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ASSESSMENT OF LEACHING POTENTIAL OF HAZARDOUS COMPOUNDS FROM DEMOLITION WASTE AND EFFECT OF ON-SITE LANDFILL IN DAM CONSTRUCTION SITE

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Abstract : Leaching potential and management strategy of demolition wastes in the dam construction site were investigated. There was no consistency in classification of the waste. Also, there was a difference in basic units for the estimation of generation amount. By converting collected data into tonnage base, unit generation of demolition waste was found as ranged from 3,400 to 3,700 ton/km^2. And the unit generation of logged tree waste ranged from 12,000 to 31,400 ton/km^2. Treatment or disposal of dam construction wastes was being done by consignment between project manager and consignor, and the major treatment methods were remote landfilling, incineration, recycling, and on site landfilling. Leaching potential of some hazardous compounds from demolition wastes were very low in all the test conducted here. Demolition wastes itself had substantial amount of heavy metal, but the leaching speed was slow enough to be negligible. Concentration of heavy metal in the water of a dam where the demolition wastes buried on-site, could be calculated as 0.016, 0.004, and 0.02 ppb for Cu, Cd, and Cr, respectively, which were fairly lower than those of drinking water standard.

Key Words : dam, demolition waste, leaching potential, long-term leaching test, on-site landfill

INTRODUCTION

Average precipitation per capita in Korea is 2,900 ton/year that is quite lower than world average of 26,800 ton/year. Also, severe seasonal and regional variations in precipitation necessitate the construction of new large dams. Another objective of the dam construction is a flood control. There are eighteen multipurpose dams that are under operation and construction in Korea. There are some problems in the construction of large dams such as conservation of nature, preservation of habitant, disposal of construction and demolition waste(C/D waste). Especially, construction of large dam results in huge amount of wastes which are generated mainly from the clearing of the areas to be submerged. Generally, the C/D wastes are landfilled, although some of them such as wood and plastics are recycled or incinerated. However, it is unreasonable to transport and bury the materials including concrete and tiles

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at the commercial landfill site. There was rare research about the leaching potential of demolition wastes in the dam construction site, although several reports dealt with general construction or demolition wastes.[1~3)]

In this study, on-site landfilling of the C/D wastes was studied in the respect to environmental pollution and burying technology. The status of generation and disposal of C/D wastes were also surveyed. And, its leaching potential and influence on water quality were monitored. Finally, the required legislation and detail approach to the on-site treatment was suggested. The results of this study could be the protocol in the management of demolished construction materials in the future dam projects.

MATERIALS AND METHODS

Site Survey and Sample Preparation

Three dam construction sites were visited in order to survey the status of generation of demolition wastes. Field operation data about the generation and the treatment of the wastes were collected. The major portion of the wastes was crushed cement mortar, concrete, slate, timber, steel, and plastics, which were sampled during the survey. Over 10 kg of each samples were collected, or 20 L of low-density wastes such as timber and plastics were sampled. These collected samples were shredded manually to the size below 5 cm, and then were ground to the size lower than 2 mm by crusher.

Leaching Test Procedures

Short term leaching test : The solid waste in Korea is classified into three groups including municipal solid waste, non-hazardous industrial solid waste, and hazardous waste. The classification can be done by short term leaching test method. In this study, the same procedure was tried to evaluate the dam construction wastes. Waste sample was mixed with leachant by the ratio of 1:10 (w/v). Target hazardous compounds were extracted under mild condition where agitation speed of 200 rpm was maintained for 6 hr at a room temperature. The extract was filtered through Wattman No.1 paper and was analyzed for each compound subsequently. Heavy metal, CN, and oil were analyzed by atomic absorption spectroscopy, spectrophotometer, and normal hexane extraction method, respectively. Other compounds including organic phosphorous, phenol, PCB (polychlorinated biphenyl), TCE (trichloroethylene), PCE (tetrachloro-ethylene) were determined quantitatively by gas chromatography. However the method seemed to be too generate to simulate rather severe condition that might occur in the stagnation area near dam, where anaerobic degradation of accumulated organic matter resulted in relatively low pH. So, additional tests were done under more severe extraction conditions (Run 2 of Table 1).

