

EPA Guidelines

Soil bioremediation

November 2005

EPA 589/05: This guideline has been prepared to assist environmental consultants and their clients with ex situ soil bioremediation in South Australia.

1. Introduction

Bioremediation, when properly managed, is an environmentally sound and cost-effective method of treating soils containing organic chemicals. Bioremediation may then enable appropriate reuse of the treated soil and minimise disposal of waste soil to landfill, whilst providing for adequate protection of human health and the environment.

The Environment Protection Authority (EPA) supports and encourages the controlled use of bioremediation to assist in the remediation of site contamination in South Australia.

This document aims to assist those undertaking bioremediation in South Australia to comply with their general environmental duty (s25 of the *Environment Protection Act 1993* (the Act)). It does not provide direction on the methods of bioremediation, rather it outlines appropriate management measures that can minimise environmental impacts arising from the process.

There are two types of bioremediation – *ex situ* (remove and treat), and *in situ* (treat in place) – and can be performed on soil or underground water. This guideline applies only to the *ex situ* treatment of soils.

Suitability for bioremediation

Bioremediation is not a new concept and is being increasingly used as a relatively economical environmental remediation technology. The *ex situ* bioremediation treatment of soil is generally undertaken in contained and managed biopiles or, subject to limitations, by landfarming.

For the purpose of this guideline, bioremediation is defined as an accelerated process using micro-organisms (indigenous or introduced) and other manipulations to degrade and detoxify organic substances to harmless compounds, such as carbon dioxide and water, in a confined and controlled environment.

Bioremediation is suitable for the treatment of a variety of organic chemicals, including:

- volatile organic compounds
- benzene, toluene, ethyl benzene, xylene (BTEX) compounds
- phenolic compounds

- polycyclic aromatic hydrocarbons (PAHs) (particularly the simpler aromatic compounds)
- petroleum hydrocarbons
- nitroaromatic compounds.

Bioremediation is generally **not** a suitable treatment option for soils containing:

- metals
- complex (high molecular weight) PAHs
- chlorinated hydrocarbons.

There are generally three stages to a soil bioremediation project:

- a laboratory-based study to determine the biodegradability of chemical substances and the ability of the indigenous or introduced micro-organisms to degrade them; generally performed off site
- a pilot trial, either on site or in the laboratory or a combination of both, to provide further data necessary for the design of the full-scale treatment
- full-scale bioremediation, conducted on site or at an approved EPA-licensed facility.

The first two stages may not be necessary for some small-scale bioremediation processes. However, for large-scale projects, the completion of stages one and two may result in considerable cost and time savings.

When considering bioremediation, the use of suitable on-site structures (such as sheds) should be examined. These structures may assist in mitigating environmental problems that may be associated with bioremediation.

2. Use of bioremediation

The EPA endorses the use of controlled bioremediation, particularly when the treated soil is suitable for reuse (e.g. on-site backfill), thereby reducing disposal of waste soil to landfill.

Consideration should be given to the NEPM¹ hierarchy for site remediation or management, outlined below from the most preferred to the least preferred:

- 1) on-site treatment of the chemical substances to reduce risk to an acceptable level
- 2) off-site treatment of excavated soil to reduce risk to an acceptable level, after which the treated soil is returned to the site
- 3) containment of soil on site with a properly designed barrier
- 4) disposal of affected soil to an approved landfill.

Before starting a bioremediation project, the nature and extent of the chemical substances in the soil should be assessed, taking into account the NEPM; then the need for remediation can be considered along with the treatment options available. An appropriate bioremediation strategy can then be developed and implemented.

