Proposal of Biological and Pysico-chemical Treatment Systems for Dioxins-contaminated Soils

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Introduction

Soil contamination caused by dioxins in and around sites of incinerators for municipal solid waste (MSW) is a concern in Japan. For example, scattering wastewater from a wet gas scrubber at a MSW incinerator in Nose, Osaka, caused contamination of soil and surface water. The concentration of dioxins in the soil at the site was approximately 8,000 pg-TEQ/g. Contamination has also occurred at sites where fly ash was placed directly on soil or where it was improperly stored, and at uncontrolled landfill sites that have received bottom and fly ash over a long period. Some countermeasures are required immediately at these dioxins-contaminated sites.

We have previously developed bioreactor systems for dioxins-contaminated water and soil[1, 2], because biological methods are inexpensive and have a low potential to produce toxic by-products. We have shown that a fungus, *Pseudallescheria boydii (P. boydii)*, isolated from activated sludge treating wastewater that contained dioxins, can degrade highly chlorinated dioxins[1]. A reaction product of octachlorinated dibenzo-p-dioxin (OCDD) was identified as heptachlorinated dibenzo-p-dioxin[1].

When treating a dioxins-contaminated site, the appropriate method for treatment must be selected, depending on the site characteristics. These include the concentration and its distribution of dioxins, the soil type (including whether dioxins from fly ash are present), and the volume of soil to be treated. Where the concentration of dioxins is too high for biological methods to be effective, a combination of biological and physico-chemical methods can be effective.

We have developed both physico-chemical and biological methods for the treatment of dioxin contamination, including a solvent extraction process using ethanol for contaminated soils[3], a pretreatment process for contaminated water using ultraviolet light[3], and a bioreactor system[4, 5]. In addition, posttreatment processes have been developed, such as a solvent extraction process of dioxins remaining in contaminated soils after treatment in the bioreactor[5] and a process for sterilizing *P. boydii*[6]. These processes should be combined, depending on the site characteristics.

This study proposed biological and pysico-chemical treatment systems for dioxins-contaminated soils. We tested combination of biological and physico-chemical methods, particularly taking into consideration the concentration of dioxins, and the type of contaminated soil.

Remedial strategy for a dioxins-contaminated site

In general, there are two alternative methods for the remediation of dioxins-contaminated soil: removal of soil for on-site treatment or *in situ* remediation. The appropriate method is chosen based on a consideration of the cost of the treatment process, the time required for remediation, and the technical and social feasibility of the method.

When treating a dioxins-contaminated soil, a particular concentration of dioxins may be critical for selecting the most appropriate method, as dioxins are highly toxic and a high concentration may require urgent remediation of the soil. As shown in Figure 1, where dioxins concentrations in soil are high, the contaminated soil is removed in order to prevent the contaminant spreading. The soil is then treated using a bioreactor or some other methods such as incineration. In contrast, where the dioxins concentration is low, *in situ* bioremediation may be appropriate after the contamination has been contained by inserting a vertical barrier and capping around the contaminated area.

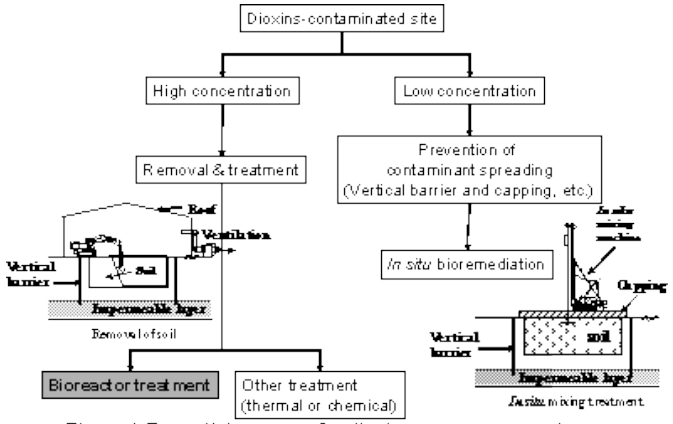

Figure 1 Remedial strategy for dioxins-contaminated site

Bioreactor treatment system for the removed soil

Figure 2 shows bioreactor treatment system for the removal soil, where either liquid-phase or solid-phase treatment can be used.

Liquid-phase treatment

In the liquid phase treatment, as shown in Figure 3, dioxins are extracted from the contaminated soil with solvents such as ethanol, and the extracted dioxins are concentrated and treated in a bioreactor using *P. boydii*. If there are significant quantities of highly chlorinated dioxins in the soil, ultraviolet light treatment may be effective in degrading these compounds.

