환경영향평가 제14권 제2호 (2005) pp.47~53

연구논문

Assessment of Stabilization of An Open-dumping Landfill

- A Case Study of Noeun Landfill -

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(Manuscript received 22 October 2004; accepted 23 March 2005)

비위생매립지의 안정화 평가

- 노은 매립지 사례연구 -

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(2004년 10월 22일 접수, 2005년 3월 23일 승인)

요 약

노은 매립지는 사용종료된지 5년이 경과된 비위생매립지로 최종복토는 되어 있으나 침출수 차집시설 및 매립가스 포집설비가 제대로 갖추어지지 않은 상태이다. 환경부의 사용종료 매립지 정비지침에 의하면 침출수의 BOD/CODcr 비율이 1/10 수준임으로 침출수의 안정화 과정이 거의 완결상태로 진행되고 있는 것으로 판단된다. 매립지 가스의 안정화 측면에서는 CH_4의 비율이 5%정도이기 때문에 안정화가 거의 이루어진 것으로 볼 수 있다. 매립된 쓰레기 중에서 플라스틱을 제외한 가연물 함량이 3.97 - 9.34%이기 때문에 매립폐기물은 안정화 기준에 미흡한 상태이다. 그리고 지하수는 대장균 항목이 지하수 수질기준 생활용수 기준에 미흡하여 안정화 기준을 충족시키지 못하고 있다. 노은매립지는 매립지 안정화의 속도가 평가 대상별로 상이하게 진행되는 것으로 평가된다.

주요어 : 매립지 안정화, 침출수, 매립지 가스

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I. Introduction

Landfills have been the most common means of MSW(municipal solid waste) disposal in South Korea. Until 1980s, for the treatment of MSW generated in South Korea, approximately 85% had been placed in municipal solid waste landfills(MOE, NIER, 2004). Regardless of how much reuse, recycling, and energy recovery is achieved, some fraction of MSW must be disposed at the landfill(P. Aarne *et al*., 2002)

From the middle of 1990s, open-dumping landfill has been prohibited in South Korea. Landfills which were closed are now being regulated strictly to be used as other land-uses such as residential buildings, farming, etc(KRRRC, 1995 ; Hwang *et al*., 2002).

In order to utilize a closed landfill site for other purposes, the assessment of the stabilization level of landfill is indispensable for the determination of the proper land-uses. In this study, among open-dumping landfills that were located at Chungbuk province, Noeun landfill at Chungju city which could impact Namhan river which flows into Lake Paldang was selected to assess the stabilization characteristics of an open-dumping landfill(CRETDC, 2004).

MSW which were deposited in landfills stabilize by a combination of physical, chemical, and biological decomposition. The landfill is a form of biochemical reactor, similar to anaerobic digestor in a wastewater treatment plant(Debra *et al*., 2002).

The progress toward final stabilization of landfill, MSW is subject to the physical, chemical, and biological factors within the landfill environment, the age and characteristics of landfilled waste, the operational and management controls applied, as well as the site-specific natural conditions(Kanti, 2000 ; Sleats, 2000).

To assess the stabilization level of this open-dumping landfill for seeking the adequate method for post-closure management, landfilled waste was analyzed on the basis of physical components, after then characteristics of leachate, landfill gases, and groundwater were analyzed chemically. The analysis results were evaluated by "The Criteria of Landfill Stabilization" that promulgated by Korean Ministry of Environment (Table 1).

II. Materials and Methods

Noeun landfill is a type of depression landfill

Table 1. Criteria of Landfill Stabilization

Classification	Criteria
Leachate and Groundwater	1. BOD/CODcr in leachate should be less than 0.1 2. Contaminant concentrations in leachate should not be more than leachate effluents criteria. 3. Contaminant concentrations in groundwater should not be more than groundwater quality criteria.
Landfill Gas	1. Concentration of CH_4 should be less than 5%
Wastes Landfilled	1. Contents of combustibles should be less than 5% or C/N should be less than 10.
Etc.	1. Adverse effects to surroundings due to bad odor, geophysical stability of landfill, surface water qualities, soil analysis should not be recognized.

<Source>: Ministry of Environment, Republic of Korea, Guidelines for Post-closure Management of Landfill, 2001.

located between small hills. Surface water from Noeun landfill flows through a small ditch which converge into Hanpo stream. Hanpo stream runs through 12km and then confluxing with Namhan river at the point of 90 km distant from Lake Paldang.

A small ditch which underdrains through a dike of Noeun landfill was dry in the dry season. The reason that the ditch had little water was considered that coarse sands were prevalent at this site. Hydrogeological characteristics of this landfill seemed to result in infiltration of most precipitates.

Noeun landfill was operated from June, 1992 to June, 1999 for disposal of municipal solid waste which generated from this rural area. Residential area(143 homes, 457 population) is about 4 km distant from this landfill(Table 2).

