INFORMATION BULLETIN

THERMAL TREATMENT TECHNOLOGIES

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PURPOSE OF THIS INFORMATION BULLETIN

This document supplements information provided in the Industrial Waste Resource Guideline 622, *Soil remediation technologies in Victoria*. It has been developed to give an overview of thermal treatment technologies (TTTs) currently or soon to be available in Victoria, how they work, where the technology has come from and why they are used.

WHAT ARE TTTs?

TTTs are soil remediation technologies that physically – through the use of heat – remove organic contaminants from soil and other solid matrices. The contaminants are then captured and treated, or destroyed. Any air emissions discharged to the environment (off-gas) must comply with policy and regulations. Remediated soil is then tested to verify whether it is clean fill, or whether the hazard has been reduced for the purposes of reuse or disposal.

HOW DO TTTs WORK?

Thermal treatment is a two-step process (see Figure 1).

The initial step separates contaminated feed material into soil and contaminants This is accomplished by heating the contaminated soil beyond the boiling point of the hazardous compounds. The soil is thus cleaned (becoming treated material) and the contaminants – now in gaseous form – are moved to a treatment system using vacuum.

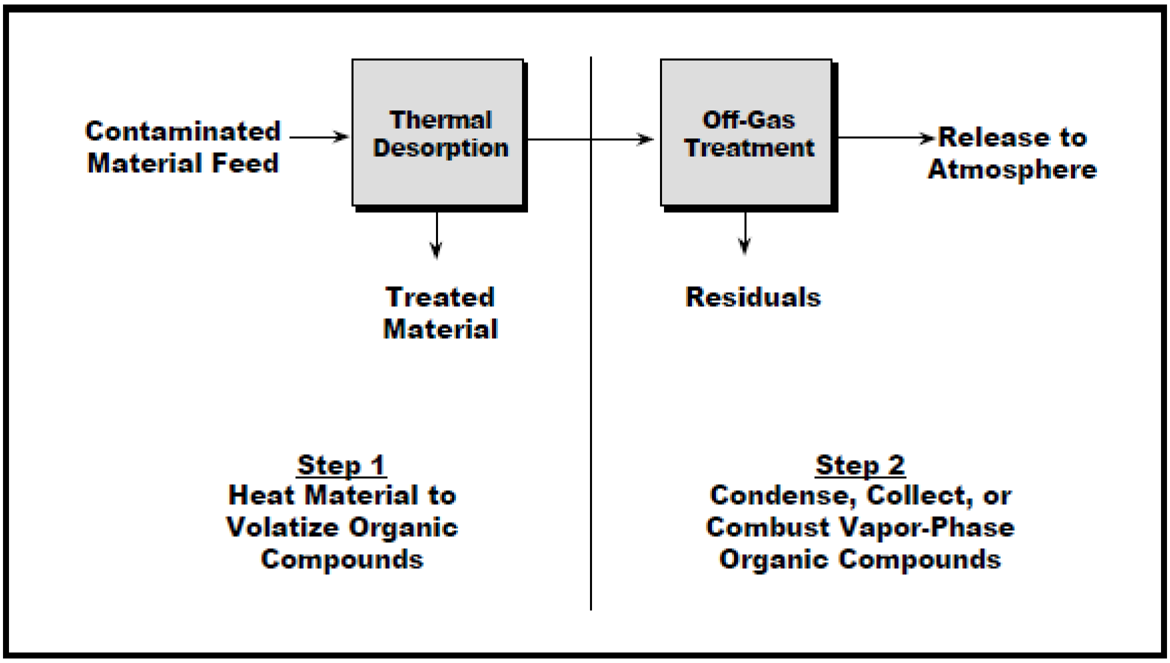

Figure 1: Generic thermal desorption process

(figure reproduced with permission: United States of America. Department of the Navy. Contract Report CR 98.008-ENV *Overview of Thermal Desorption Technology*. Port Hueneme, CA: 1998).

The second step involves the treatment of the recovered contaminants (off-gas treatment). Depending on the TTT used, they will either be condensed for reuse or safe disposal, or destroyed using combustion. Any off-gases that are produced in this process will be scrubbed (harmful substances are removed) prior to release into the atmosphere. Residuals, such as baghouse dust and scrubber sludge, are analysed and disposed of appropriately.

Figure 2 on page 4 details the process of site characterisation to soil remediation and contaminant destruction for offsite TTT.

