# Panel discussion: Proper waste disposal and the remediation of contaminated sites

## Débat de spécialistes: Gestion correcte des décharges et dépollution des sites contaminés

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ABSTRACT: The most important waste management strategy is to minimize environmental impact of waste. The techniques used are reduction of waste generation, development of suitable intermediate techniques, reutilization and recycling of waste, and establishment of safe and proper disposal landfill scenarios. This paper focuses on the establishment of safe and proper disposal landfill sites and the Japanese strategy for waste disposal landfills. A case study on illegal dumping of hazardous waste in Japan is introduced. Containment and remediation technologies are also discussed together with the advantages of newly-developed methods.

RESUME: Les plus importantes questions que soulèvent la gestion des déchets dans le but de minimiser l'impact sur l'environnement sont la réduction de la production de déchets, le développement de techniques intermediaires appropriées, la réutilisation et le recyclage des déchets et la mise en place de scenarios d'enfouissement des déchets corrects et sûrs. Ce document se focalise sur le dernier de ces thèmes et sur la stratégie japonaise pour une gestion par enfouissement des déchets, de plus une étude de cas sur les décharges illegales de déchets dangereux est presentée. Les techniques de contenerisation et de décontamination sont aussi abordées avec les avantages qu'apportent les méthodes nouvellement developpées.

## 1 INTRODUCTION

Human actions which bring about sustainable development are required so that a prosperous civilization can coexist with a sound environment. Environmental geotechnics has and will play an important role in preserving our environment.

The quantity of waste generated is increasing and will lead to an increase in frequency of illegal dumping of waste. The quality of the waste is often lowered due to contamination by toxic substances. Furthermore, disposal sites are being filled faster than was originally predicted, and isolation and safe-containment systems should be established in order to avoid ground and groundwater contamination.

The major objectives in the safe disposal and containment of any type of waste include (Mitchell, 1996):

(1) The construction of liners, floors, walls, and covers that adequately limit the spread of pollutants and the infiltration of surface waters,

(2) The containment, collection and removal of leachate from landfills,

(3) The control, collection, and removal or utilization of landfill gases,

(4) The maintenance of landfill stability,

(5) Monitoring to ensure that the necessary long-term performance is being achieved.

The classification of waste coincides with the levels of contamination. Waste which is explosive, toxic, infectious or of a nature otherwise harmful to the health of human being or the living environment is classified as specially-controlled waste. Constant precaution is required in respect to such specially-controlled waste at all stages from discharge to disposal, and a specific disposal method is prescribed for each substance. Industrial waste which contains mercury, cadmium, lead, PCB or other hazardous substances and does not meet the prescribed standards based on elution tests, are classified into the designated hazardous industrial waste category. The Environmental Standard was introduced to safeguard human health and to preserve the living environment. The Effluent Standard was introduced to control the quality of water discharge from factories and other business establishments into public waters and seepage of water into the ground. The classification of degree of waste contamination depends strongly on the characteristics of the

Table 1 Environmental standards and judgment criteria for industrial waste

| Substance | Environment standard | Effluent standard | Landfill disposal | |
|---|---|---|---|---|
| | Environmental water and ground | Drainage | Sludge | Ashes, slug soot and dust |
| Unit | mg/L | mg/L | mg/L | mg/L |
| Alkyl mercury compound | Not detected | Not detected | Not detected | Not detected |
| Mercury or a compound thereof | 0.0005 | 0.005 | 0.005 | 0.005 |
| Cadmium or a compound thereof | 0.01 | 0.1 | 0.3 | 0.3 |
| Lead or a compound thereof | 0.01 | 0.1 | 0.3 | 0.3 |
| Organic phosphorus compound | | 1 | 1 | |
| Hexavalent chromium compound | 0.05 | 0.5 | 1.5 | 1.5 |
| Arsenic or a compound thereof | 0.01 | 0.1 | 0.3 | 0.3 |
| Cyanide compound | Not detected | 1 | 1 | |
| PCB | Not detected | 0.003 | 0.003 | 0.003 |
| Trichloroethylene | 0.03 | 0.3 | 0.3 | |
| Tetrachloroethylene | 0.01 | 0.1 | 0.1 | |
| Dichloromethane | 0.02 | 0.2 | 0.2 | |
| Carbon tetrachloride | 0.002 | 0.02 | 0.02 | |
| 1,2-dichloroethane | 0.004 | 0.04 | 0.04 | |
| 1,1-dichloroethylene | 0.02 | 0.2 | 0.2 | |
| Cis-1,2-dichloroethylene | 0.04 | 0.4 | 0.4 | |
| 1,1,1-trichloroethane | 1 | 3 | 3 | |
| 1,1,2-trichloroethane | 0.006 | 0.06 | 0.06 | |
| 1,3-dichloropropene | 0.002 | 0.02 | 0.02 | |
| Ciulam | 0.006 | 0.06 | 0.06 | |
| Cymagin | 0.003 | 0.03 | 0.03 | |
| Ciobenkalb | 0.02 | 0.2 | 0.2 | |
| Benzene | 0.01 | 0.1 | 0.1 | |
| Selenium or a compound thereof | 0.01 | 0.1 | 0.3 | 0.3 |
| Basis | | Environmental standard × 10 | = Effluent standard | = Effluent standard |

