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Electrical Surveys at the Seokdae Waste Landfill of Pusan

부산 석대 폐기물 매립지에서의 전기탐사

Kiehwa Lee (이기화)* and Jong-Ryeol Yoon (윤종렬)*

Abstract : Electrical surveys were conducted at the Seokdae waste landfill in July, 1996. Within the landfill, 4 lines of dipole-dipole surveys and 7 Schlumberger soundings were carried out and 2 soundings in front of the landfill. In the landfill, interpretations of the survey data show low resistivity zones below 10 Ωm to a depth of 50 m from the surface and such low resistivity zones of the D block are thicker than those of the other blocks by about 2~10 m. Considering the depth of the bedrock and the height of waste reclamation, no evidence of bedrock contamination by leachate is indicated. But it is inferred that the weathered zones are contaminated in the landfill. In the block A and B, minor fault having the strike of N70°W have been confirmed by dipole-dipole surveys, so future contamination of the bedrock by leachate is possible. The degree of ground contamination is the highest in the D block due to the leachate plume mainly heading for this block. On the other hand, electrical soundings do not indicate ground contamination by leachate in the front area of the landfill.

요 약 : 부산 석대 폐기물 매립지에서 1996년 7월중 전기비저항탐사를 실시하였다. 매립지 내부에서는 쌍극자탐사 4측선과 슐럼버져 수직탐사 7측점이 수행되었으며, 매립지 전방지역에서는 수직탐사 2측점이 수행되었다. 자료의 해석결과, 매립지 내부에서는 10 Ωm 이하의 낮은 비저항값을 가지는 층이 지표하 50 m 까지 나타났으며, D 블록의 경우는 다른 블록들보다 이러한 저비저항대가 약 2~10 m 정도 두껍게 나타났다. 이 지역의 기반암 심도와 매립고를 고려할 때, 매립지 내부에서는 침출수에 의한 기반암의 오염은 진행되지 않았으나 풍화대는 오염된 것으로 판단된다. 그러나 A, B 블록에서 N70°W의 주향을 가지는 소규모의 단층이 쌍극자탐사자료에 확인되어, 추후 기반암의 침출수오염 가능성을 배제할 수 없다. 또한 다른 블록들에 비하여 D 블록의 지층오염 정도가 가장 심한 것으로 나타났는데 이는 침출수의 주 유동방향이 D 블록을 향하고 있기 때문인 것으로 생각된다. 한편, 매립지 전방지역에서는 비저항자료에 의한 지층의 침출수오염 징후는 발견되지 않았다.

INTRODUCTION

From 1987 to 1993, domestic wastes of Pusan had been dumped in the Seokdae waste landfill which is located at Seokdae-dong, Haeundae-gu, Pusan. The area and the volume of the dumped waste are 514,345 m^2 and 12,848,317 m^3, respectively, which are the largest in Pusan (Haeundae-gu district office, Pusan, 1993). The Seokdae waste landfill is divided into 4 blocks named A, B, C and D block (Figure 1). Each block has different dump volumes and periods. Detailed present conditions of the waste dump for each block are shown in Table 1.

Originally, for the prevention of ground contamination by leachate in and around the landfill, the facilities of leachate treatment and slurry walls were installed. But these facilities do not work presently. Thus many environmental problems such as the groundwater contamination, offensive odor and poisonous gas generation etc. have been produced in and around the landfill.

In this study it is intended to provide the basic information on leachate distribution in the landfill which is needed to prevent further ground contamination and build the effective plan of stabilization of the landfill. Generally, geophysical methods provide economic and convenient means to investigate contaminant plumes from the landfill. Among the various geophysical methods, the electrical method is most commonly adopted in geophysical surveys of landfills (Carpenter *et al.*, 1990; Ross *et al.*, 1990; Lee and Yoon, 1995). In this study, dipole-dipoles surveys and Schlumberger soundings were carried out in and around the Seokdae landfill to elucidate the aspect of ground contamination by leachate from the landfill.