TYPES OF TECHNOLOGIES

TTTs may be categorised in many different ways, depending on which aspect one wishes to focus on. These can include location of deployment, mode and type of operation, energy used, heating system, desorption temperature and feed system.

This information bulletin will provide an overview of four subcategories, which demonstrate the versatility of TTT.

1. direct and indirect fired thermal desorption
2. enhanced thermal conduction
3. in situ thermal remediation
4. indirect heated thermal desorption.

Technologies 1 to 3 are currently available in Victoria. Indirect heated thermal desorption is not yet offered in Victoria.

Common features of technologies 1, 2 and 4 include feed soils that are generally pre-treated to facilitate the most efficient, effective and uniform heating and remediation of the soil. Common pre-treatments include: crushing; blending with a soil of different texture, contaminant loading or moisture content; addition of lime; drying; and screening.

Soil pre-treatment is not necessary for in situ thermal remediation.

1 Direct and indirect fired thermal desorption

Most direct or indirect fired thermal desorption units use a rotary kiln where the heat source – an open flame or combustion gas generated by a flame, respectively – is located inside the kiln. Soil is fed through the unit continuously. Once the temperature exceeds the boiling point of the contaminants in the soil they are separated ('desorbed') from the soil matrix through volatilisation.

This type of TTT can be set up as permanent facility or as mobile unit at a contaminated site.

The capacity of these continuous-feed systems depends on the size of the kiln. The units currently available in Victoria have approximate capacities ranging from 10,000 to 100,000 tonnes per annum.

2 Enhanced thermal conduction

This method is often referred to as the 'Quonset hut' process because it involves the sealing of a soil mound with a structure of that name. Enhanced thermal conduction is an indirect thermal treatment technology where hot air is piped through the soil via heating rods, which are placed at regular intervals throughout the soil mound. Treatment temperatures and times are adjusted to suit the contaminant/s of concern.

A Quonset hut system is usually set up on site.

This is a batch type system. Batch sizes average 600 to 700 tonnes and treatment times range between one and two weeks.

3 In situ thermal remediation

As the name implies, in situ thermal remediation is deployed on site. It is unlike any of the other systems mentioned, as it requires no excavation of soil, which is left in place.

Vertical or horizontal rods are driven into the contaminated soil at predetermined intervals (usually based on modelling data) to ensure consistent heating of the soil matrix. Types of heating differ with technology, which can include hot air injection, steam injection, electromagnetic heating, electrical resistance heating, vitrification and electrothermal dynamic stripping. Volatilised contaminants are extracted from the soil using methods such as soil vapour extraction or multiphase extraction.

The system stays in place until cleanup targets have been achieved – usually several months. This technology is capable of cleaning up soil beneath buildings and other infrastructure, with minimal impact on operational activities.

4 Indirect heated thermal desorption

Indirect heated thermal desorption usually uses a rotary kiln but, in contrast to direct and indirect fired thermal desorption, the heat source is external to the desorption chamber and the kiln is completely sealed (airtight). The risk of combustion is eliminated, as there is no direct contact between the soil and the heat source, and the atmosphere within the rotary kiln is oxygen-free. This allows the treatment of soils with particularly high levels of contamination. Soil is delivered to the unit using continuous-feed systems.

Like direct and indirect fired thermal desorption units, indirect heated thermal desorption units may also be set up as permanent, offsite facilities or as mobile units.

There is currently no indirect heated thermal desorption unit operating in Victoria. However, one such unit has recently received a works approval and is predicted to have a capacity of around 70,000 tonnes per year.

WHY USE TTTs?

TTTs can deal with contaminant types and loadings that many other remediation technologies cannot. Current best-practice facilities can deal with all types of organic contaminants, including persistent organic contaminants such as polychlorinated biphenyls, organochlorines and pesticides.

Another reason for using thermal technologies is that they are fast in comparison with other remediation methods (see *Soil remediation technologies in Victoria*, EPA publication IWRG622, for an overview of alternatives). Treatment time ranges from minutes for desorption units to weeks or months for batch or in situ technologies, respectively.

WHERE TO USE TTT?

TTTs come in a range of designs, capabilities and capacities. Some thermal units are highly mobile and have a small footprint and, thus, can be moved quickly and set up in very small spaces. Other systems can be installed under existing infrastructure such as buildings or roads, allowing remediation without demolition of structures or significant impact on the day-to-day operations at a site.

