Solution for the Environmental Protection of Soil and Underground Water

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The Soil Contamination Countermeasures Law came into force in February 2003, and Mitsubishi Heavy Industries, Ltd. (MHI) was registered as a licensed survey institution. Thereupon, MHI started a large-scale soil survey project and completed it in November 2003. Further, MHI completed on-site remediation of PCBs-contaminated soil, for the first time in Japan, in March 2003, and subsequent work ordered by a private company was successfully completed in January 2004. MHI, answering the needs of society, deals with the whole process from survey to countermeasures, thereby offering solutions to soil and underground water environmental preservation.

1. Introduction

The history in Japan of soil pollution developing into social problems goes back to the Ashio Copper Mine Mineral Poisoning Incident, which took place in 1880. In the 1960s soil pollution by cadmium brought about serious health problems, and in the 1980s cases of soil and underground water contamination by volatile organic compounds (VOCs) such as trichloroethylene and dioxins etc. were discovered one after another.

In recent years, cases of discovery of contamination have drastically increased as voluntary environment surveys have become more common for redevelopment of ex-plant/factory sites, for acquisition of ISO 14000, or for preservation and confirmation of the economic values of land properties to be acquired or sold.

The Soil Contamination Countermeasures Law was enacted on 22 May 2002 and came into force on 15 February 2003, making soil survey compulsory and standardizing the survey procedure, thereby opening a new era for all phases of countermeasure procedure, including soil and underground water contamination survey and remediation.

2. Survey based on the Soil Contamination Countermeasures Law

2.1 Soil Contamination Countermeasures Law

The purpose of the Soil Contamination Countermeasures Law is to protect peoples' health by defining the subjects of survey for determining soil conditions and by providing countermeasures to prevent danger to human health caused by soil contamination.

The survey of soil is conducted by the following procedure:

(1) The history of the subject land property is surveyed by using publicly available data and interview results.
(2) The presence of soil contamination is estimated.
(3) The survey plan (survey density etc.) is developed.
(4) The surface soil layer is surveyed to 2-dimensionally locate the positions where pollution is present.
(5) The soil is 3-dimensionally surveyed in detail to obtain the depth of soil contamination.
(6) Based on the result of such survey, a countermeasure work plan is developed and carried out.

Thus, soil survey will proceed stage-by-stage based on the result of each preceding stage. MHI has an established system to carry out a consistent operation from survey through to countermeasure implementation, thereby offering a total solution to the preservation of the soil and underground water environment.

2.2 Status of the Soil Contamination Countermeasures Law enforcement

The status of the enforcement of the Soil Contamination Countermeasures Law as of 15 November 2003 shows that a total of 374 locations have been scheduled to be surveyed, of which work at 205 locations has been postponed, and 65 locations have been surveyed, with reports submitted already or now under preparation. Thus, although surveys at many locations have been postponed, these locations will eventually be surveyed in the future.

Further, some financial institutions have stated that they would reduce to zero the valuations of some land properties in some specific areas listed on their property ledger if soil pollution was discovered on the land. In the real estate business, soil survey is becoming essential before any transaction, so that the real estate business conditions are drastically changing in connection with soil pollution due to the enforcement of the Soil Contamination Countermeasures Law.

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2.3 Approach to soil survey

MHI participated in the soil survey/remediation business in 2000 and was registered as a licensed survey institution under the Soil Contamination Countermeasures Law in January 2003. During the period from June 2003 to November 2003, MHI carried out a soil survey project of the largest class, based on the Soil Contamination Countermeasures Law.

This project was at an ex-factory site of approximately 180 000 m^2, and was carried out as to all 25 pollutants designated by the Soil Contamination Countermeasures Law. This survey project is outlined in **Table 1**. Approximately 2 400 samples were analyzed in this survey. In order to perform the survey fast, a self-moving boring machine (Geoprobe) was used, as shown in **Fig. 1**.

The project was completed successfully in a short time with full information control, employing past survey experience and comprehensive engineering capability. Further, the method of the survey and the possible health effects caused by industrial contamination, etc. were explained to the neighbors, and where the survey discovered any contamination, a corresponding countermeasure plan was compiled.

3. Soil remediation work

3.1 Soil remediation technology

The techniques that are inexpensive, workable in a short period of time and easily accepted by the public, are required for soil remediation. Especially, much is expected of both on-site soil remediation and off-site soil remediation by low cost techniques.