OVERVIEW OF THE GEOLOGY

This area is composed of andesitic rocks, rhyolitic rocks,

*서울대학교 지질과학과(Department of Geological Sciences, Seoul National University, Seoul 151-742, Korea)

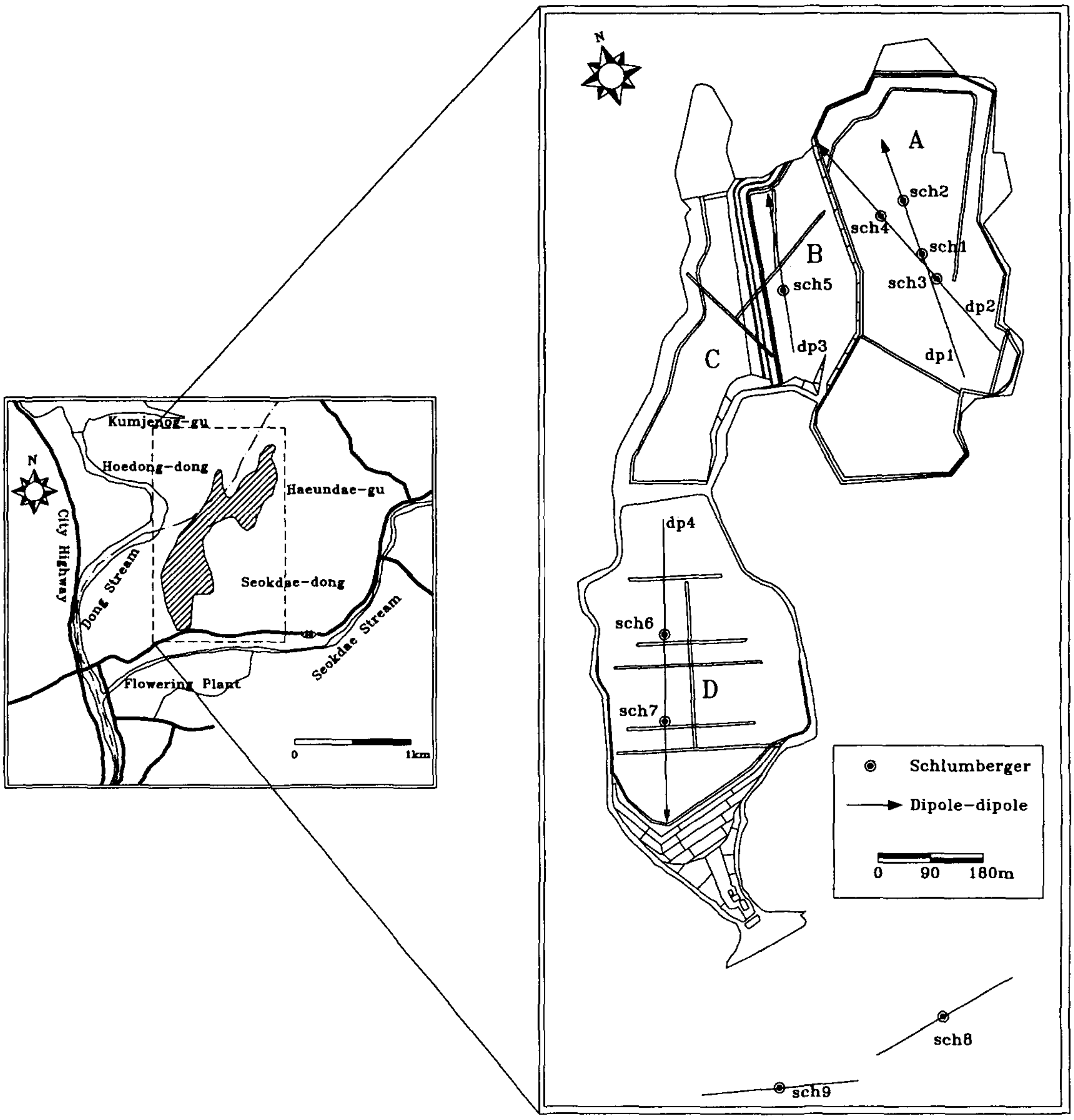

Figure 1. The location map of the electrical surveys.

dyke rocks and alluvium. Andesitic rocks are distributed in the eastern part of the Seokdae landfill and composed of fine grained andesite, porphyritic andesite and brecciated andesite. Fine grained andesite is hard, compact and dark bluish green or dark green in color. Porphyritic andesite is well shown in the right side of the access road of the landfill. Under the microscope the porphyritic andesite shows porphyritic and trachytic texture and it is composed of plagioclase, hornblende, minor of quarts, sphene, ilmenite and magnetite (Son *et al.*, 1978).

