the Table 9, "Generalized Site Grade", in order to evaluate the suitability of concerned landfill sites.

2. Numerical rating system

To assess the relative risks to groundwater imposed by solid and hazardous waste landfill sites, the prioritization systems examine four factors; ① the relative health hazards posed by the materials present and the way that they are managed, ② the proximity of the site to a water supply well or sensitive aquifer areas, ③ the number of people likely to be affected by groundwater contamination, ④ the suscedptibility of the aquifer to be contaminated at that location.

The Numerical Rating System was created by

Harry E. LeGrand for the purpose of evaluating waste disposal sites. For each site the estimated numerical value for each of the factors is added and the total expressed as a number that characterizes the landfill site. At this stage the site can be described with respect to relative hydrogeological conditions but not necessarily with respect to the possibility of contamination from various types of wastes or contaminant input.

1) Step 1

Determine the distance on ground between contamination source and water supply or designated boundary.

Point value	0	1	2	3	4	5	6	7	8	9
distance(m)	>2000	1000-2000	300-999	150-299	75-149	50-74	35-49	20-34	10-19	0-9

Where the water table lies in permeable consolidated rocks, 6 points should be alloted on distance scale; in poorly permeable rocks, 4 points should be allotted.

2) Step 2

Estimate the shallowest depth to the water table below the base of contamination source more than 5% of the year.

Point value	0	1	2	3	4	5	6	7	8	9
depth(m)	>60	30-60	20-29	12-19	8-11	5-7	3-4	1.5-2.5	0.5-1	0

Where the water table lies in permeable or moderately permeable consolidated rocks, 6 points should be allotted; in poorly rocks, 4 points should be allotted.

3) Step 3

Estimate water table gradient from contamination site.

Point value	0	1	2	3	4	5

0** : Gradient away from all water supplies that closer than 1,000 m

1 : Gradient almost flat

2 : Gradient less than 2% toward water supply, but not the anticipated direction of flow

3 : Gradient less than 2% toward water supply and is the anticipated direction of flow

Table 10. Permeability-sorption for the site

Type		Clay		Clay with sand no more than 50% sand		Sand with 15~30% clay		Sand with less than 15% clay		Clean fine sand		Clean gravel or coarse sand	
Thickness of unconsolidated materials over bedrock in meters	More than 30	0		2		4		6		8		9	
		I	II	I	II	I	II	I	II	I	II	I	II
	25~29	0	1	1	2	3	4	5	6	7	8	9	9
	20~24	0	2	1	3	4	5	5	6	7	8	9	9
	15~19	0	3	1	4	4	6	5	7	7	8	9	9
	10~14	0	4	2	5	4	6	5	7	7	9	9	9
	3~ 9	1	6	2	7	5	7	5	8	7	9	9	9
	< 3	2	8	3	8	5	9	5	9	7	9	9	9

1) U. S. Department of Agriculture Particle Size Classification.

2) Second top row is for site areas where no consolidated rock occurs closer than 30 meters below land surface. Type of unconsolidated material assigned represents that through which contaminated water is likely to flow (unsaturated zone, above water table and generally the upper 2~10 meters of material below water table).

3) Category I : Unconsolidated material overlies shale or other poorly permeable consolidated rock.
Category II : Unconsolidated material overlies permeable consolidated rock (fractured or jointed igneous and metamorphic rocks, caverneous carbonate rocks and faults).

Table 11. Geological distribution at boring points (Unit : m)

Type	Marine sediments	Colluvium	Alluvium	Weathered zone	Bedrock	Sum
s1	3.0	–	–	3.5	9.4	15.9
s2	14.5	4.0	–	3.8	–	22.3
s3	5.0	3.8	–	5.7	1.9	16.4
s4	5.6	3.4	–	12.8	2.2	24.0
s5	11.6	4.1	–	–	2.1	17.8
s6	18.5	3.0	–	2.5	–	24.0
s7	17.7	3.7	–	2.6	–	24.0
s8	10.8	4.8	–	6.4	2.0	24.0
s9	9.2	1.4	9.4	4.0	–	24.0
s10	12.5	–	4.0	4.4	4.9	26.0

s1~s10 : Boring points for geological survey in Kimpo Metropolitan Ladfill.

Table 12. Generalized site grade based on critical hydrogeologic parameters

Grade	Total points
Excellent	<10
Very good	11~14
Good	15~17
Fair	18~20
Poor	>20

4 : Gradient greater than 2% toward water supply, but not the anticipated direction of flow

5 : Gradient greater than 2% toward water supply and is anticipated direction of flow

4) Step 4

Estimate permeability-sorption for the site of the contamination source.

5) Step 5

Completion of site numerical description.

Add all point values determined in Steps 1 through 4. Then compare the total point value with the following table to evaluate critical hydrogeologic factors of landfill sites.