Long term leaching test : It is necessary to estimate long term leaching properties of dam construction wastes, as lifetime of a dam is usually long. ALT (accelerated leaching test) was used in this long term test. ALT is based on the theory that leaching speed can increase with leachant/sample ratio and temperature.[4,5)] So, ALT can be done within relatively shorter time compare to other long term tests such as ANS 16.1.[6)] To predict long term leaching of a heavy metal from the ALT data, its total amount in a solid sample should be known

Table 1. Experimental condition of short term leaching test

Test	Particle size (mm)	Initial pH	Leaching time (hr)	Agitation speed (rpm)
Run 1	< 10	6.0	6	200
Run 2	< 2	4.0	12	250

preliminary. So, concrete, cement, and slate were digested with strong acid.[7] Solid sample solubilized entirely, and the solution was analyzed for heavy metal concentration. Volume of leachant was determined based on surface area of solid sample where planimeter was used. Leachant/sample ratio was 20/1 (volume/area). Acetate buffer (pH 4.3) was used as a leachant. There was no agitation, but temperature was maintained high (50℃) enough to accelerate leaching speed. Leachant was replaced with new one at a specified time interval (2 hr, 9 hr, 1~11 day). Leachate was concentrated by 50 times in a rotary evaporator, and heavy metal concentration of the concentrate was analyzed.

Leaching Lest in landfill simulator : Leaching properties of heavy metals from C/D waste were tested in the landfill simulator as shown in Figure 1. Three simulators whose diameter and height were 30 cm and 100 cm (volume 71 L) were installed to investigate the effects of leachant pH and topsoil (Table 2). Mixed demolition wastes from a dam construction site were collected and incorporated into the simulator. The waste was composed of concrete as a major material, and other constituents such as bricks, timber, gravel, and sand were small. Average particle size were about 2 cm for concrete and others ranged widely from the size of sand to that of timber. In Run 4, 15 cm of sandy topsoil was located over the waste to estimate the possible retardation effect with it. For the test of low pH effect (pH 4), some amount of sulfuric acid were added to tap water. Leachant flow was maintained at a rate of 21 mL/min. Leachate was sampled from the top of simulator every four days. Total operation time of the simulator was 3 months.

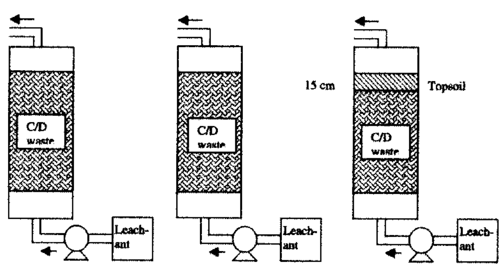

Figure 1. Schematic diagram of landfill simulator system.

Table 2. Experimental condition of lysimeter

Parameter	Control	Run 3	Run 4
pH of leachant	7	4	7
Topsoil	None	None	15 cm

RESULTS AND DISCUSSION

Current Status Survey

Table 3 summarized the status of generation and treatment of demolition waste that was generated from the clearing areas to be submerged by dam construction. It was difficult to compare the generation status between three dams surveyed. Especially, there was no consistency in classification of the waste. Also, there was a difference in basic units for the estimation of generation amount.