On-site soil remediation can be conducted without excavating polluted soil, but it used to require a long time to complete in cases of soil contamination with VOCs. Recently, however, a biological technology which allows soil remediation quickly has been developed, and MHI has started to study use of it.

On the other hand, off-site soil remediation can be conducted at low cost using a large facility with a high operation rate. This method has the advantage that the land can be used immediately after excavating all the polluted soil. Off-site soil remediation is the mainstream method in the Netherlands, an advanced country as far as soil remediation is concerned, and this method will be adopted more often in Japan in the future.

Thus, low cost and short time treatment techniques are being developed for practical application with VOCs and heavy metal pollutants, but there have been no techniques easily acceptable by the public that are applicable to PCBs, which is difficult to deal with. Thus, the establishment of measures for dealing with PCBs-contaminated soil has long been delayed.

3.2 PCBs-contaminated soil remediation technology

In July 2001, the Law for the Promotion of Environmentally Sound Destruction of PCB Waste came into force. The demand for PCBs contaminated soil remediation is expected to grow as a result of interaction between the acceleration of PCBs waste and enforcement of the Soil Contamination Countermeasures Law.

At the present time, PCBs-contaminated soil remediation techniques include the solvent extraction system(1), a soil melting system, a base catalyzed decomposition system, an anaerobic thermal system, etc., and widespread efforts are being made on the laboratory level to adapt them to practical use.

MHI imported a solvent extraction method from the United States, which is considered to be publically acceptable as a PCBs-contaminated soil remediation system. MHI successfully combined the solvent extraction system with its own solvent handling techniques because MHI is a top manufacturer of solvent gas-treatment plant. As a result, MHI has built up its own treatment system in compliance with the relevant Japanese laws and regulations and adaptable to Japanese soil and contamination conditions.

The solvent extraction system extracts and separates pollutants from soil by soaking the contaminated soil in a solvent. The stability of this method is high as the treatment is carried out at normal temperature and pressure, and the treatment cost is low.


Fig. 1 Self-moving boring machine (Geoprobe)

Table 1 Outline of survey work

Item	Details	Remarks
Survey area	180 000 m^2	
Substances subject to survey	VOCs, heavy metals, agricultural chemicals, etc.: 25 substances in all	Alkyl mercury is not included.
Excavation points ▪VOCs ▪Heavy metals ▪Agricultural chemicals, etc.	 443 points 1 344 points 6 points	Each number of excavation points includes duplicated points.
Analyzed samples ▪VOCs ▪Heavy metals ▪Agricultural chemicals, etc.	 845 samples 1 524 samples 7 samples	The number of VOCs analysis samples for soil and soil gas analysis.

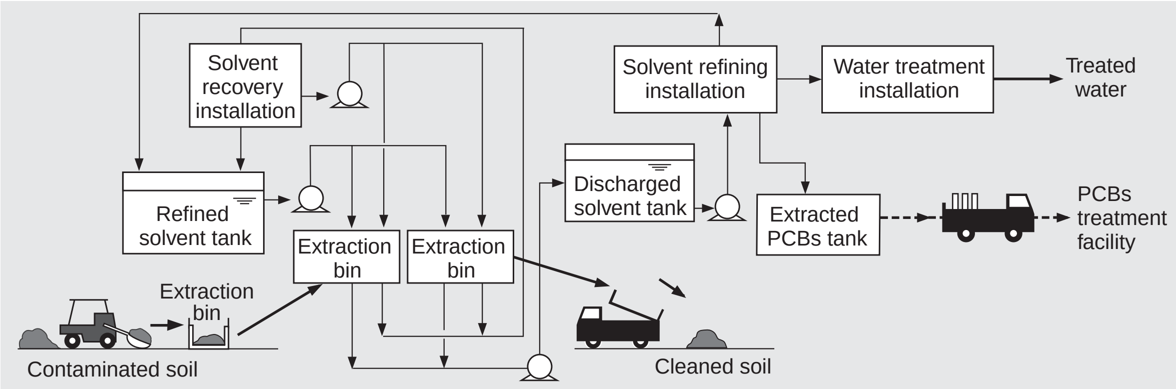

Fig. 2 Solvent extraction system treatment flow

Figure 2 shows the treatment flow of this system. This system consists of the following three installations.