In the western part of the landfill, rhyolite which intruded in andesitic rocks occurs. This rock shows porphyritic and flow structures and is mainly composed of quartz, orthoclase and plagioclase. Many cracks and joints are well developed in this rock and the main directions of the joints are N6°E/86°NW and N87°W/29°SW (Chung, 1995).

Table 1. Present conditions of the waste dump for each block (from Haeundae-gu district office, Pusan, 1993)

	Sum	A block	B block	C block	D block
Dump Area (m^2)	514,610	220,853	60,443	72,657	160,657
Dump Depth (m)	-	30~39	31~34	31~34	23~31
Dump Volume (m^3)	12,854,317	5,798,907	1,813,290	1,332,313	3,909,807
Dump Period	87, 6~93, 5	89, 3~93, 5	90, 4~91, 12	90, 4~91, 4	87, 6~93, 5

Alluvium comes out in valley and lowland of this area partly and consists of gravel, sand and weathered soil.

Geological mapping of the study area revealed Hoedongri fault and several joints (Haeundae-gu district office, Pusan, 1992). Hoedongri fault which has the strike of N15°E lies in the northwestern part of the landfill. The dip of the fault is almost vertical and the width of the fault zone is about 3 m.

SURVEYS AND INTERPRETATIONS

Electrical soundings with Schlumberger array and dipole-dipole surveys were carried out using LUND imaging system which includes ABEM SAS 300B in July, 1996. Considering the depth of the bedrock in the landfill is about 40~60 m from the surface (Haeundae-gu district office, Pusan, 1993), maximum distance between measuring point and current pole was set as 146 m in Schlumberger soundings. In dipole-dipole surveys, electrode separation number is 8 and electrode interval 25 m.

Sounding data were interpreted with interactive forward modelling method (Kim and Lee, 1993). Interactive method is superior to inversion method in that existing known geological information can be included in interpreting process. On the other hand, dipole-dipole data were interpreted by 2-D inversion which smoothness constraint method is imposed on (Constable *et al.*, 1987; Inman, 1975; Kim, 1987).

The number of boring data inside and around the landfill is 4 and 5, respectively. But boring depth in the landfill is too shallow to penetrate the weathered zone and bedrock. So, these boring data were not directly included in interpretation of electrical survey data.

Inside of the Seokdae Waste Landfill

Dipole-dipole surveys : A total of 4 dipole-dipole surveys were made in the A, B and D block of the landfill (Figure 1). Since the dump volume of the A block is the largest in the landfill, two dipole-dipole surveys were carried out in this block. In the other blocks, one dipole-dipole survey was performed. However, in the C block, because of irregular topography and thick grass, dipole-dipole survey could not be made.

Figure 2 and 3 show interpretation results of DP1 and DP2 carried out in the A block. Some noises due to poor grounding conditions are shown in the observed apparent resistivity pseudo-sections of DP1 and DP2.

Generally, it is known that dipole-dipole survey data is sensitive to the inhomogeneities in shallow depth. However, despite of the surface noise, interpreted resistivity structures of this study is relatively stable and reasonable. This indicates that subsurface of the landfill is saturated with leachate.