waste and the analytical methods used, in particular elution techniques (Kamon, 1996). Table 1 summarizes the environmental standards and judgment criteria for industrial waste in Japan as related to water quality (Tanaka, 1996). The remediation target should be below the levels indicated in Table 1.

## 2 DISPOSAL STRATEGY TO MINIMIZE ENVIRONMENTAL IMPACT

Leachate from waste at waste disposal sites poses a potential environmental risk. A proper disposal technique based on the properties of the waste must be selected.

Disposal standards are provided for each type of waste. Waste disposal landfills can be divided into three types according to environmental pollution potential as shown in Figure 1.

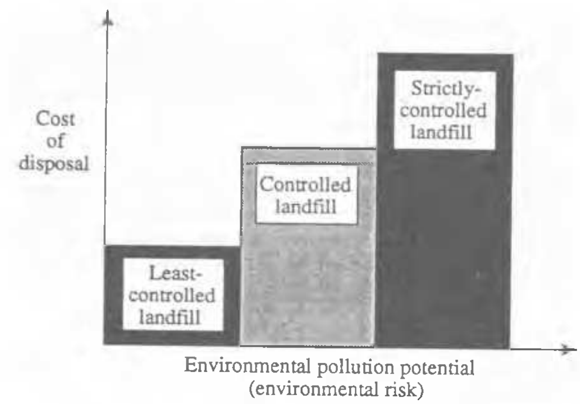


Figure 1 Classification of waste disposal sites by environmental pollution potential

1) Disposal of waste at a strictly-controlled landfill site

Waste which is likely to generate a leachate hazardous to human health and industrial waste containing hazardous metals or similar substances are brought to a strictly-controlled landfill site for final disposal. These waste are fully isolated from the environment.

2) Disposal of waste at a controlled landfill site

Waste which is likely to generate a leachate detrimental to the preservation of the living environment is brought to a controlled landfill site for final disposal. Its leachate, similar to that from domestic waste, has large BOD and COD contents and contains organic substances but does not contain hazardous metals or similar substances. The leachate is collected through seepage control and treated carefully to prevent the leachate from contaminating the soil or water system.

3) Disposal of waste at a least-controlled landfill site

Waste which usually generates no foul water is finally disposed of at a least-controlled landfill site. The types of waste in this category are demolition waste, glass, ceramics, plastics, metal and rubber which are supposedly free of dissolved hazardous metals. These waste are stable and do not decompose or generate foul water.

The technical requirements differ according to the characteristics of each type of waste and therefore the disposal cost will also vary accordingly.

## 3 REMEDIATION OF CONTAMINATED SITES

### 3.1 *Basic concept of remediation work*

Contamination from waste poses a potential threat to our natural resources and human health. From the remediation standpoint, the most important factors are likely to be a definition of the cleanup target, technical and cost feasibilities, natural recovery estimates, and the ability to distinguish and/or control continuing contamination.

Different remediation methods for contaminated sites are available (Jessberger, 1996; Kovarick and Kingscott, 1996).