Noeun landfill site was dug out at 3 points into 4.5~5.0m by excavator to sample and analyze waste and LFG. The depth of final soil cover and landfilled waste were 0.2~0.4m and 4.1~4.8 m each(CRETDC, 2004). Proximate analysis was proceeded with the waste excavated. Landfill gas(LFG) extraction device was installed for LFG sampling at the two excavated points. LFG such as CH_4, CO_2, O_2, H_2S were analyzed on the site, NH_3 was absorbed into solution and analyzed in the laboratory according to "Korean Standard Methods of Air Pollution"(MOE, 2002).

Leachate seemed to leak from landfill, and groundwater could be contaminated(Phlip *et al*., 2002). Groundwater was sampled from 2 monitoring wells at Noeun landfill site and leachate was sampled from the effluent of landfill which flowed out at the bottom of dike. Groundwater and leachate samples were chemically analyzed on the basis of "Korean Standard Methods of Water Pollution"(MOE, 2002).

III. Results and Discussion

An important characteristic of the organic component in MSW is that most of it can be biodegraded into leachate, gases and relatively inert and inorganic materials (Issa *et al*., 1998). At Noeun landfill(Table 3), the fraction of organic materials was 19.46 - 27.12% with food garbage already decomposed, and the fraction of inorganic materials(incombustibles) such as glass, ceramics, dirt, and metals account for 72.88 - 80.54%. Among combustible landfilled wastes, the ratio of plastics was as high as 73.69%.

Moisture content is considered the most important factor in MSW decomposition and landfill gas(LFG) production. From Table 4, the results of proximate analysis of landfilled waste at Noeun landfill were moisture 10.4 - 28.2%, total solids 71.81 - 89.59%, volatile solids 65.78 - 78.57%, fixed solids 21.43 - 34.22%, respectively. The moisture content of textiles, waste papers, and timbers were relatively high.

Table 2. Outlines of Noeun Landfill

1. Location of Landfill : Noeun & Shinni, Chungju City, Chungbuk Province	2. Period of Landfill : 92. 6 ~ 99. 6
3. Area of Landfill : 9,034m^2	4. Capacity of Landfill : 27,102m^3
5. Average Daily Landfilled Quantity : 5ton	6. Average Waste Height : 4m
7. Landfilled Wastes(ton/day) : Briquettes Ash(0.5),Food Garbage(0.5), Waste Papers(1.0), Etc(3.0)	

Table 3. Physical Characteristics of Landfilled Wastes

Components \ % by weight		Site1	Site2	Site3	Average	Range
Combustibles	Food garbage	-	-	-	-	-
	Waste papers	1.18	1.59	0.98	1.25	0.98 ~ 1.59
	Textiles	2.84	3.24	2.92	3.00	2.84 ~ 3.24
	Plastics	18.59	14.42	19.26	17.42	14.42 ~ 19.26
	Timbers	0.25	0.12	0.06	0.14	0.06 ~ 0.25
	Rubbers, Leathers	4.26	0.09	1.12	1.82	0.09 ~ 4.26
	Sub-total	27.12	19.46	24.34	23.64	19.46 ~ 27.12
Incombustibles	Glass, Ceramics	4.22	1.53	2.31	2.69	1.53 ~ 4.22
	Metals	3.24	0.42	0.12	1.26	0.12 ~ 3.24
	Soil and etc.	65.42	78.59	73.23	72.41	65.42 ~ 78.59
	Sub-total	72.88	80.54	75.66	76.36	72.88 ~ 80.54
Total		100	100	100	100	

Table 4. Proximate Analysis of Combustible Landfilled Wastes

% by weight / Component	Average Ratio in Combustibles	Moisture	Total Solids (TS)	TS	
				Volatile Solids(VS)	Fixed Solids(FS)
Food garbage	-	-	-	-	-
Waste papers	1.25	27.05	72.95	78.57	21.43
Textiles	3.00	28.19	71.81	65.78	34.22
Plastics	17.42	14.05	85.95	75.08	24.92
Timbers	0.14	26.39	73.61	66.44	33.56
Rubbers, leathers	1.82	10.41	89.59	73.48	26.52
Total	23.64	-	-	-	-

The more the quantity of easily digested nutrients, the higher the rate of LFG generation. Numerous toxic materials, such as heavy metals, can retard bacterial growth and consequently retard LFG production. Within the optimum pH range, methanogenic bacteria grow at a high rate, so methane production is maximized(Vesilind *et al*., 2002).

Owing to the limitation of this study, the impact of toxic material into LFG generation was not considered fully. According to Table 5, at Noeun landfill, the concentration of CH_4, CO_2, H_2S, and NH_3 in LFG were 3.4 - 5.8%, 13.0 - 17.0%, 1.5 - 2.0 ppm, and 0.8 - 1.7 ppm, respectively.

As a typical constituents of biologically active MSW landfill gas, CH_4 account for 45 - 60% and CO_2 makes up 40 - 60% by volume(P. Aarne *et al*., 2002), From this composition data, Noeun landfill seemed to be in the process of the final state of landfill stabilization. During this maturation phase, reappearance of oxygen may be observed(P. Aarne *et al*., 2002). At Noeun landfill, oxygen ranging from 4.6% to 5.7% was found in LFG.