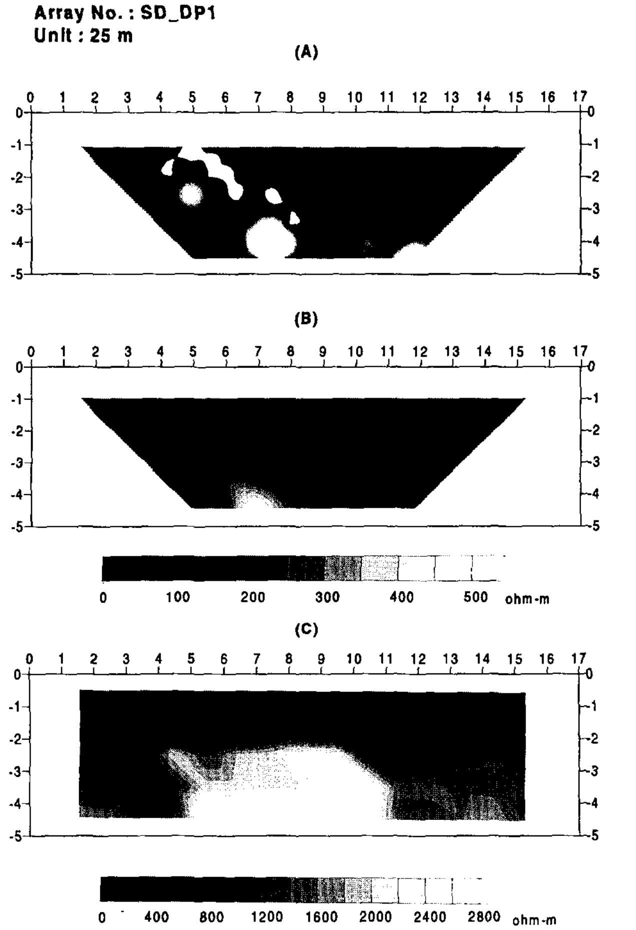

Figure 2. Dipole-Dipole survey data and their interpretations of DP1 in the A block. (A) observed apparent resistivity pseudo-section, (B) theoretically calculated apparent resistivity pseudo-section and (C) inverted resistivity structure.

Interpretations of DP1 and DP2 show low resistivity zones having resistivities of about 0.1~5 Ωm exist to the depth of about 50 m from the surface. Considering usual resistivities of ground, the resistivity values of these zones are extremely low. Similarly, Schlumberger soundings, Sch1~Sch4 arranged to lie along DP1 and DP2 lines, also show low resistivity layers. Therefore, these low resistivity zones are considered as saturated zone with leachate. Interpreted model in Figure 2 shows somewhat irregular resistivity structure in the middle of section. It seems that this irregularity results from the noise included in observed data. But as a whole, inverted resistivity structure is relatively stable and this is the same as the others. On the other hand, the resistivity structure of DP2 is different from that of DP1. Figure 3 shows extensive low resistivity zone at the left end of the inverted section. This extensive low resistivity zone may be related with bedrock contamination by leachate, or may result from the mathematical error at the boundary during inversion process. It is interesting that two minor faults appear near the pole No. 9

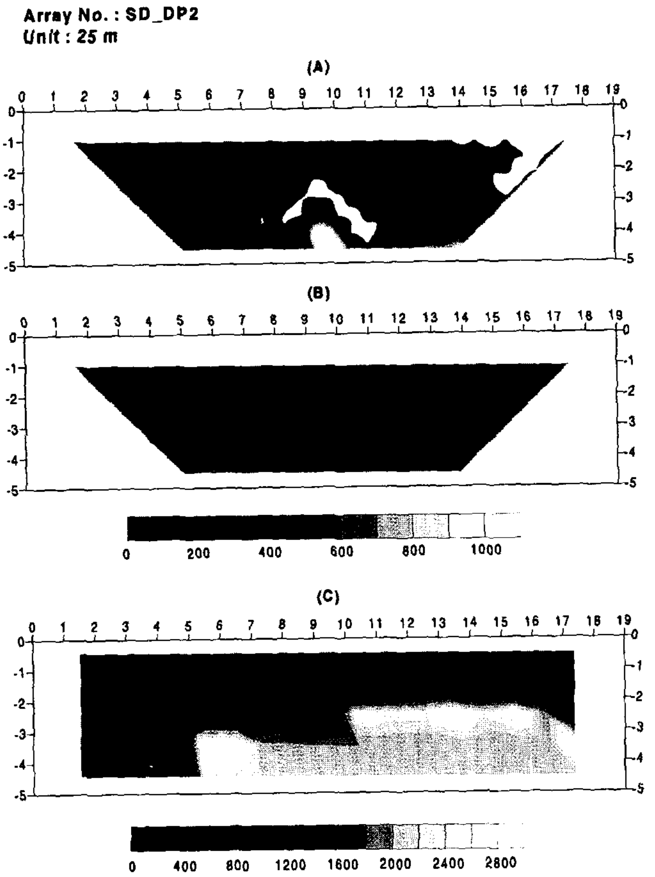

Figure 3. Dipole-Dipole survey data and their interpretations of DP2 in the A block. (A) observed apparent resistivity pseudo-section, (B) theoretically calculated apparent resistivity pseudo-section and (C) inverted resistivity structure.