Remedial measures include:

(1) Providing containment by cutting off migration pathways by
- (a) capping systems
- (b) vertical cut-off walls

Table 2 Strategy for proper remediation

| Step | Subjects for remediation | Remarks |
|---|---|---|
| 1 | Characterization of initial situation | 1) Protection objective<br>2) Trigger values<br>3) Individual planning intentions |
| 2 | Pre-evaluation | 1) Technical applicability test<br>2) Comprehensive test |
| 3 | Site specific remedial scenarios | 1) Compatibility of site conditions |
| 4 | Determination of remediation targets | 1) Determination of level of remediation and site specific importance |
| 5 | Detailed evaluation | 1) Monitoring remediation work<br>2) Evaluation of effectiveness and residual risks |
| 6 | Economic consideration | 1) Qualify cost estimate<br>2) Consideration of cost effectiveness |

- (c) basal lining systems
- (d) active pneumatic or hydraulic measures, and/or
- (e) immobilization.

(2) Decontamination of contaminated ground by
- (a) physical treatment
- (b) thermal treatment
- (c) microbiological treatment, and/or
- (d) soil washing.

(3) Replacement of contaminated soil and waste: this method should not be used as the contaminated soil and waste still need to be properly disposed of.

Decontamination is the preferred remedial measure, but it is not cost effective. Providing containment is the accepted substitute for decontamination. It must be ascertained that with containment, any risk to humans and the environment are eliminated. Containment is in principle a temporary remedial action and must provide for cleanup activities to be undertaken in the future. An effective monitoring system will show if and when additional remedial action is necessary.

In selecting a proper remedial measure, a step-wise strategy should be adopted as shown in Table 2. After cost evaluations, a remedial concept is proposed which contains the scope of the remediation and the measures to be taken for each case.

### 3.2 *Containment and isolation*

There are three approaches to contaminant partitioning of waste. These approaches are: (1) beneficial use or open-water disposal, (2) solids retention, and (3) hydraulic isolation. The confined disposal facility (CDF) design criteria, based on contaminant level and pathway, are shown in Figure 2.

The CDF should be used for containing contaminated waste that cannot be released without control to the environment. Contaminants within the CDF can be discharged to the environment through six potential pathways (Richardson et al., 1995).

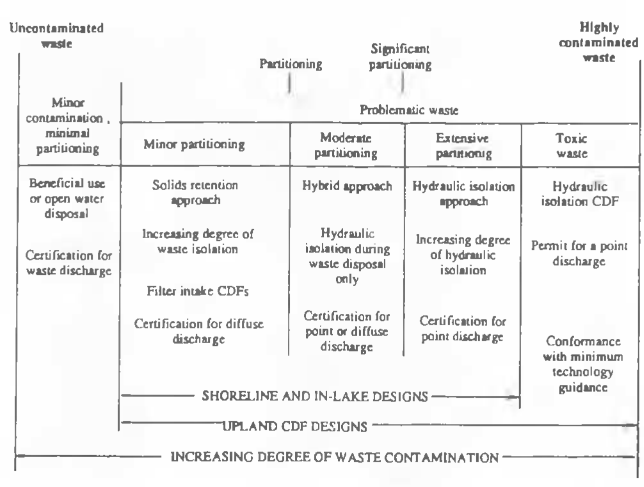


Figure 2 CDF design criteria based on contaminant levels and pathways

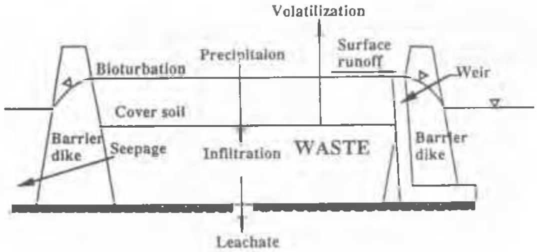


Figure 3 Contaminant pathways for in-lake CDF

These pathways are shown in Figure 3 and include three water-borne pathways (seepage, leachate and surface runoff), two pathways related to the direct uptake of the contaminants by plants or animals (bioturbation), and an airborne emission of contaminants (volatilization).

The methods for limiting contaminant pathways from CDFs for problematic waste include the addition of engineered barrier and/or water-balanced components in dikes, basins, and covers. The operational alternatives for establishing pathway barriers are also important. Thus, the basin of the CDF could be lined using compacted clay liner (CCL) or it could be sealed by placing an initial layer of clean fine-grained material in the CDF. Either barrier layer could be effective in limiting the movement of leachate from the waste into the groundwater beneath the CDF.