Where net export of soil is required (for example, in tunnels or basements) or where development pressures require the removal of soil off site, permanent offsite facilities allow these soils to be removed for treatment. Such facilities provide an alternative to the disposal of the contaminated soil to landfill, and the associated legacy issues.

ARE TTTs SAFE?

TTTs are mature, proven technologies that have been safely deployed in North America and in Europe since the 1980s. All TTTs introduced to Victoria in recent years have their genesis in the US, Canada or Europe and have been modified to meet local standards and regulations. Several sites in Victoria have been remediated using TTT in recent years.

WHAT APPROVALS ARE NEEDED?

The *Environment Protection (Scheduled Premises and Exemptions) Regulations 2007* list activities that require a licence to operate. That is, the operators require permission from EPA (along with other statutory approvals, such as a planning permit from council) to conduct their activities.

Permanent TTT facilities that receive contaminated soils will require an EPA approval to set up the facility and an EPA licence to start operating. They are categorised as A01 'Prescribed Industrial Waste Management', because they receive contaminated soils, which are a prescribed industrial waste.

EPA undertakes an approval process known as a works approval to assess whether the facility will meet regulatory environmental standards set out in policies and Regulations. As Victoria does not have many of these facilities EPA has also assessed such facilities against European environmental standards.

An in situ plant may be exempt from works approvals and licences under the Regulations if it is a temporary plant for onsite treatment, with a cumulative operating time of 12 months within any three-year period, as long as it meets regulatory environmental standards.

These statutory tools allow EPA to monitor whether sites comply with environmental requirements. All TTT activities must comply with the relevant legislation.

REFERENCE

United States of America. Department of the Navy. Contract Report CR 98.008-ENV *Overview of Thermal Desorption Technology*. Port Hueneme, CA: 1998..

Figure 2: Soil remediation process flow chart – off site TTT

Process description	Process steps	Legislation regulating processes
Soil sampled to determine contaminant type and concentration. If suitable for TTT, excavate soil and transport in EPA permitted vehicle to receiving facility.	Site characterisation, excavation and transport	IWRG[1] *Sampling and analysis of waters, wastewaters, soils and wastes* (EPA publication IWRG701) IWRG *Soil sampling* guidance (IWRG702) IWRG *Permit to transport prescribed industrial waste* (IWRG811) IWRG *Waste transport certificates* (IWRG821) SEPP[2] (Prevention and Management of Contaminated Land) SEPP (Groundwaters of Victoria)
Prior to unloading of soil, check and record waste transport certificates and permits. In a fully enclosed building with air purification system, conduct the following: Unload soil; Store soil according to hazard category / odour; and, Pre-treat soil (screening, crushing, blending etc); Sample feed soil to ensure contaminant concentrations are appropriate for the treatment process.	Soil acceptance, storage and pre-treatment at the treatment facility	Licence conditions [*Environment Protection (Scheduled Premises) Regulations 2007*][3] Financial assurance set as per *Guidelines for determining financial assurances – Schedule 4 premises* (EPA publication 456) Soils contaminated with polychlorinated biphenyls (PCBs) can only be accepted if premises have an approved PCB environment improvement plan.
Feed soil into rotary dryer (desorption unit). Heat soil to approx. 450 °C to 550 °C to separate contaminants from soil. Draw desorbed contaminants into conversion chamber for destruction. Cool and rehydrate soil.	Soil treatment	Licence conditions [*Environment Protection (Scheduled Premises) Regulations 2007*]
Sample soil to check if Fill Material Standard achieved. Return soil with residual contamination immediately to soil treatment area. Store soil that is validated to be clean inside an enclosed building; or in storage bays (bunded hardstand) under tarpaulin and in moist condition. Repatriate clean soil to site of origin or reuse elsewhere. At all times, monitor dust in real time. If increased then remoisten or cover soil.	Management of clean soil and soil to be validated	Licence conditions [*Environment Protection (Scheduled Premises) Regulations 2007*]
Destroy desorbed contaminants in conversion chamber by exposing to temperatures of between 900 °C and 1100 °C for minimum of 2 seconds. Quench gas stream exiting chamber to prevent reformation of dioxins and furans (an additional polishing step may be required). Filter particulates in the off-gas stream in a bag house. Remove acids in gas stream with acid scrubber. Continuously monitor emissions from stack. Ensure risks are minimised through operation of automatic alarms and process interlocks.	Destruction of contaminants from desorption process and control of emissions to air	Licence conditions [*Environment Protection (Scheduled Premises) Regulations 2007*]