Data of the generation amount were not available in dam A. In dam B, the unit of collected data was tonnage basis, while the wall area of structure was the basis in dam C. A more consistent system seemed to be necessary in the future to facilitate integrated management of dam construction waste. All the data were converted to tonnage base in Table 3. Logging operation was found to generate the largest amounts of tree waste. And, brick, timber, and soil were the major constituents in the waste that were generated from the demolition of structures such as building, house, school, store, and office. Based on the data of Table 3, the unit generation of the waste was obtained as shown in Table 4. Unit

Table 3. Status of dam construction waste in Korea

Waste		Dam A	Dam B	Dam C	Current treatment/disposal
Waste generated from demolition operation of structures (building, house, school, store, office)	Soil (ton)	-	8,786	1,795	Recycling, remote/on site landfilling
	Brick (ton)	-	7,665	4,834	Recycling, remote/on site landfilling
	Concrete (ton)	-	656	872	Recycling, remote/on site landfilling
	Asphalt (ton)	-	-	-	Remote landfilling if any
	Timber (ton)	-	4,480	-	Incineration
	Plastics (ton)	-	-	-	Incineration
	Steel (kg)	-	-	-	Recycling after transportation
	Galvanized iron sheets (kg)	-	46.3	-	Remote landfilling
	Slate (ton)	-	498	-	Remote/on site landfilling
	Roofing tile (ton)	-	171	-	Remote/on site landfilling
Farm soil (m^3)		-	-	-	No treatment
Manure (m^3)		2,500	389	-	Consignment treatment
Well (m^3)		-	-	-	Close
Agricultural waste (ton)		460	1,151 m^2	-	Consignment treatment
Tree (ton)		191,955	26,400	9,700	Incineration, recycling
Bridge (EA)		9	4	-	No demolition, or demolition and on site landfilling

Table 4. Unit generation of demolition wastes

	Dam A	Dam B	Dam C
Submerging area (km^2)	36.24	6.01	2.20
Logging area (km^2)	8.80	0.84	0.81
Demolition waste (ton)	-	22,256.00	7,501.00
Tree (ton)	191,964.00	26,400.00	9,700.00
Unit generation (ton/km^2)			
Demolition waste	-	3,703.16	3,409.55
Tree	21,814.09	31,428.57	11,975.31
DGN* of submerging area	-	4.16	3.51

* DGN : degree of green naturality

generations of demolition waste were about 3,700 and 3,400 ton/km^2 for dam B and dam C, respectively. The site of dam B had more structure of public usage than dam C did, so the unit generation became larger. The unit generation of logged tree ranged from 12,000 to 31,400 ton/km^2. It increased with the DGN implying the increase of biomass.

Treatment or disposal of dam construction wastes was being done by consignment between project manager and consignor as described in Table 3. The consignors were subcontracting with the trade of demolition operation. They collected the demolished wastes, and treated each waste after separation as described in Table 3. They separated concrete and cement from mixed wastes and recycling them into building stuff after grinding and sieving. Other waste constituents such as paper, timber, steel, and plastics were being collected by small recycling agents. The wastes that had low recycling potential due to a few recyclable materials were disposed in regional landfill sites. Occasionally, the demolished wastes such as asphalt were buried on site with simple separation of recyclable matter. However, there were increasing interests on hazards and aesthetic problem in drought season especially.

Table 5. Results of short term leaching test (Run 1) (unit : mg/L)

Compounds	Standards	Detection limits	Slate	Concrete	Cement	Plastics	Steel	Timber
Pb	3	0.04	ND	ND	ND	ND	ND	ND
Cu	3	0.008	ND	ND	ND	0.053	ND	0.031
As	1.5	0.005	ND	ND	ND	ND	ND	ND
Hg	0.005	0.0005	ND	ND	ND	ND	ND	ND
Cd	0.5	0.002	ND	ND	ND	ND	ND	ND
Cr^{6+}	1.5	0.01	0.185	ND	ND	ND	ND	ND
CN	1	0.01	ND	ND	ND	ND	ND	ND
TCE	0.3	0.0005	ND	ND	ND	ND	ND	ND
PCE	0.1	0.0005	ND	ND	ND	ND	ND	ND
Org. P	1	0.0005	ND	ND	ND	ND	ND	ND
Oil	8	0.01	ND	ND	ND	ND	ND	ND
Phenol	2	0.0005	ND	ND	ND	0.003	ND	0.008
PCB	50	0.0005	ND	ND	ND	ND	ND	ND