Creating a vertical barrier by cut-off walls is one of the most effective methods. A newly-developed diaphragm wall method, the trench cutting & re-mixing deep wall (TRD) method, is considered to be highly cost-effective for creating a vertical barrier. This method uses a chain-saw type cutter device for digging and mixing. The cutter device is inserted into the ground up to the necessary depth to make a continuous soil-cement wall as illustrated in Figure 4. The TRD method has the following advantages:

(1) The continuity of the wall is very high and the permeability is very low.

(2) The wall is homogeneous and can be as deep as 30 meters. The original ground condition is modified by the wall as shown in Figure 5.

(3) The digging capability of the cutter device is high enough to be applied to gravel and cobble grounds.

(4) The height of the construction device is low (4 m) and the machine stability is high.

The wall is usually constructed vertically. To apply it to disposal sites, an inclined wall can be constructed by inclining the device. The angle of the inclined wall that has been successfully constructed is 60 degrees from the vertical.

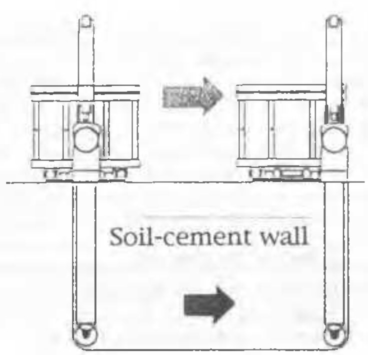


Figure 4 Schematic of TRD method

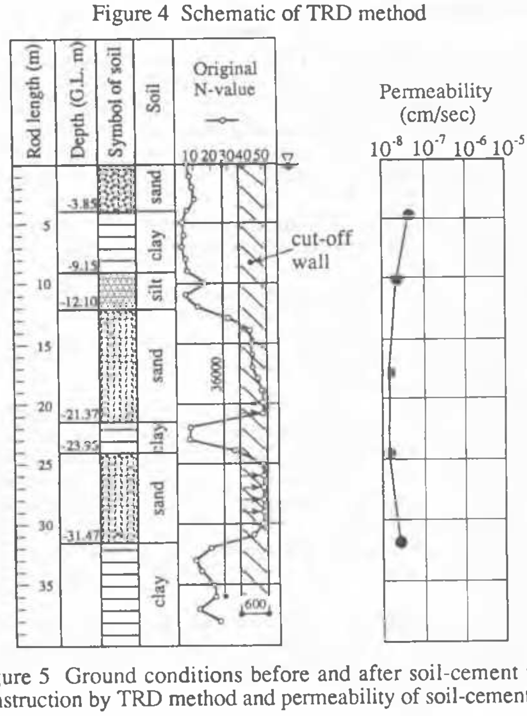


Figure 5 Ground conditions before and after soil-cement wall construction by TRD method and permeability of soil-cement

3.3 *Remediation*

Uncontrolled release of heavy metals and organic chemical substances into the ground has resulted in widespread ground and groundwater contamination. The remediation of sites with contaminated grounds should be performed as soon as possible. Solidification techniques have the potential to stabilize or treat soils which would permit safe containment.

The soil-mixing technique has increasingly been relied upon for in situ remediation of contaminated soils (Day and Ryan, 1995). Depending on the application, different diameter mixing augers (1 to 4 m) can be used to inject cement, bentonite and other stabilizers to modify soil properties and thereby remedy contaminated grounds. A major advantage of the Deep Mixing Method (DMM) is its ability to treat soils at great depths without excavation, shoring or dewatering. Thus, it is relatively low cost and allows less exposure of wastes to the surface environment.

When a quick lime powder of DMM is injected into a contaminated clay ground, the induced heating by the reaction of the quick lime with water can easily remove volatile organic compounds (VOCs). The following introduces an example of Japanese experience with DMM (Yabuta et al., 1996).

Figure 6 shows the remediation system for a VOCs contaminated site in Japan with DMM. One of the advantages of DMM is that it can be applied to a clay soil ground, where the most popular Vacuum Vapor Extraction Method cannot be applied. Another advantage is its ability to work under a removable hood. The hood is an open-bottom cylinder which covers the surface of the column while mixing is performed directly below. The hood is lowered onto the soil and the mixing