1 IWRG = Industrial Waste Resource Guidelines.
2 SEPP = State environment protection policy.
3 The *Environment Protection (Scheduled Premises) Regulations 2007* aim to control the operation of premises in order to ensure there is no adverse effect on the environment. Prior receiving a licence an operator must obtain a works approval, which permits an occupier to construct works at the premises subject to the specific conditions detailed in the works approval.
The occupier must meet environmental quality requirements for all segments of the environment. This includes meeting the general provisions of the *Environment Protection Act 1970*, State environment protection policies and industrial waste management policies. In particular:

- *Environment Protection (Industrial Waste Resource) Regulations 2009*
- *State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade)* No N-1 1989
- *State Environment Protection Policy (Waters of Victoria)* 2003
- *State Environment Protection Policy (Groundwaters of Victoria)* 1997
- *State Environment Protection Policy (Prevention and Management of Contamination of Land)* 2002
- *State Environment Protection Policy (Air Quality Management)* 2001.

The *Licence Management Guidelines* (EPA publication 1322) assist licence-holders to understand and manage their licence.

GLOSSARY

Full name	Abbreviation	Description
Carcinogenic		Any substance capable of causing cancer is considered carcinogenic.
Desorption		The separation of one substance from the surface of another.
Dioxin		Dioxins are a group of pollutants that are formed during combustion processes in industrial processes such as paper pulp bleaching and herbicide manufacturing, as well as during waste incineration and forest fires. Dioxins are known to accumulate in humans and wildlife, and are teratogenic, mutagenic and carcinogenic.
Endocrine disruptor		Endocrine disruptors are substances that may interfere with the body's endocrine system. They affect humans and animals alike. Consequences of endocrine disruptions include birth defects, cancers and developmental disorders.
Furan		Furan is a colourless and flammable liquid. It is toxic and a possible human carcinogen. Furans can also be used to denote a family of related chemicals with similar properties to the specific chemical furan. Furans are used in industry to dissolve substances and can be produced from natural substances – such as pine, oats and corn – with strong acids.
Heavy metals	e.g. As, Zn, Pb, Cd, Hg, Ni, Cr	The term 'Heavy metal' is used here to encompass metallic elements and metalloids, such as lead (Pb), zinc (Zn), arsenic (As), cadmium (Cd), mercury (Hg), chromium (Cr), copper (Cu), molybdenum (Mo), antimony (Sb) and nickel (Ni). Some heavy metals are naturally present in the environment at trace concentrations or in a particular valency, at which they may be an essential nutrient to people and other life forms. Other heavy metals (including cadmium, arsenic, lead and mercury) are toxic in any concentration or valency.
In situ		Latin for 'in position'. In the context of soil remediation it means 'on site, in the ground'.
Mutagenic		A substance is mutagenic if it is capable of causing genetic mutation.
Organochlorine compounds	OCCs	Organochlorine compounds (which also include dioxin and furans) are predominantly human-made compounds that are very stable in the environment and are rapidly absorbed by organisms. Organochlorine compounds are known endocrine disruptors and it is considered highly likely that many of these compounds are carcinogenic (e.g. 'Agent Orange').
Polychlorinated biphenyls	PCBs	Polychlorinated biphenyls are part of a group of toxic persistent organic pollutants. PCBs are odourless and tasteless liquids. Up until the late 1970s PCBs were widely used in the production of transformers, capacitors, flame retardants and sealants. In 1975, Australia banned the importation of PCBs. The International Agency for Research on Cancer considers it highly likely that these compounds are carcinogenic. PCBs are confirmed endocrine disruptors and have been linked with the occurrence of diabetes.
Prescribed industrial waste	PIW	In Victoria hazardous waste is referred to as prescribed industrial waste. For the precise definition please view the *Environment Protection (Industrial Waste Resource) Regulations 2009*.
Teratogenic		A substance is teratogenic if it is capable of disturbing the development and growth of a fetus or an embryo. This may result in birth defects or termination of a pregnancy.
Vitrification		Vitrification refers to the process in which contaminated soil is electrically heated until it effectively melts the soil. Organic contaminants are volatilised during this process and the off-gas is treated, or disposed of appropriately. Upon cooling, the molten matrix turns into glass, thus encasing inorganic contaminants.