• ARTICLE — VOL. 1

Remediation of oil-contaminated soil in Okinawa using a multi-microbial consortium agent

A treatability test on soils unique to Okinawa demonstrates the effectiveness of a multi-microbial consortium agent at removing oil

BioRangers

• Overview

Oil-contaminated soil in Okinawa

In recent years, as US military bases have been returned in Okinawa, soil contamination by oil and other substances has come to the surface and become a serious problem. The prevailing lime mixing method is criticised for altering the properties of the soil, while excavation removal is constrained by limited destinations and incurs enormous costs to ship soil off the islands. Bioremediation is therefore drawing high expectations; however, soils unique to Okinawa are widely distributed, and interest is focused on its effectiveness and applicability.

Target **Oil-contaminated soil in Okinawa (returned base land, etc.)**	Method **Bioaugmentation using the multi-microbial consortium agent Oppenheimer Formula™**
Test soils **High concentration (Kunigami maaji) and medium concentration (Jaagaru)**	Evaluation indicators **Changes in TPH concentration and total microbial count**
Conclusion **Oil removal is fully feasible regardless of soil type or concentration**	

• Technology

Bioremediation and multi-microbial consortia

Bioremediation is a technology that harnesses the ability of microorganisms to break down contaminants. This technology is a bioaugmentation in which the multi-microbial consortium agent Oppenheimer Formula™, containing a high concentration of diverse microorganisms, is applied to the contaminated site, reliably breaking down contaminants into harmless organic matter (ultimately water and carbon dioxide). The agent is a microbial consortium collected from natural environments across various regions, and through the interactions (teamwork) of the individual microorganisms that compose it, it can adapt to a wide range of contaminants and environments.

• Comparison

Comparison with lime mixing

Lime mixing is a method in which quicklime is mixed into contaminated soil and the heat of reaction separates and removes volatile components. The characteristics of the two methods are shown below.

	Lime mixing method	Bioremediation
Materials	Quicklime	Microbial agent, nutrients, etc.
Regulation	Handling 500 kg or more of quicklime requires notification to the fire department (Cabinet Order on the Regulation of Hazardous Materials, Article 1-10)	None in particular
Effect on the human body	When calcium oxide contacts skin or the airways it can cause inflammation or breathing difficulty	None in particular. Tested for pathogenicity, toxin production, effects on flora and fauna, ecotoxicity, etc.
Equipment	Tents, dust collectors, activated-carbon adsorption units, etc.	None in particular
Conversion to farmland	Difficult due to strong alkalinisation. Heavy metals leach more readily	Possible, as soil properties are unchanged
Effect on high-concentration oil	No effect obtained and heavy oil components remain. Off-site shipping may be required	In-situ remediation is possible. Breakdown rate varies with concentration, soil type and temperature
Rating	△	○

Because lime mixing alters soil properties and makes conversion to farmland difficult, and because dust damage is also a problem, expectations for bioremediation are rising.

• Soil types

Soils unique to Okinawa

Okinawa's soils differ greatly from those of other prefectures and vary widely in being alkaline, acidic, clayey and so on. Because Okinawan soils are distinctive, it is necessary to accumulate tests using local oil-contaminated soil and a record of remediation results. Three representative types are shown below.

Type	Characteristics	Distribution
Kunigami maaji	Strongly acidic clayey soil (red to yellow)	Distributed mainly in the northern region of Okinawa's main island
Shimajiri maaji	Alkaline clayey soil mixed with Ryukyu limestone (reddish brown). Good permeability and drainage	Distributed mainly in the central and southern parts of Okinawa's main island and on Miyako Island
Jaagaru	Alkaline heavy clayey soil (grey to greyish brown). Poor drainage, but resistant to drought	Distributed mainly in the southern region of Okinawa's main island

• Method

Treatability test (suitability test for biological treatment)

We conduct treatability tests using Okinawan soils. Here we present a test targeting high-concentration oil-contaminated soil (Kunigami maaji) and medium-concentration oil-contaminated soil (Jaagaru).