Table 6. Results of short term leaching test (Run 2) (unit : mg/L)

Compounds	Standards	Detection limits	Slate	Concrete	Cement	Plastics	Steel	Timber
Pb	3	0.04	ND	ND	ND	ND	ND	ND
Cu	3	0.008	ND	ND	ND	ND	0.079	0.031
As	1.5	0.005	ND	ND	ND	ND	ND	ND
Hg	0.005	0.0005	ND	ND	ND	ND	ND	ND
Cd	0.5	0.002	ND	ND	ND	ND	ND	ND
Cr^{6+}	1.5	0.01	ND	ND	ND	ND	ND	ND
CN	1	0.01	ND	ND	ND	0.01	ND	ND
TCE	0.3	0.0005	ND	ND	ND	ND	ND	ND
PCE	0.1	0.0005	ND	ND	ND	ND	ND	ND
Org. P	1	0.0005	ND	ND	ND	ND	ND	ND
Oil	8	0.01	ND	ND	ND	ND	ND	ND
Phenol	2	0.0005	ND	ND	ND	0.007	ND	0.008
PCB	50	0.0005	ND	ND	ND	ND	ND	ND

Short Term Leaching Properties

Table 5 and Table 6 show the results of short term leaching test. There were no hazardous compounds that conspicuously exceeded standards. Almost every compound was detected within detection limits. Especially, all the specified compounds were not detected in concrete and cement that were major portion of demolition waste. The concentration was fairly lower than standards, even though some compounds were over detection limits (Table 7). As a result, the wastes including concrete, cement, slate, steel, timber, and plastics could be classified as non-hazardous wastes that could be disposed in municipal solid waste landfill site.

There can be two reasons why the leaching potential was low. One is the total content of hazardous compound is originally low. The other is the extraction speed is too slow to leach sufficiently in these short term tests. Data of total heavy metal content determined by acid digestion method (Table 8) revealed that substantial amount of heavy metal such as Cu, Pb, and Cr existed in the wastes. So, it could be concluded that extraction speed was too low to be detected in the short term test.

Long Term Leaching Properties

It was impossible to predict long term leaching concentration, because no heavy metal was detected in the test although leachate

Table 7. Concentrations of compounds detected in short term leaching test

Compounds	Slate (Detected/Standard)		Plastics (Detected/Standard)		Steel (Detected/Standard)		Timber (Detected/Standard)	
	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2
Cu	-	-	1/57	-	-	1/38	1/97	-
Cr^{6+}	1/8	-	-	-	-	-	-	-
CN	-	-	-	1/100	-	-	-	-
Phenol	-	-		1/286	-	-	1/250	1/250

Table 8. Background concentration of heavy metals in inorganic wastes by total digestion technique (unit : mg/L, converted to the value of leaching test)

	Cu	Cd	Pb	Cr^{6+}	Mg	Ca	Zn
Cement	3.63	0.36	8.33	77.4	770	2500	12.30
Concrete	2.97	0.32	5.49	82.2	890	900	4.95
Slate	11.40	0.30	10.00	21.8	2800	7200	30.00

Table 9. Results of long term leaching test

		Heavy metal concentration of leachate sample*(mg/L)								Detection Limits (ppb)
Sampling time		2 hr	9 hr	1 day	3 day	5 day	7 day	9 day	11 day	
Cement	Cu	ND	ND	ND	ND	ND	ND	ND	ND	0.16
	Cd	ND	ND	ND	ND	ND	ND	ND	ND	0.04
	Cr	ND	ND	ND	ND	ND	ND	ND	ND	0.20
Concrete	Cu	ND	ND	ND	ND	ND	ND	ND	ND	0.16
	Cd	ND	ND	ND	ND	ND	ND	ND	ND	0.04
	Cr	ND	ND	ND	ND	ND	ND	ND	ND	0.20
Slate	Cu	ND	ND	ND	ND	ND	ND	ND	ND	0.16
	Cd	ND	ND	ND	ND	ND	ND	ND	ND	0.04
	Cr	ND	ND	ND	ND	ND	ND	ND	ND	0.20