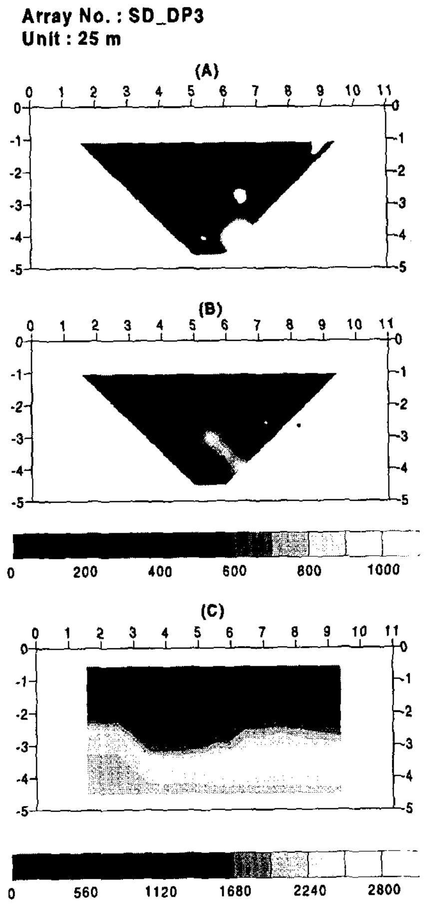

Figure 4. Dipole-Dipole survey data and their interpretations of DP3 in the B block. (A) observed apparent resistivity pseudo-section, (B) theoretically calculated apparent resistivity pseudo-section and (C) inverted resistivity structure.

and 16. Especially, minor fault near the pole No. 9 is also confirmed in the DP3 survey data of the block B. In inverted resistivity structure of DP3, fault is clearly represented between the pole No. 2 and 3 (Figure 4). Judging from these results, minor fault developed in the block A and B have the strike of N70°W and this strike agrees with the main direction of joint system in these blocks (Haeundae-gu district office, Pusan, 1992). It appears that the leachate originating from the block A and B migrates to the C block through such minor fault and flows out through Hoedongri fault which is developed at the northwestern part of the C block. According to Haeundae-gu district office (1992), leachate flowed out of the landfill to Hoedong-dong in 1991. After leachate outflow slurry wall was installed but it does not work properly now. Thus it is urgent to make preparation for leachate outflow and slope collapse.

The interpretation result of dipole-dipole survey line DP4 is shown in Figure 5. Low resistivity zone also appears as in the other sections. The low resistivity zone becomes thick at the both ends of DP4. On the whole, compared with the other blocks, the low resistivity zone of the D block is thicker than those of the other blocks. Considering topographic gradient, it is believed that main plume of leachate moves toward the D block. Thus it seems that this flow of leachate causes the thicker low resistivity zone of DP4 than those of DP1～DP3.

Putting these results of the dipole-dipole surveys together, low resistivity zones of about 0.1～5 Ωm extend to the depth of about 50 m from the surface. Considering the height of waste reclamation of 30～40 m and the depth of the bedrock of 15～20 m from the surface (Haeundae-gu district office, Pusan, 1993), no evidence of bedrock contamination is indicated. But it appears that weathered zone of the landfill is contaminated by leachate.

Schlumberger soundings : A total of 7 Schlumberger soundings were made in the Seokdae waste landfill (Figure 1). All soundings were arranged to lie along the dipole-dipole survey line to enhance the confidence of interpreted resistivity structures. Results of these soundings and their interpretations are shown in Figure 6 except for Sch6 which is very similar to Sch7.