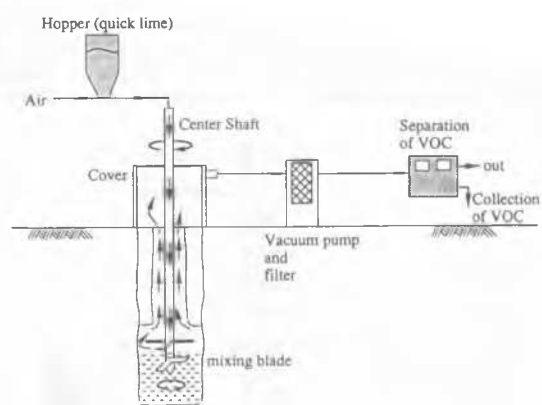


Figure 6 Remediation flow by DMM

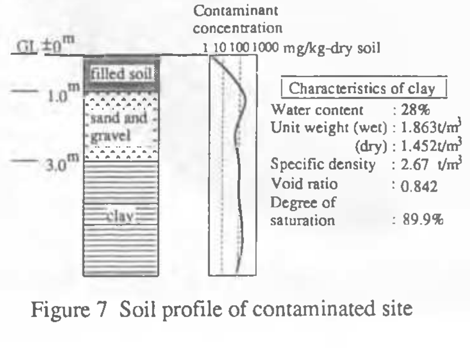


Figure 7 Soil profile of contaminated site

Table 3 Contents of hazardous substances on Teshima Island

| Substances | Sampling sites | Distribution of content (mg/kg) less than 0.1 | 0.1 ~ 1 | 1 ~ 10 | 10 ~ 100 | 100 ~ 1000 | 1000 ~ 10000 | more than 10000 | Maximum content |
|---|---|---|---|---|---|---|---|---|---|
| Cadmium, Cd | 19 | | | 12 | 7 | | | | 87 |
| Lead, Pb | 19 | | | | 1 | 5 | 12 | 1 | 14000 |
| Arsenic, As | 19 | | 1 | 10 | 7 | 1 | | | 100 |
| Mercury, Hg | 19 | 1 | 6 | 12 | | | | | 4.3 |
| PCB | 19 | 1 | | 11 | 7 | | | | 58 |
| Nickel, Ni | 19 | | | | 3 | 16 | | | 440 |
| Copper, Cu | 19 | | | | | 3 | 13 | 3 | 49000 |
| Zinc, Zn | 19 | | | | | 2 | 14 | 3 | 31000 |
| Dioxins | 22 | 2 | 9 | 10 | 1 | | | | 39 |

Note: Unit of Dioxins is ng-TEQ/g

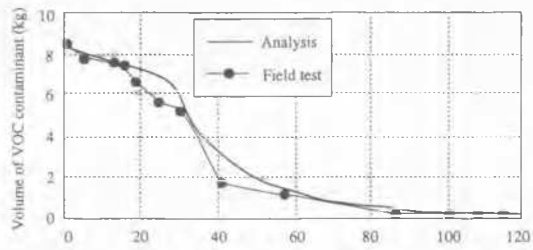


Figure 8 Results of remediation

blades are started while quick lime is introduced. A negative pressure may be kept on the head space of the hood to remove any vapors into a vapor treatment system during construction of a column. The installed columns overlapped each other in order to treat all the desired areas. Soil profile of the site is shown in Figure 7. The contaminated layer spread from the ground surface to the deep clay layer. The improved depth was from the ground surface to 5.5 m below the ground surface. The contaminating substances are TCE, PCE, c-DCE, etc. and the maximum contaminant concentrations were 265.5 mg/kg-dry soil of TCE and 329.7 mg/kg-dry soil of c-DCE. After injection of 100 or 150 kg/m$^3$ of quick lime for two mixing cycles, a large volume of VOCs was extracted from the contaminated ground, as shown in Figure 8. The amount of removed VOCs in the field agreed well with the values computed from the air flow rate.

## 4 SITE CONTAMINATED BY ILLEGAL WASTE DUMPING

Hanashima et al. (1996) reported a case of illegal dumping of industrial hazardous waste on a small island in Japan, which has been dubbed the Japanese version of the Love Canal Incident.

A large quantity of hazardous waste was illegally dumped on Teshima Island in the scenic Seto Inland Sea of Japan. An industrial waste disposal company, which collects car shredder dust and other wastes ostensibly for recycling, illegally dumped and burned approximately 460,000 m$^3$ (510,000 tons) of the waste on a field. The profile of the ground and groundwater levels are shown in Figure 9. The site investigation revealed more than 30 hazardous substances as shown in Table 3. Toxic substances such as lead, PCB and dioxins were detected in the waste at high concentrations. These contaminants were also detected in the groundwater beneath the waste. Environmental contamination caused by the waste has not been clearly detected. According to the direction of the groundwater flow, however, it is highly possible that the toxic substances in the dumped waste have penetrated into the marine environment.