Based on the "The Criteria of Landfill Stabilization" that promulgated by Korean Ministry of Environment, if CH_4 in LFG is higher than 5%, the landfill waste is not sufficient for

Table 5. Results of Analysis of Landfill Gas

Date	Types	Site1			Site2		
		1st	2nd	Average	1st	2nd	Average
21 Sep., 2003	CH_4(%)	4.1	4.3	4.2	5.7	5.8	5.75
	CO_2(%)	13.0	14.0	13.5	16.0	15.0	15.5
	O_2(%)	5.7	5.6	5.65	4.9	5.3	5.10
	H_2S(ppm)	1.6	1.5	1.55	1.7	1.8	1.75
	NH_3(ppm)	0.8	0.9	0.85	1.0	0.9	0.95
15 Oct., 2003	CH_4(%)	4.0	4.1	4.05	5.6	5.3	5.45
	CO_2(%)	15.0	14.0	14.5	16.0	17.0	16.5
	O_2(%)	5.2	5.1	5.15	4.9	4.7	4.80
	H_2S(ppm)	1.7	1.7	1.7	1.8	1.9	1.85
	NH_3(ppm)	0.9	1.0	0.95	1.2	1.3	1.25
16 Nov., 2003	CH_4(%)	3.9	3.8	3.85	5.1	5.0	5.05
	CO_2(%)	16.0	14.0	15.0	15.0	13.0	14.0
	O_2(%)	4.8	5.0	4.9	4.9	4.9	4.90
	H_2S(ppm)	1.7	1.8	1.75	1.9	2.0	1.95
	NH_3(ppm)	1.4	1.3	1.35	1.5	1.5	1.50
9 Dec., 2003	CH_4(%)	3.5	3.4	3.45	4.3	4.2	4.25
	CO_2(%)	16.0	15.0	15.5	17.0	16.0	16.5
	O_2(%)	5.1	4.8	4.95	4.9	4.6	4.75
	H_2S(ppm)	1.6	1.6	1.6	1.9	1.9	1.90
	NH_3(ppm)	1.5	1.4	1.45	1.6	1.7	1.65

the completion of stabilization progress. From this criteria, Noeun landfill was still in the process of waste stabilization.

As water percolates through the landfill, contaminants are leached from the solid MSW. The composition of landfill leachate is strongly influenced by wastes and environmental conditions such as precipitation rates, site hydrogeology, pH, moisture, redox potential, and temperature. The rate and characteristics of leachate produced from a landfill reflect the microbial process and landfill conditions(Edward *et al.*, 1995 ; Jay *et al.*, 2002).

From Table 6, the pH of leachate at Noeun landfill was 6.9, at this pH the stabilization process of leachate could proceed easily. BOD/CODcr in leachate was 0.13 - 0.18 which means the waste stabilization of this landfill was still not completed. Based on the "The Criteria of Landfill Stabilization", if BOD/CODcr in leachate is higher than 1/10, the leachate is in stabilization situation. Groundwater was sampled from 2 monitoring wells located at inside and outside of landfill. From this groundwater samples, all contaminants except E. coli were adequate for "The Criteria of Domestic Use in Groundwater Criteria"(MOE, 2003).

IV. Conclusion

In order to assess waste stabilization of an open-dumping landfill which is located at the upper drainage basin of Lake Paldang utilized

Table 6. Analysis of Leachate and Groundwater
(mg/L, except pH and E.Coli.)

Types	Leachate	Groundwater 1	Groundwater 2
BOD_5	2.7	-	-
BOD_{10}	2.9	-	-
BOD_{15}	3.5	-	-
BOD_{20}	3.8	-	-
COD_{Mn}	11.3	1.2	0.2
COD_{Cr}	20.9	-	-
PH	6.9	5.7	6.6
SS	4.2	-	-
T-N	2.26	-	-
T-P	0.130	-	-
NO_3-N	2.2	3.5	2.3
Cl-	3.8	14.1	11.4
NH_3-N	ND	ND	ND
Cd	-	0.0005	0.0004
Cr	-	0.001	0.001
As	-	ND	ND
Hg	-	ND	ND
Pb	-	0.357	0.032
Cr^{+6}	-	ND	ND
TCE	-	ND	ND
PCE	-	ND	ND
Organic-P	-	ND	ND
Phenol	-	ND	ND
CN^-	-	ND	ND
E. Coli.	-	Detected	Detected
TPH	-	ND	ND

for Seoul Metropolitan water supply, the Noeun landfill site was surveyed. Leachate, groundwater, landfill gas, landfilled wastes at this landfill were analyzed, and the analysis results were assessed from "The Criteria of Landfill Stabilization".

From these results, this open-dumping landfill was not completely stabilized. Waste stabilization in landfills is accomplished through a complex sequence of biologically, chemically, and physically mediated events. Based on results from this study, it can be concluded that the criteria factors of waste stabilization is proceeded in different rates at different site-specific conditions.

From this result, the land-use of this landfill site for another purpose should be put off until the stabilization of landfilled waste will be completed.

Acknowledgements

This work was supported by grant No. (Chungbuk 03-1-50-74) from Chungbuk Regional Environmental Technology Development Center.

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최종원고채택 05. 04. 06