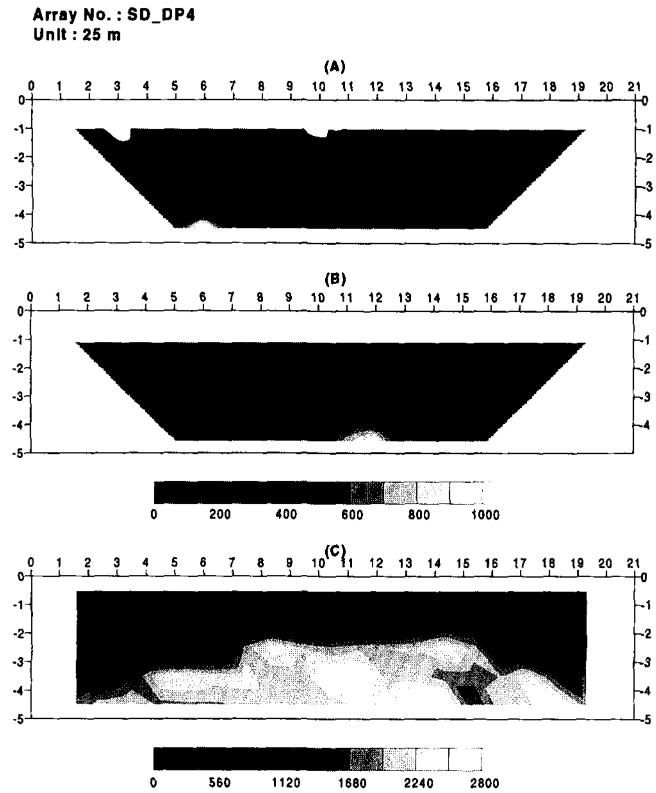

Figure 5. Dipole-Dipole survey data and their interpretations of DP4 in the D block. (A) observed apparent resistivity pseudo-section, (B) theoretically calculated apparent resistivity pseudo-section and (C) inverted resistivity structure.

On the whole, observed apparent resistivity values are very low ranging 0.1~10 Ωm and could be interpreted in terms of 4-layer structure.

Schl~4 made along DP1 and DP2 lines in the block A show somewhat different trends from each other. Soundings Schl and Sch2 have trends that resistivities increase with depth. It is remarkable that the resistivities of the first layers in the block A is very low compared with those of landfills of other areas. These very low resistivities of the first layers ranging from 0.05 to 20 Ωm are also shown in the other blocks. The second layers of the block A also have very low resistivities of 0.03~1 Ωm with mean thickness of about 5 m and the same may be said of the other blocks. Generally, considering the case of the Nanjido landfill, the resistivity structure of landfill have 4 layers regarded as waste layer, partially saturated zone with leachate, fully saturated zone with leachate and bedrock (Lee and Yoon, 1995), respectively. But in this study, the first and the second layers have very low resistivities below 10 Ωm regarded as resistivity of leachate. Because the resistivities of the first and the second layers are very low as much as those of the third layers, the first and the second layers are indistinguishable from the third layers. Such low resistivity zones of shallow depth are

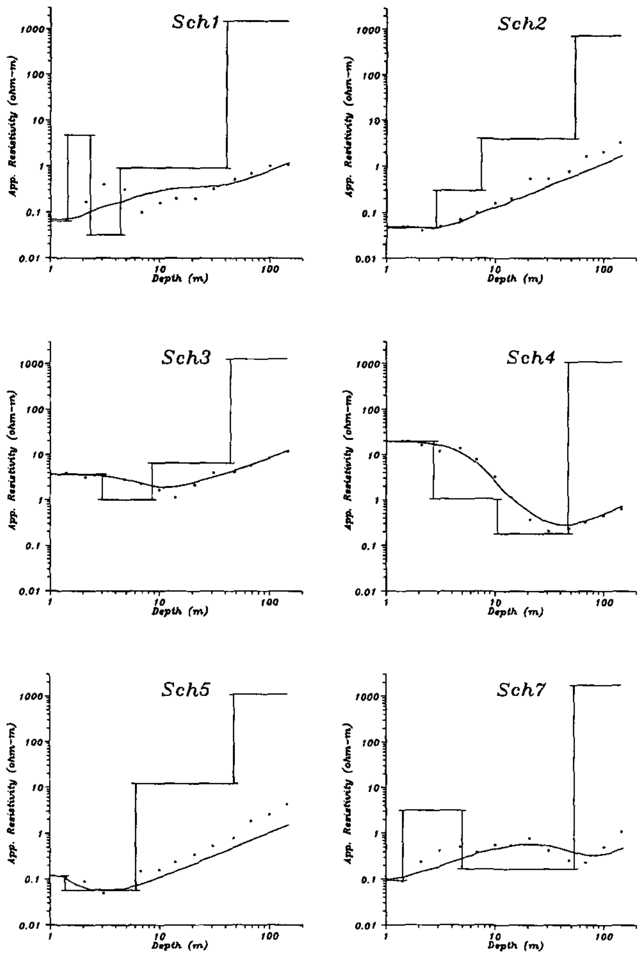

Figure 6. Schlumberger soundings and their interpretations in the Seokdae landfill. Observed data and theoretically calculated values are marked by dots and solid lines. Jagged lines represent interpreted resistivity structure.

also confirmed in the previous results of the dipole-dipole surveys. From these facts, it can be concluded that leachate level is very high in all blocks.

