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# In-Pile Thermal Desorption for Treatment of Dioxin-Contaminated Soil in Japan

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**ABSTRACT:** A demonstration of thermal treatment of dioxin-contaminated soil was completed in Japan, under the sponsorship of the Japan Ministry of the Environment. TerraTherm's proprietary In-Pile Thermal Desorption process was demonstrated to successfully treat the soil to the required standard of 1,000 picograms of 2,3,7,8-tetrachlorodibenzodioxin (TCDD) toxic equivalents (TEQ) per gram (i.e., pg-TEQ/g), over a 28-day operation period, where the soil was heated to a minimum temperature of 325$^{o}$C and exposed to vacuum extraction. Off-gases were treated using thermal oxidation and activated carbon adsorption, meeting the Japanese air emission standards. A detailed environmental impact assessment was completed, with favorable outcome for the thermal process.

## INTRODUCTION

Dioxins are extremely toxic and recalcitrant compounds known to accumulate in soil and sediment and bioaccumulate in the food chain. These contaminants are important in most industrialized countries, including Japan (EMAI, 2007; MOE, 2008). Laboratory and field data from US projects have indicated that heating soil to 325$^{o}$C with a residence time of several days is sufficient for thorough dioxin destruction and removal (Baker and LaChance, 2003).

Dioxins are hydrophobic and adsorbed strongly to soils and sediments. Therefore, many sites contaminated with dioxins have relatively shallow impacts (less than 1 m deep). For such sites, the geometry does not favor In Situ Thermal Desorption (ISTD), due to the large surface area and heat losses. Instead, placement and treatment of the contaminated material in piles, also known as In-Pile Thermal Desorption (IPTD), can lead to favorable geometries and offers options to insulate the treatment cell. A successful demonstration of IPTD was completed by Baker et al. (2002). In addition, a large field-scale treatment of a wood-treating site where large amounts of dioxins had been released was completed successfully using ISTD (Yargeau and Bierschenk, 2007). The treated soil was demonstrated to meet the California standards for residential soils (1 μg/kg 2,3,7,8-TCDD TEQ = 1,000 pg-TEQ/g).

This paper presents a demonstration of IPTD conducted on dioxin-contaminated soil in Japan (Baker et al., 2009).

## TEST DESCRIPTION AND IPTD DESIGN

A demonstration-scale study of TerraTherm's IPTD technology was recently conducted at Yamaguchi Prefecture, Japan under the sponsorship of the Japan Ministry of the Environment (MOE). The IPTD technology, which is a variant of ISTD, was employed to apply heat to dioxin-contaminated soil to achieve a target temperature of 325°C, under vacuum extraction.

A steel cube with dimensions of 1.5 m in all three directions was used for the demonstration (Figure 1). Four heater borings placed just inside the corners provided heat. A central heated extraction well was used for vapor extraction. A vapor seal was placed at the top, and air inlet ports installed. The tank was instrumented with seven temperature monitoring strings, each with 4 thermocouples, and seven pressure monitoring screens (Figure 2). The extracted gas was treated through a flameless thermal oxidizer, cooled through a heat exchanger, passed through a series of granular activated carbon (GAC) beds and then released into the atmosphere through a stack. A series of detailed sampling and analysis was used to track the system's performance.