This incident brought public attention to the prefectural administration's negligence, inadequate legislation, and the insufficient processing capability of the industrial waste disposal company. The incident also highlighted the many problems involved in waste disposal especially cost of remediation and construction of industrial waste treatment plant or final disposal site. The local residents demanded the removal of the illegally dumped waste and official justification gave momentum to resolving cases like this one through the environmental pollution arbitration system.

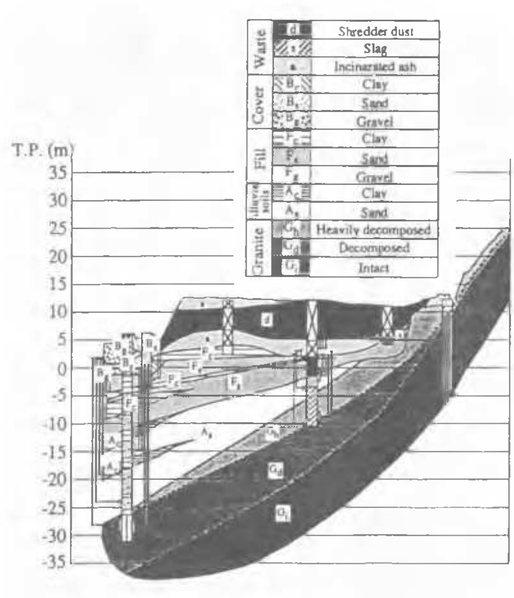


Figure 9 Profile of ground and groundwater levels of contaminated site on Teshima Island

## 5 CONCLUSION

Proper waste disposal landfills and the environmental impact of hazardous substances in waste landfills were discussed. Many remediation techniques are available in a carefully controlled operation system. However, waste contamination can still be a daunting problem from technical and regulatory standpoints. Agencies at various levels, working together with the industries and the public, have made progress in developing regulatory and technical approaches to cleaning up heavily contaminated sites and to identifying sites that require urgent action. No single regulatory or technical approach will work in all situations. Increasing recognition of the problem by various authorities, and with additional resources and new approaches being applied on all fronts, we appear to be on the way to reducing the environmental impact of hazardous waste disposal.

## REFERENCES


Day, S.R. and Ryan, C.R. 1995. Containment, stabilization and treatment of contaminated soils using in situ soil mixing, *Proc. Geoenvironment 2000*, ASCE, 1349-1365.

Hanashima, M., Takatsuki, H. and Nakasugi O. 1996. A case study of environmental contamination caused by illegal dumping of hazardous wastes, *Waste Management Research*, Vol. 8, No. 2, pp. 4-15.

Jessberger, H. 1996. Technical committee of environmental geotechnics, ISSMFE activities, *Preprint of 2nd ICEG; IS-Osaka'96*, pp. 1-28.

Kamon, M. 1996. Geotechnical utilization of industrial wastes, *Preprint of 2nd ICEG; IS-Osaka'96*, pp. 67-84.

Kovarick, Jr.,W.W. & Kingscott, J. 1996. Status of remediation technology in the United States, *Preprint of 2nd ICEG; IS-Osaka'96*, pp. 263-283.

Mitchell, J.K. 1996. Geotechnics of soil-waste material problems, *Preprint of 2nd ICEG; IS-Osaka'96*, pp. 85-102.

Richardson, G.N., Petrovski, D.M., Chaney, R.C. & Demars, K.R. 1995. State of the Art: CDF contaminant pathway control, *Dredging, Remediation, and Containment of Contaminated Sediments*, ASTM., STP1293, pp. 195-219.

Tanaka, M. 1996. Risk management for landfill disposal of solid waste, *Preprint of 2nd ICEG; IS-Osaka'96*, pp. 301-313.

Yabuta, H., Higaki, K. and Ujiie, M. & Iwasaki, T. 1996. Removal of volatile organic compounds from clay layer, *Grouting and Deep Mixing-IS-Tokyo '96*, ed. by Yonekura, et al., 1; pp. 787-792.