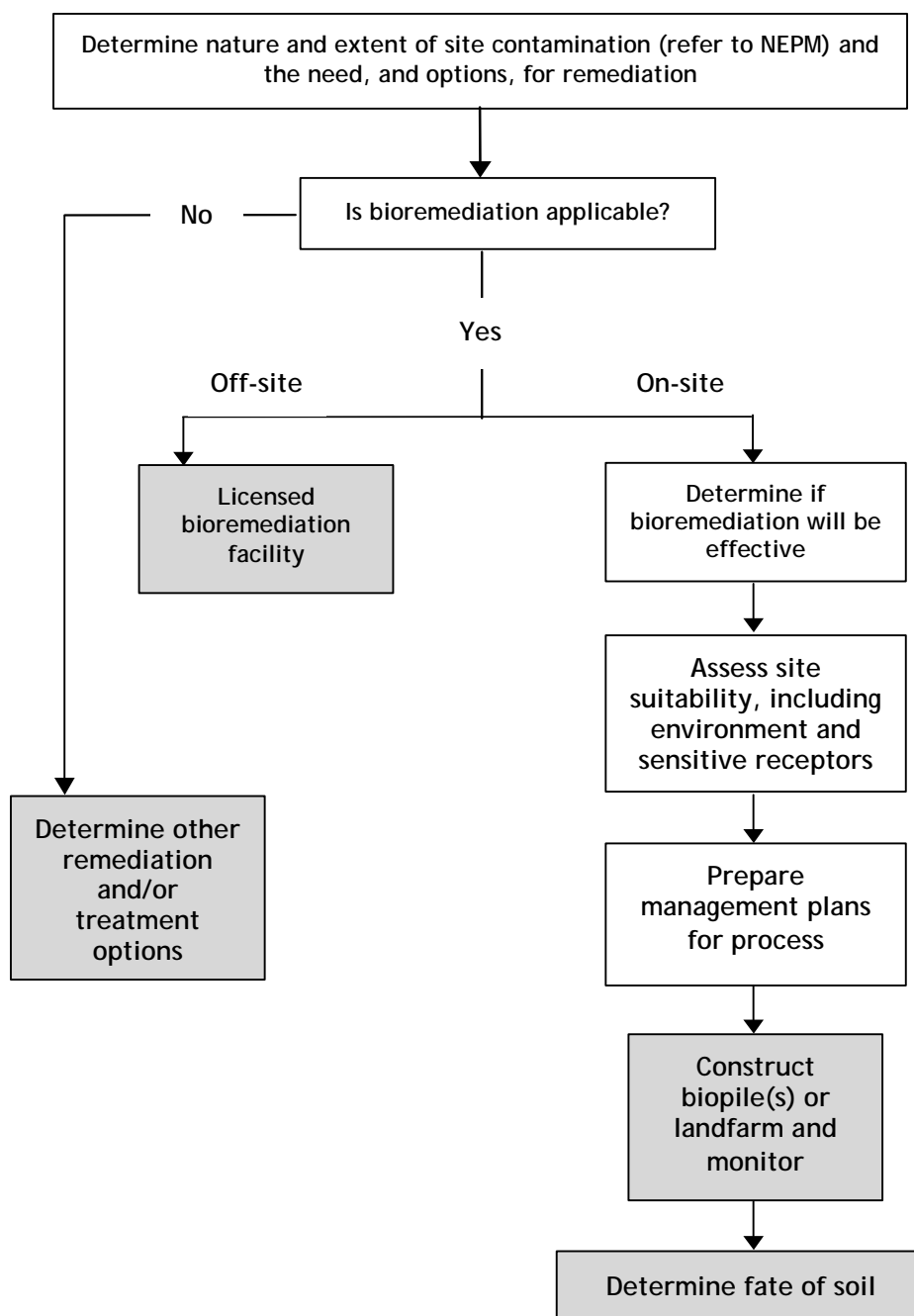
It is important to recognise that chemical-affected soils may contain substances that are not suitable for bioremediation. This should be considered when determining the feasibility of bioremediation, the need for alternative remediation treatments, and the reuse or disposal of treated soil.

The management of bioremediation will depend on the nature and concentration of chemical substances, as well as the proximity of the bioremediation process to sensitive environments and

¹ National Environment Protection (Assessment of Site Contamination) Measure 1999

human activities. The EPA considers that any proposal for bioremediation should demonstrate adequate safeguards for the protection of human health and the environment. Considerations include the control, minimisation and monitoring of emissions or discharges from the bioremediation process.