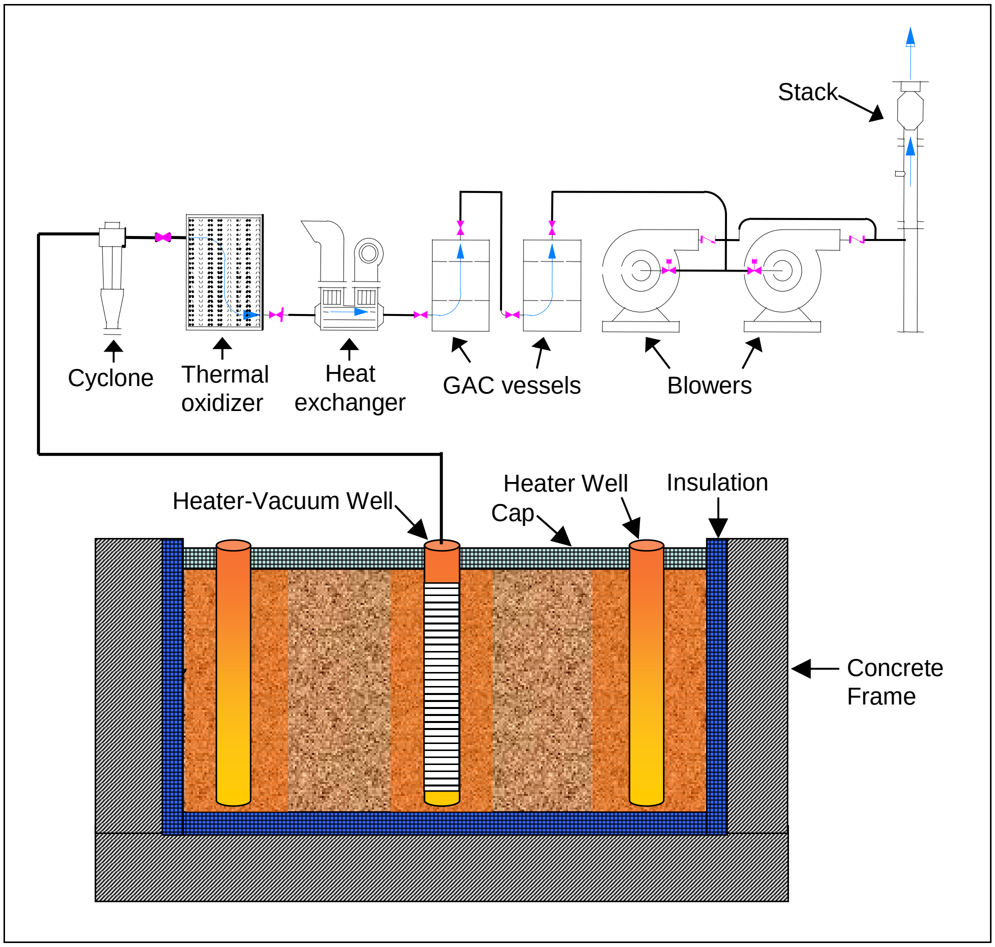


**FIGURE 1. IPTD testing setup and principle.**

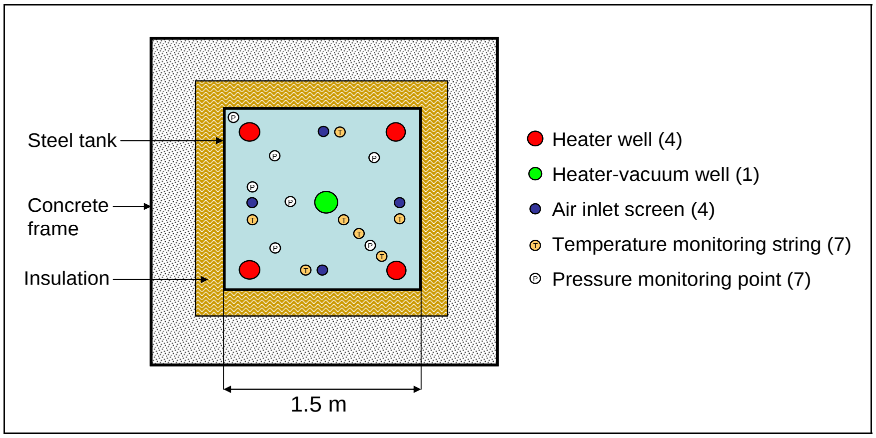


**FIGURE 2. IPTD cell plan view.**

The demonstration involved treatment of 4 metric tonnes of soil contaminated with 1,800 pg-TEQ/g of dioxins. This soil mass was subjected to vapor extraction for a 28-day operation period, during which time it was heated for 22 days (day 1 through 23). Dioxins were desorbed during heating and mostly decomposed in the soil. A detailed mass and energy balance was kept, documenting the performance. Dioxin analyses followed JISK (2008) protocols.

## RESULTS

Figure 3 shows the temperature increases caused by the heating, along with the concentration of dioxins in the extracted vapors. Note that the coolest locations in the soil tank reached the designed minimum treatment temperature of 325°C after 18 days of heating, followed by 6 days of treatment at this temperature. The dioxin emission peaked around day 7-10, when the soil was being heated quickly and exhibited temperatures between 60 and 450°C. Before the heat was turned off on day 23, the concentration of dioxins in the off-gas was extremely low for several days, indicating that the majority of the contaminants had been removed in the early stage.

Concentrations of 2,3,7,8-TCDD toxic equivalents in the vapor phase are reported in units of nanograms of TEQ per normal cubic meter (ng TEQ/Nm$^3$).

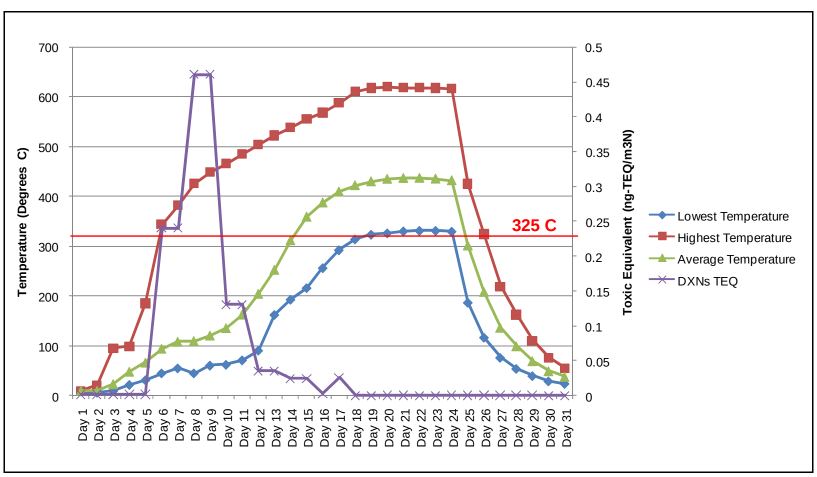


**FIGURE 3. Temperatures in the cell and 2,3,7,8-dioxin TEQ concentration in vapor.**

Table 1 shows the characteristics of the soils before and after IPTD treatment. Note that the soil was desiccated by the treatment, and some loss of soil mass was detected. This loss was likely due to oxidation of soil organic matter.