(1) Contaminated soil remediation installation

The contaminated soil remediation installation consists of extraction bins in which contaminated soil is filled, a refined solvent tank to store the refined solvent, a discharged solvent tank to store the solvent after extraction, and pumps. Contaminated soil is filled into the extraction bins, the solvent is poured in from the refined solvent tank, and the contaminated soil is soaked in the solvent in the extraction bins to extract and separate the pollutants.

At this time, the water contained in the contaminated soil is also extracted. After extraction, the solvent is discharged from the extraction bins and stored in the discharged solvent tank. By repetition of this process, the contaminated soil can be cleaned till the required cleanliness is reached.

This is a highly reliable system, without mechanical problems, since it adopts a simple extraction method wherein the contaminated soil is not stirred mechanically but remains still in place. Further, it is capable of lot-by-lot treatment control.

Fig. 3 Actual soil sample testing facility

(2) Solvent refining installation

The solvent refining installation consists of a solvent refining tower and a PCBs enriching tower. Firstly, in the solvent refining tower, the PCBs and water is separated from the discharged solvent containing PCBs and water. After the solvent is refined, the solvent is sent to the refined solvent tank for re-use. Secondly, in the PCBs enriching tower, the pollutant is separated from the water so as to be concentrated and treated separately. The separated water is discharged, treated in a water treatment installation and then discharged out of the system.

In the process of treatment, even a minute content of PCBs cannot be allowed to remain in the solvent or in the separated water. MHI has successfully constructed a compact mobile-type refining installation that removes all PCBs, enabling economical on-site recycling of the solvent.

(3) Solvent recovery installation

The solvent recovery installation consists of a blower, condenser and activated carbon tower. Steam is sent to the extraction bins to evaporate the solvent remaining in the extraction bins, and the evaporated solvent is drawn by the blower from the extraction bins, cooled and condensed by the condenser and recovered by adsorbing it in an activated carbon tower. The solvent absorbed by activated carbon is separated by steam so that the carbon may be re-activated. The soil after remediation can be used to backfill the original location.

This system has been employed successfully many times in the United States, one of the most advanced countries as regards soil remediation technology, and use of it has been authorized by the Environment Protection Agency (EPA) of the United States. This system, depending on solvent selection, can also extract and separate agricultural chemicals and dioxins. The contaminated soil has a complicated variety of soil quality, types of pollutants and densities of co-existing materials. Economical, safe and dependable treatments are being proposed using systems capable of fast and high accuracy evaluation, most suitable solvent, extraction treatment cycle and remediation performance to subject soil, utilizing the compact and simple real sample testing facility, as shown in **Fig. 3**.

3.3 First on-site PCBs contaminated soil remediation project in Japan

In March 2001, used high-voltage capacitors were found to have been unlawfully dumped in Kita Ward of Kobe City, and some soil was discovered to have been contaminated with PCBs that had leaked from the capacitors. In fiscal 2002, a verification test[(2)–(4)] of this PCBs contaminated soil was completed, using the solvent extraction system of MHI, this being the first on-site PCBs contaminated soil remediation work in Japan carried out as a joint research project by MHI and the National Institute for Environmental Studies and the municipality of Kobe.

In order to confirm the safety of this treatment system prior to the operation on site, a preliminary test was performed by analyzing the PCBs concentration at each emission point (where PCBs may possibly leak in the worst case) using laboratory testing equipment and actually sampled contaminated soil. **Table 2** shows the results. The test of the actually contaminated soil verified the capability of the treatment system to consistently reduce the concentration down to below the legal PCBs environmental quality standard for soil, and it also confirmed that the treatment system is capable of removing dioxins.

Based on the results of the preliminary test, the soil remediation plant was installed on site, and on-site soil remediation was started. **Table 3** shows the results of the verification test by the solvent extraction system for all 47 lots of PCBs contaminated soil. The completion of the treatment was determined when the soil treated cleared the legal environmental quality standard for soil.

The solvent extraction treatment cycle was set with some design margin to ensure sufficient soil remediation after 8.4 cycles on average. Further, the safety of the treatment system as a whole was confirmed by periodical monitoring of PCBs concentration, etc. at the verification test equipment and surrounding environment, with results satisfying the established control target values. The soil thus cleaned was used to backfill the original location.

During the on-site PCBs contaminated soil remediation performed this time, precious data and know-how which the laboratory tests could not provide were obtained, and the actual soil remediation performance of the solvent extraction system and the negligible PCBs emission to the environment were confirmed. This test provided us with a foothold to start upgrading treatment performance and reducing treatment cost for various types of contaminated soil containing PCBs and dioxins, etc. by means of the selection of the solvent most suitable for the properties of the pollutants to be removed and the properties of the contaminated soil, and by upgrading the solvent extraction system, and so forth.