A flowchart outlining the strategy involved in bioremediation activities is provided in the figure below.



Strategy for bioremediation activities

3. Landfarming

Landfarming is a form of bioremediation. It is an above-ground process that involves placing affected soil on a prepared surface and aerating it by regular turning. Soil amendments (for example, fertilisers) are sometimes added. The movement of oxygen through the soil pile promotes aerobic degradation of organic chemicals. Landfarming is a passive form of bioremediation and generally requires an extended timeframe.

As landfarming will probably release emissions directly to the atmosphere, it should not be used where it may have an adverse effect on sensitive receptors, and particularly in built-up or residential areas. As a remediation option, landfarming is ineffective in treating substances such as metals and complex PAHs, but may be useful for some volatile organic chemicals.

The EPA considers that landfarming may be an acceptable form of bioremediation only:

- on large isolated sites that are remote from potentially susceptible receptors

or

- within approved EPA-licensed facilities where conditions are included in the EPA authorisation.

Care should be taken to ensure that additional pollutants are not introduced during the landfarming process. All bioremediation projects must comply with all legislative requirements. The following sections of this guideline should assist with meeting these obligations.

4. Feasibility assessment (laboratory and pilot trials)

A preliminary feasibility assessment should be made on a site-and-soil-specific basis to establish the likelihood of success, practicability and effectiveness of the proposed bioremediation scheme. These assessments will determine the presence of indigenous micro-organisms, whether there is a need to introduce degrading species (because there are insufficient indigenous organisms), and the timeframe required.

Feasibility assessments should be conducted in the laboratory and/or in the field. Laboratory assessments provide an indication of the ability of indigenous soil organisms to degrade the chemical substance(s) of concern under controlled conditions. Field trials are useful for optimising process parameters, including the method and concentration of nutrient application, the effectiveness of maintaining soil moisture content, airflow rates, and leachate generation.

Feasibility assessments are made to determine:

- biodegradability of key chemical(s)
- biological activity indicated by the rate of oxygen consumption or carbon dioxide generation
- degradation rates of chemical substance(s)
- the need for microbial degrading species and their effects on degradation rates.

5. Management plans

Two management plans should be prepared for bioremediation processes – a bioremediation management plan (BMP), which outlines the management and control of the bioremediation process itself; and an environmental management plan (EMP), which addresses all known and potential environmental management problems. They can be prepared separately or together as a remediation management plan. If prepared as a single document, the same level of detail is required, but this may reduce duplication.

Bioremediation management plan

A BMP should be prepared for all bioremediation activities. If an audit is being undertaken on the site from where the soil originated, then the Environmental Auditor (Contaminated Land) should review the BMP and EMP documents.

As a minimum, the bioremediation management plan should include the following information:

- volume of soil to be treated and the concentrations of all relevant chemical substances, as well as their source and characteristics
- remediation target concentrations and predicted time for achieving these targets
- the planned uses or destination of treated material, and options for material not successfully treated and/or containing other chemical substances
- suitability of site for the bioremediation program
- proposed construction of facility
- proposed management details – including reporting and corrective action
- details of treatment process, e.g. mixing, stockpiling area, bulking agents or other additives – sources, nature and mixing processes
- details of stormwater collection and leachate treatment systems
- details of water and nutrient recycling to maintain soil moisture (as far as practicable) or, if not recycled, the details of treatment and disposal
- details of mains water connections to ensure the protection of the supply, using reduced pressure zone (RPZ) valves or similar
- methods of extraction and treatment of volatile compounds before release to the atmosphere, and how their emission will comply with EPA policy and guidelines
- details of proposed soil sampling program and analytical procedures – sample numbers, parameters, frequency
- details of the bioremediation performance monitoring program.