We tried to extract dioxins from contaminated soil that was sampled from Nose, Osaka, and investigated the optimum conditions for dioxins removal[3]. As a result, we found that ethanol (80% v/v in water at 78.3^{o}C for 1 minute) could extract 99% of the dioxins based on TEQ from the Nose sample. The extraction rate was relatively high, as most of the dioxins seemed to be located on the surface of soil particles. Ethanol could not extract any dioxins from fly ash. Therefore, extracting dioxins using ethanol can be effective for treating contaminated soils, where the dioxins are of the type that can be extracted easily.

When the extracted dioxins (400 ng/mL-ethanol) were added to water and were treated with ultraviolet light for 90 minutes, a dechlorination reaction occurred as shown in Table 1. In addition, we confirmed that *P. boydii* could degrade about 85% of the remaining dioxins after UV[7].

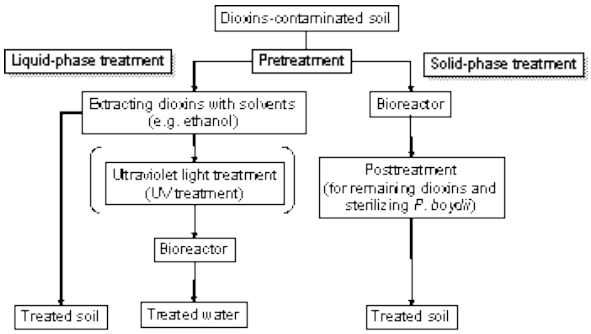

Figure 2 Bioreactor treatment systems for the removed soil

Table 1 Ultraviolet degradation of dioxins in ethanol extract from contaminated soil[3]

	TCDD +TCDF	P5CDD +P5CDF	H6CDD +H6CDF	H7CDD +H7CDF	OCDD +OCDF
Degradation ratio (%)	-50	68	40	57	71

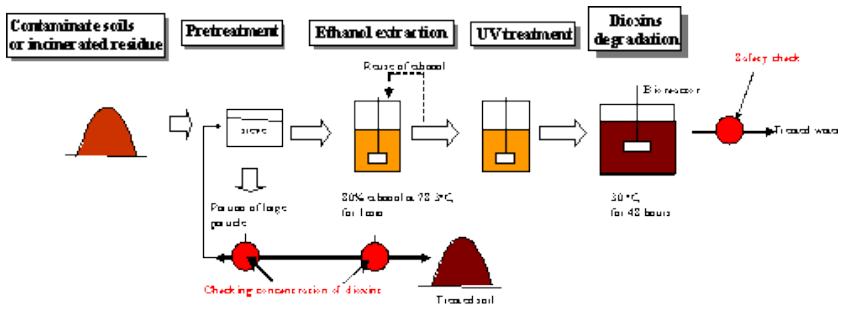

Figure 3 Liquid-phase treatment system for treatment of dioxins contaminated soil

Solid-phase treatment

Where it is difficult to extract dioxins from contaminated soil, such as in soil mixed with fly ash, a solid-phase treatment system may be more effective, as shown in Figure 4. We studied the effectiveness of treating two kinds of contaminated soil that contained fly ash by using a bioreactor (5 L), in which a slurry (1 kg of soil and 2.4 L of water) that had a water content of 70% was agitated with *P. boydii* at 30^{0}C for 48 hours to 96 hours. Between 40% and 60% of the dioxins were degraded (initial concentration 173 pg-TEQ/g and 2,210 pg-TEQ/g to final concentration 66 pg-TEQ/g and 1,340 pg-TEQ/g, respectively)[5].

Since *P. boydii* is a weakly pathogenic fungus, ranked at the lowest level in Japanese guidelines, a heat sterilizing process was added to the system. The sterilizing conditions have been reported by Ishii et al.[6].

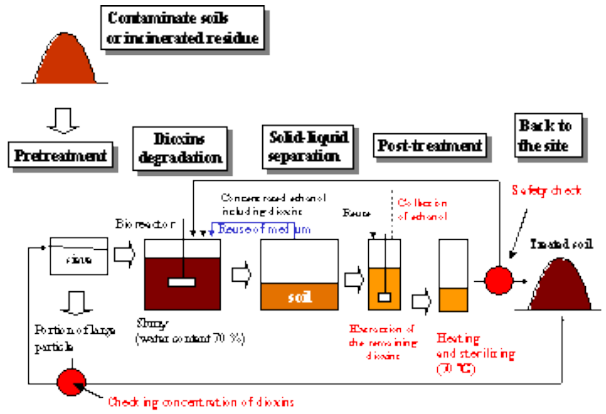

Figure 4 Solid-phase treatment system for dioxins-contaminated soil[5]

Acknowledgments

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