Results and Discussion

Hydrogeological data surveyed by the above methods are as follows;

The results combining the hydrogeological data, Table 11~15, at Kimpo Metropolitan Landfill with the DRASTIC method and NRS are as follows;

Table 13. Measurements of water table in monitoring wells

Classification	Water tables (m)			
	1992. 10. 8		1992. 10. 14	
	Below surface	Above sea level	Below surface	Above sea level
s2	0.78	1.851	0.78	1.851
s3	1.90	2.037	1.64	2.297
s4	0.55	3.246	0.64	3.156
s5	0.70	2.537	0.86	2.377
s6	0.83	3.358	1.16	3.028
s7	0.17	2.256	0.48	1.946
s8	0.00	2.536	0.00	2.536
s9	0.64	2.283	0.74	2.183
s10	0.74	2.382	0.74	2.382

*s2~s10 : Boring points for geological survey in Kimpo Metropolitan Landfill.

According to Table 9, the DRASTIC values of Kimpo Metropolitan Landfill can be classified as grade "good". And on the basis of Table 12, the NRS values of Kimpo Metropolitan Landfill can be classified as grade "good" and "fair". In considering these analysis. Kimpo Metropolitan Landfill should be supplemented by equipping with adequate leachate treatment facilities.

To avoid the rise of hydraulic head caused by leachate, which may accelerate the penetration through the natural clay liner at Kimpo Metropolitan Landfill, leachate collection and pumping equipments are necessary. At Kimpo Metropolitan La-

Table 14. Soil texture and porosity

Classification	Silt & clay (%)	Sand (%)	Porosity
s1	96.8	3.2	0.487
s2	93.1	6.9	0.491
s3	90.7	9.3	0.459
s4	97.4	2.6	0.494
s5	93.6	6.4	0.493
s6	81.3	18.7	0.459
s7	89.2	10.8	0.468
s8	99.2	0.8	0.563
s9	98.8	1.2	0.538
s10	87.7	12.3	0.475

*s1~s10 : Boring points for geological survey in Kimpo Metropolitan Landfill.

Table 15. Hydraulic conductivity of the upper confining layer

Boring points	Hydraulic conductivity (cm/sec)	Boring points	Hydraulic conductivity (cm/sec)
s1	5.1×10^{-6}	s6	5.7×10^{-6}
s2	2.0×10^{-6}	s7	2.6×10^{-7}
s3	4.3×10^{-6}	s8	3.3×10^{-6}
s4	5.0×10^{-6}	s9	2.2×10^{-6}
s5	5.7×10^{-6}	s10	2.9×10^{-6}

*s1~s10 : Boring points for geological survey in Kimpo Metropolitan Landfill.

Table 16. Calculation of DRASTIC values of boring points at Kimpo Metropolitan Landfill site

Classification	D	R	A	S	T	I	C	Sum
s1	10	8	4	4	10	3	1	130
s2	9	8	4	4	10	3	1	125
s3	10	8	4	4	10	3	1	130
s4	10	8	4	4	10	3	1	130
s5	10	8	4	4	10	3	1	130
s6	10	8	4	4	10	3	1	130
s7	10	8	4	4	10	3	1	130
s8	10	8	4	4	10	3	1	130
s9	10	8	4	4	10	3	1	130
s10	10	8	4	4	10	3	1	130

Table 17. Calculation of NRS values of boring points at Kimpo Metropolitan Landfill site

Classification	Step 1	Step 2	Step 3	Step 4	Sum
s1	1	8	2	7	18
s2	1	8	2	5	16
s3	1	7	2	7	17
s4	2	8	2	7	19
s5	2	8	2	5	17
s6	2	8	2	4	16
s7	1	9	2	4	16
s8	2	9	2	5	18
s9	1	9	2	7	19
s10	1	8	2	5	16

ndfill, the natural clay liner is not compacted mechanically. Consequently, the natural clay liner has hydraulic conductivities from 5.7×10^{-8} cm/s to 2.6×10^{-7} cm/s, which are not adequate the landfill criteria that the hydraulic conductivity should be under 1.0×10^{-7} cm/s.

Summary

The hydrogeological characteristics of Kimpo Metropolitan Landfill constructed for the disposal of solid wastes generated from Seoul Metropolitan area were surveyed and analyzed in order to evaluate the hydrogeological suitability. Hydrogeological suitability was evaluated by DRASTIC and NRS, which are largely accepted hydrogeological evaluation methods for landfill sites.

The result of evaluation is as follows :

1) The number of marks calculated by DRASTIC method are ranging from 125 to 130, which are come under grade "good".

2) The number of marks calculated by NRS

method are ranging from 16 to 19, which are come under grade "good" and "fair".

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