Environmental management plan

An EMP should be prepared for all bioremediation processes. Specific EMP items to be considered for the effective management of environmental issues associated with bioremediation include:

- environmental monitoring of the bioremediation process – e.g. air quality monitoring within the site and at site boundaries – to ensure no on- or off-site adverse impacts, including proposed methods for recording, assessing and dealing with problems and complaints
- information on subsurface soil conditions, in particular permeability and the potential to retard chemical substances resulting from site activities
- information on the suitability of materials to be used to construct the low permeability liner for the base and stormwater ponds, if applicable (see **Appendix**)
- details of stockpile management – including planned containment, management and monitoring measures to prevent migration of odour, vapour, dust and leachate from the stockpiled soils to underlying soil and groundwater
- hydrogeological information, including depth to groundwater, water quality, flow direction, existing groundwater users (including locations relative to site) and consideration of the need for a groundwater monitoring program

- confirmation, through assessment of likely noise levels associated with the proposed plant, that the process will comply with EPA *Environment Protection (Machine Noise) Policy 1994* (e.g. extraction blowers, additional vehicle movements)
- details of how volatile gases will be processed – including modelling if necessary to address volatile organic vapours in the soil and dust generated during mixing, transfer and loading – to ensure compliance with EPA policies and guidelines
- measures taken to prevent or limit emissions of dust and odour during the delivery of waste material for bioremediation, and during stockpile movement and management
- detailed site plans showing location of infrastructure, separation distances, adjacent land uses, sensitive receptors, human receptors, and locations of surface water bodies.

All bioremediation activities must comply with the relevant legislation and should take into account the documents listed in **Section 9 – References and further reading**.

6. Validation (post-remediation)

The time frame for bioremediation is often case-specific. Treatment is complete only when targets have been achieved, or it can be demonstrated that the chemicals of concern do not pose a risk to human health or the environment.

In determining the end-use suitability of soil, the EPA recommends that:

- bioremediated soils are sampled and tested to determine their suitability for reuse or landfill
- if the treated materials are only suitable for disposal to landfill, the classification of the materials for disposal is to be made by an environmental consultant (refer to the landfill licence conditions, if needed)
- the suitability of bioremediated soils for use as a resource is assessed and the results are compared with suitable criteria
- the concentrations of chemical substance should be less than, or equal to, the target criteria. Criteria should demonstrate that the residual concentration of a chemical substance will not pose a risk to human health and/or the environment, including leaching to groundwater.
- the number of samples collected and analysed for the validation of bioremediated and stockpiled soil should be adequate to provide a statistically reliable result, taking into account the intended use of the soil
- sampling procedures take into account Schedule B(3) of the *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPM) and Australian Standard AS4482 *Guide to sampling and investigation of potentially contaminated soil*.
- leachate validation testing is undertaken in accordance with Australian Standard AS 4439.3 – 1997 for *Wastes, sediments and contaminated soils*. Other testing may be required depending on the soil and chemical characteristics.

7. Reporting

The EPA recommends that, on completion of the bioremediation program, a report be issued which documents all of the activities undertaken, particularly:

- the final concentrations of chemical substances in the soil following bioremediation
- the fate of the treated soil and the details of how it was, or is to be, managed to ensure the adequate protection of human health and the environment
- if material was disposed of to an EPA-licensed facility, the classification of the materials for disposal and evidence of disposal.

In the case of a site that is being audited, this report should be given to the Environmental Auditor (Contaminated Land) for inclusion in the Site Audit Report. A Site Audit Report is recorded and retained by the EPA and is available under Section 7 of the *Land and Business (Sale and Conveyancing) Act 1994*. Owners of properties where environmental assessments and bioremediation activities have been undertaken must notify prospective purchasers of this by answering 'yes' to question 1(2) in accordance with the subordinate Regulations.

The completion of progress reports should also be considered by the owner or consultant, particularly if long-term bioremediation is undertaken.

8. Approved commercial bioremediation facilities

The establishment of a commercial bioremediation facility requires development approval in accordance with the *Development Act 1993*. There is currently one EPA-licensed facility for bioremediation in South Australia, located at the Southern Waste Depot (SWD), McLaren Vale.

9. References and further reading

Environment Protection Authority (SA), *Environment Protection (Machine Noise) Policy 1994*, EPA, Adelaide.