After IPTD treatment, the soil contained dioxins at a concentration of 23 to 140 pg-TEQ/g or an average concentration of 68 pg-TEQ/g, which is below 1,000 pg-TEQ/g, the environmental standard for soil in Japan. A detailed mass balance for dioxins showed that the majority of the dioxins were destroyed in the soil, supposedly by oxidation reactions.

**TABLE 1. Soil weight, moisture content and dioxin concentrations before and after IPTD treatment.**

| | Wet weight (kg) | Moisture content (%) | Dry weight (kg) | Total dioxins (pg/g) | Toxic equivalent (pg-TEQ/g) | Remedial standard (pg-TEQ/g) |
|---|---|---|---|---|---|---|
| Before IPTD | 4,014 | 29.1 | 3,109 | 77,000 | 1,800 | 1,000 |
| After IPTD | 2,886 | 0.4 | 2,874 | 2,430 | 68 | |

The exhaust gas from the stack showed a concentration of 0.0000012 ng-TEQ/$m^3$N to 0.000083 ng-TEQ/$m^3$N - below the Japanese emission standard for dioxins in the exhaust gas (0.1 ng-TEQ/$m^3$N) and lower than the Japanese environmental standard for dioxins in ambient air of 0.0006 ng-TEQ/$m^3$N. The dioxins concentrations in the gas phase measured at various locations in the treatment train are shown in Figure 4.

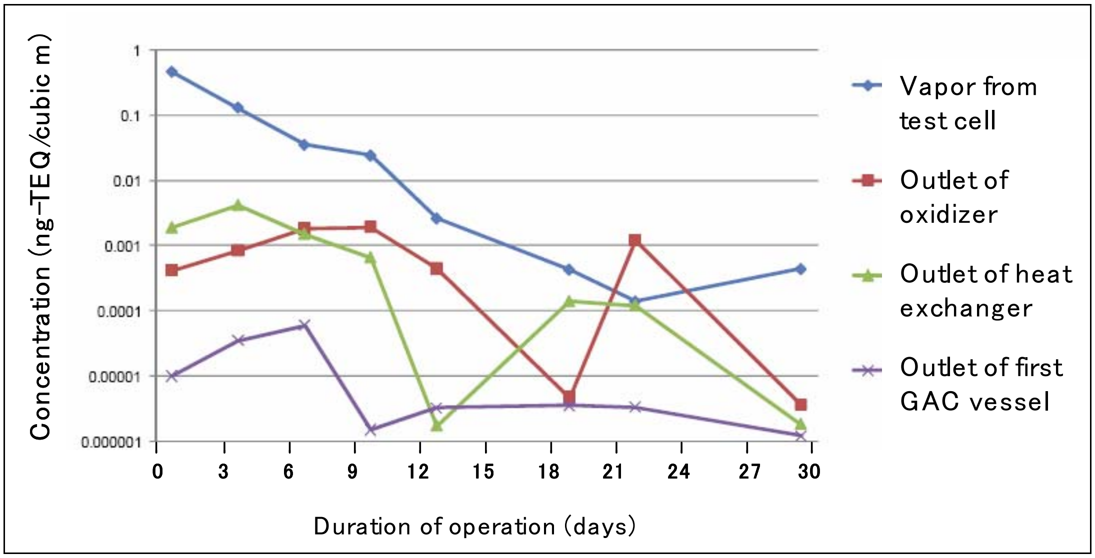


**FIGURE 4. Vapor phase concentration of 2,3,7,8-dioxin TEQ at various locations in the treatment system.**

The potential for *de-novo* synthesis of dioxins was investigated through an intensive sampling effort. No significant evidence of dioxin formation was found.

## CONCLUSIONS

The IPTD technology was demonstrated as being capable of reaching the Japanese treatment standard for dioxins, while producing a lower environmental burden compared with other existing methods for treating soil and sediment contaminated with dioxins. As a result of the test, the IPTD technology was accepted by the Japanese MOE for use in treating dioxin-contaminated soil and sediment in Japan, and the results posted to their Japanese language website, http://www.env.go.jp/press/file_view.php?serial=4684&hou_id=11882, thus clearing the way for wider use of the IPTD technology in Japan. In addition, these results were consistent with those observed for dioxins at prior ISTD projects in the U.S., in Alhambra, CA (Yargeau and Bierschenk, 2007), Cape Girardeau, MO (USEPA, 1998) and Ferndale, CA (Conley and Lonie, 2000).

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