Table 2 Results of preliminary test

	Item	Test results	Remarks
Soil before remediation	PCBs concentration in soil (mg/kg)	118	
	DXNs toxicity equivalent (pg-TEQ/g)	830	Law Concerning Special Measures against Dioxins Environmental Quality Standards for Soil (1 000 pg-TEQ/g)
Soil after remediation	PCBs concentration in leachate (mg/L)	Not detected	Environmental Quality Standards for Soil (not detected)
	PCBs concentration in soil (mg/kg)	0.1	
	DXNs toxicity equivalent (pg-TEQ/g)	2.4	
Discharged water	PCBs concentration (mg/L)	0.0005 - 0.0023	Water separated from contaminated soil: Discharged Water Quality Standards (0.003 mg/L)
PCBs condensed liquid	PCBs concentration (wt%)	18	
Tank vent gas	PCBs concentration (mg/m^3_N)	0.00005	Exhaust Gas Quality Standards (Provisional) (0.15 mg/m^3_N)

Table 3 Results of verification test

Item		Test results	Remarks
Treated soil quantity (ton)		92	
PCBs concentration in soil after remediation (mg/L)		Not detected in any lot	Before remediation: average 88 mg/kg Environmental Quality Standards for Soil (not detected)
PCBs concentration in discharged water (mg/L)		Less than 0.003	Water separated from contaminated soil etc. Discharged Water Standards (0.003 mg/L)
Environment monitoring PCBs concentration	Ventilation air of soil handling building (mg/m^3_N)	Less than 0.0015	Exhaust Gas Quality Standards (Provisional) (0.15 mg/m^3_N)
	Tank vent gas (mg/m^3_N)	Less than 0.0015	
	Downstream river/pond (mg/L)	Not detected	Environmental Quality Standards for Underground Water (not detected)

The successful on-site soil remediation resulted in this system receiving public acceptance so that MHI was able to obtain a second project from a private company at another site. The installations used in the mentioned on-site test were moved to the second project site, and the on-site soil remediation for this project was commenced in September 2003 and was completed successfully in January 2004.

3.4 PCBs contaminated soil remediation scheme

The solvent extraction system is now being employed in a project to remove PCBs-derived dioxins from contaminated soil in Ota Ward of Metropolitan Tokyo. This Ward had been designated for the first time within the country as an area subject to the application of the Law Concerning Special Measures against Dioxins.

In this project, which is scheduled to commence in fiscal 2004, decisions have already been made to separate PCBs from the contaminated soil by the solvent extraction method and to treat the separated PCBs by MHI's hydrothermal decomposition system at a PCBs treatment facility being prepared by Japan Environment Corporation in Koto Ward.

Thus, the MHI scheme for detoxication of PCBs contaminated soil using MHI's proprietary separation and detoxication technology is now being recognized and more widely employed.

4. Conclusion

MHI will continue to make efforts to reduce the cost of soil survey with keeping the survey quality, and develop new technologies to upgrade soil treatment capacity and reduce total cost by increasing the equipment size and installation of off-site plants.

Further, MHI will expand its activities into not only PCBs and dioxins but also poisonous substances which are increasingly causing pollution problems, such as agricultural chemicals, and will apply to contaminated sediment in addition to contaminated soil.

In the future, MHI, taking advantage of its capability to undertake the whole task of soil remediation from soil survey to countermeasures, will continue to propose solutions to the preservation of soil and underground water environment and so to contribute to the needs of society in their own way.


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References

(1) Eto et al., Remediation of PCBs Contaminated Soil by Solvent Extraction Method, Technical Journal of Geo-Environmental Protection Center No.6 (2003) p.33

(2) Takigami et al., Remediation of PCBs Contaminated Soil by Solvent Extraction Method and Monitoring, 9th Conference for Contamination of Soil & Underground Water and Countermeasure No.139 (2003)

(3)Sakai et al., Development of the Monitoring Technique in Remediation of PCBs Contaminated Soil - The First Remediation Verification of PCBs Contaminated Soil in Japan -, The Monthly Journal of Global Environment April (2004) p.98

(4) Eto et al., The First Success in on-site Remediation for PCB contaminated Soil, Mitsubishi Juko Giho Vol.41 No.1 (2004) p.34