— — 2003, *Environment Protection (Water Quality) Policy 2003 and Explanatory Report*, EPA, Adelaide

— — 2003, EPA Guideline (EPA 386/03) *Air Quality Impact Assessment Using Design Ground Level Pollutant Concentrations (DGLCs)*, EPA, Adelaide.

— — 2003, EPA Guideline (EPA 373/03) *Odour Assessment Using Odour Source Modelling*, EPA, Adelaide.

— — 2004, EPA Guideline (EPA 080/04) *Bunding and Spill Management*, EPA, Adelaide.

National Environment Protection Council, *National Environment Protection (Assessment of Site Contamination) Measure 1999*.

Appendix: Construction of impermeable base layers

The two options below using concrete or asphalt are preferred to that using non-synthetic compacted clay liners, based on durability and performance. Design and construction should be based on site-specific factors, taking into account the nature of the chemical substances and the site conditions (e.g. soil and hydrogeology)

Materials and methods

Approved materials/methods for constructing bioremediation pad liners:

Concrete

- fine-pour concrete top layer* – thickness to be based on quality requirements (wear, vehicle movements, etc.)
- 300 mm reinforced subgrade.

Asphalt[#]

40 mm asphalt (0/11 grade)

100 mm asphalt (0/32 grade)

300 mm reinforced subgrade

Clay/HDPE liner

Base layers constructed using a low-permeability clay liner must have a minimum hydraulic conductivity of $1 \times 10^{-9} \text{ ms}^{-1}$. If using permeable soils, the use of a concrete or synthetic liner (HDPE membrane) is required. Reliance on soils with naturally high clay or compacted clay without professionally installed barriers is not acceptable.

Construction

All areas that are to be used for the storage or bioremediation of waste should:

- be surrounded by a bund constructed to ensure containment of stormwater and leachate and prevent infiltration of external stormwater; refer to EPA bunding guidelines
- be constructed using approved materials (see above) so that all leachate is either confined to the lined area or directed to a leachate evaporation/storage basin constructed in accordance with EPA guidelines
- be constructed with a minimum gradient of 2% so that the final floor level has a gradient sufficient to enable surface water and leachate to drain to suitably lined sumps
- contain lined sump(s) which collect the leachate from the pad surface
- be constructed with drainage facilities from the sump to an external leachate evaporation/storage basin.

Bioremediation process

Bioremediation processes should be undertaken in accordance with the following requirements.

* appropriate grade and thickness of concrete to be confirmed to ensure suitability for vehicle movements. The concrete grade should be of sufficient quality to prevent ponding and/or erosion.

appropriate Australian grade of asphalt to be confirmed to ensure suitability for vehicle movements. The asphalt grade should be of sufficient quality to prevent ponding and/or erosion.

- All waste subjected to bioremediation processes must be covered to prevent or limit emissions of vapours or particle matter, and to prevent the escape of leachate or other substances.
- Measures must be taken to prevent or limit emissions of dust and odour during the delivery of waste material for bioremediation and during any rotation or movement of stockpiles.
- Waste materials for bioremediation are not to be combined with other waste or mixed with virgin materials or any other waste, unless:
 - the sources of waste display the same type of contamination

or

- scientific principles justify that the mixing of wastes will favourably enhance the bioremediation process and not cause or promote unfavourable interactions between chemical substances, or cause new chemical substances to be introduced to the waste.

Reporting and monitoring

On application, the operator should provide the EPA with information detailing the origin, quantity and nature of waste material and the proposed method of bioremediation.

Operators of ongoing facilities should provide to the EPA annually a summary of information relating to all waste materials received and subjected to bioremediation during the preceding twelve months. Alternatively, for short-term projects, the summary should be provided within two months after completion.

Further information

Legislation

Legislation may be viewed on the Internet at: www.parliament.sa.gov.au/dbsearch/legsearch.htm

Copies of legislation are available for purchase from:

Government Information Centre	Telephone:	13 23 24
Lands Titles Office, 101 Grenfell Street	Internet:	www.shop.service.sa.gov.au
Adelaide SA 5000		

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