The resistivities of the fourth layer considered as bedrock range from 270 Ωm to 1,700 Ωm. Also, the depths of the bedrock are 40~54 m with the mean of about 47 m from the surface. These results are in accordance with those of the dipole-dipole survey data. Judging from these relatively high resistivities and bedrock depths, there exists no evidence of bedrock contamination by leachate as in the dipole-dipole surveys.

The interpretations of Sch6 and Sch7, indicate the low resistivity zone of the D block is thicker than those of the other blocks by about 2~10 m. Besides, considering the height of the D block is lower than those of the other blocks by about 5~7 m, there is the possibility of bedrock contamination in this block. The reason, as previously mentioned, is that the most of the leachate mainly flows toward this block.

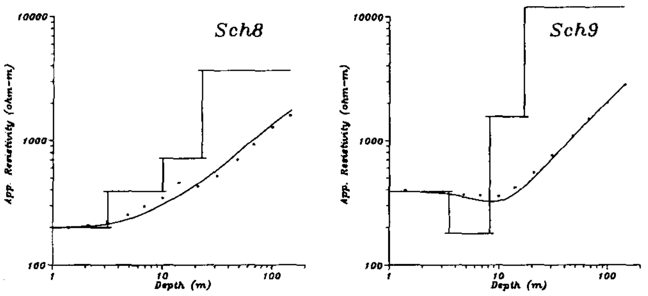

Figure 7. Schlumberger soundings and their interpretations in the front area of the Seokdae landfill. Observed data and theoretically calculated values are marked by dots and solid lines. Jagged lines represent interpreted resistivity structure.

Outside of the Seokdae Waste Landfill

To elucidate the extent of ground contamination by leachate from the landfill, Schlumberger soundings were carried out outside of the landfill. However, only 2 soundings were made in the front area of the landfill, since the Seokdae waste landfill is surrounded with mountains on three sides.

Figure 7 shows interpretation results of Sch8 and Sch9. Two soundings were interpreted as 4-layer structure. Judging from the boring data (Haeundae-gu district office, Pusan, 1993) in the circumferential area of the landfill, interpreted 4 layers can be regarded as top soil, alluvium, weathered zone and bedrock, respectively. The resistivities of the fourth layer considered as bedrock range from 3,600 Ωm to 11,000 Ωm. The depths of the bedrock is about 17~22 m close to 20 m of the boring data. Furthermore, the third layers have resistivities of 700~1,500 Ωm. Considering these relatively high resistivities, there is no evidence of ground contamination in the front area of the landfill. However, according to Chung (1995), the contents of heavy metals such as Mn, Zn, Ba, Sr and Al in groundwater are high in this area. Therefore, the counterplan for future ground contamination by leachate leakage from the landfill is needed.

CONCLUSIONS

The results of this study may be summarized as follows.

1. There is no evidence of the bedrock contamination within the landfill. However, the zone of very low resistivity values of about 0.1~5 Ωm extending down to depth of about 50 m from the surface suggests the weathered zone in the landfill may be contaminated by leachate.

2. Minor fault having strike of N70W have been found in the A and B blocks by dipole-dipole surveys. Thus the possibility of future bedrock contamination by leachate is inferred. Also, it appears that the leachate originating from the block A and B migrates to block C through such minor faults and flows out through Hoedongri fault.

3. The low resistivity zone of the D block is thicker than those of the other blocks by about 2~10 m, which results from the fact that the most of the leachate flows mainly toward this block.

4. In the front area of the landfill, no indication of ground contamination is found. However, considering that the contents of heavy metals in the groundwater are relatively high in this area, the counterplan for future ground contamination by leachate leakage from the landfill is in need.

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