* It was concentrated by 50 times before analyzing.

sample was concentrated by 50 times (Table 9). So, it was concluded that the maximum leachable concentrations of heavy metal in concrete, cement, and slate were below one fiftieth of detection limit. Based on it, heavy metal concentration in the water of a dam where these wastes was buried on-site could be calculated as follows.(Table 10)

In the same way, maximum concentrations of Cd and Cr could be calculated as 0.004 ppb and 0.02 ppb, which were 1/2,500 times lower than drinking water standards. Consequently, effect of on-site burying of dam construction waste on water quality proved to be negligible.

Leaching Properties in Landfill Simulator

Heavy metal concentrations in leachate from the simulator were below detection limit as expected. All the three simulators show the same trend. As the leachability of the wastes were negligible, the presence of topsoil did not affected heavy metal concentration. Also, the wastes were strong alkaline so that the pH of leachate maintained about 11 resulting in low extraction of heavy metals.

Strategy of Demolition Wastes Management

There was no related regulations or guidelines for the management of dam con-

Table 10. Calculation of Cu concentration in the dam water

Basic data		Cu concentration in the dam water	
Generation of demolition wastes (ton)	79,936	Maximum annual generation (μg Cu/kg sample)	$0.16 \times 365 = 58.4$
Reservoir capacity (m^3)	300×10^6	Cu leaching amount (g)	$79{,}936 \times 10^3 \times 58.4 \times 10^{-6} = 4{,}668$
Maximum daily generation (μg Cu/kg sample/day)	0.16	Concentration (ppb)	$4.668 \times 10^6/(300 \times 10^9) = 0.016$
Limit concentration of Cu in drinking water (ppm)	Below 1		

struction waste. Current regulation dealt with general construction and demolition waste. Therefore, this study suggested a special guideline concerning the management of dam construction wastes, which emphasized the possible application of on-site landfilling or burying. In the guideline, concrete, cement, and slate recommended to be landfilled on site. Of course, these wastes could be recycled after pretreatment, but transportation cost should be considered into the selection of treatment method. Generally, mobile recycling machine were more preferable than the centralized large recycling facility. Steel was classified as recyclable constituent, however most of steel was generated in the concrete waste so that the separation was not easy. In that case, on site landfilling was recommended instead of recycling. Preferred alternative for timber waste was recycling with shredding evenly. The unrecyclable timber suggested to be incinerated. A timber with antiseptic should also be incinerated, but fly ash should be tested its leachability of hazardous compound to be landfilled. Plastics are not likely to leach hazardous compounds enough to be treated on site. However, plastic film could appear on the water surface, which was not aesthetically desirable. Surface soil near the livestock farm should be removed to be treated at another site, while other soil could be present as it was.

CONCLUSION

In this research, leaching potential and management strategy of demolition wastes in the dam construction site were investigated. The unit generation of demolition waste was found as ranged from 3,400 to 3,700 ton/km^2. And the unit generation of logged tree waste ranged from 12,000 to 31,400 ton/km^2. At the result of short term leaching test, there were no hazardous compounds that conspicuously exceeded standards. Therefore, the wastes including concrete, cement, slag, steel, timber, and plastics could be classified as non-hazardous wastes that could be disposal in municipal solid waste landfill site.

Based on the result of long term leaching test, maximum concentrations of Cd and Cr in the water of a dam where these wastes was buried on-site could be calculated as 0.004 ppb and 0.02 ppb, which were 1/2,500 times lower than drinking water standards. Consequently, effect of on-site burying of dam construction waste on water quality proved to be negligible.

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