The soil sample is passed through a 5 mm sieve to homogenise it, and a pre-test (initial) sample is taken.
TPH is measured by a third-party analytical institution; everything else is measured in-house.
1 kg of soil is placed in a stainless-steel tray, and an essential-element aqueous solution and nutrients dissolved in dechlorinated tap water are added and stirred well.
The multi-microbial consortium agent is added and stirred. In the medium-concentration test, a series without additives is also prepared for a comparative test.
The soil is stirred once daily and moisture is replenished as needed so that the surface stays damp. On designated days the soil condition is observed and a sample is taken and analysed in the same way.
Measurement items: total microbial count (direct microscopy / EB fluorescent staining), pH, nitrogen and phosphorus, oil odour and oil sheen, etc.

• Results — high

Test results (high concentration, Kunigami maaji)

The TPH concentration and total microbial count before and after treatment are shown in Table 3, and their changes over time in Figure 1. TPH (C6–C44) decreased from an initial value of 13,000 mg/kg to 6,200 mg/kg on day 14, while the total microbial count increased about sixfold.

TPH (mg/kg-dry)	Initial	Day 7	Day 14
C6～C44	13000	9300	6200
C6～C12	<240	85	53
C12～C28	13000	9100	6100
C28～C44	<240	77	49
Total microbial count (cells/g-wet)	7.91E+07	3.48E+08	4.69E+08

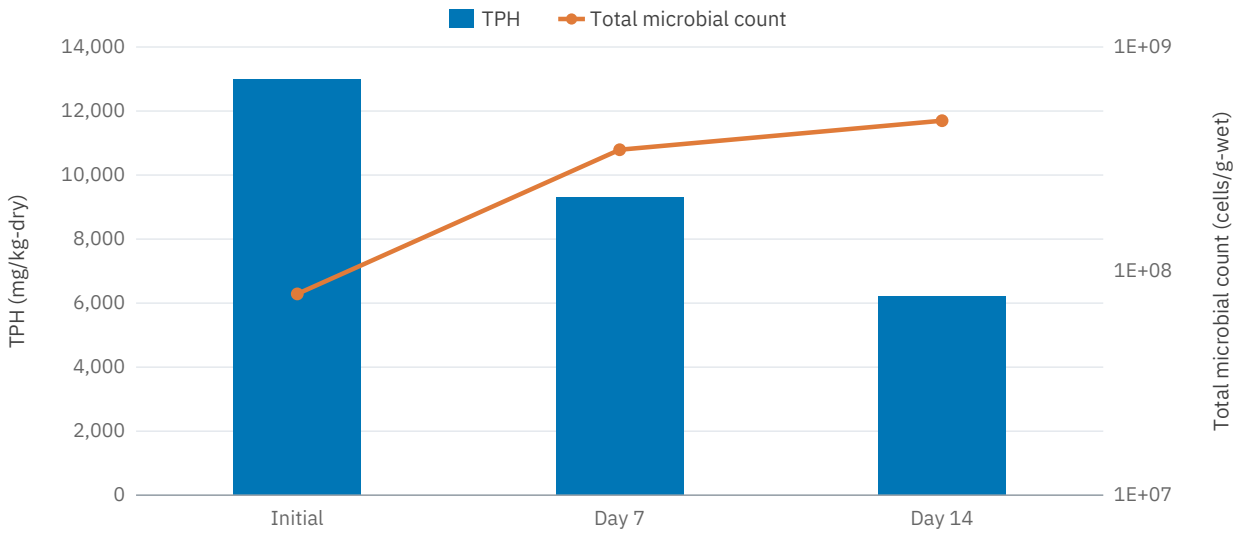

Figure 1 Changes in TPH concentration and total microbial count in the high-concentration test

• Results — mid

Test results (medium concentration, Jaagaru) and assessment

In the medium-concentration test, we compared the agent with and without addition (Table 4 and Figure 2). With addition, TPH (C6–C44) decreased markedly from an initial value of 7,600 mg/kg to 780 mg/kg on day 70, and the total microbial count also increased. Without addition, the value was 5,300 mg/kg on day 70, showing little decrease, and the microbial count also declined.

TPH C6～C44 (mg/kg-dry)	Initial	Day 14	Day 28	Day 42	Day 70
With addition	7600	5900	3800	1600	780
Without addition	7600	6900	6000	6000	5300

Total microbial count (cells/g-wet)	Initial	Day 14	Day 28	Day 42	Day 70
With addition	5.81E+08	5.17E+09	3.53E+09	6.37E+09	6.51E+09
Without addition	5.81E+08	2.39E+08	1.69E+08	1.36E+08	1.16E+08

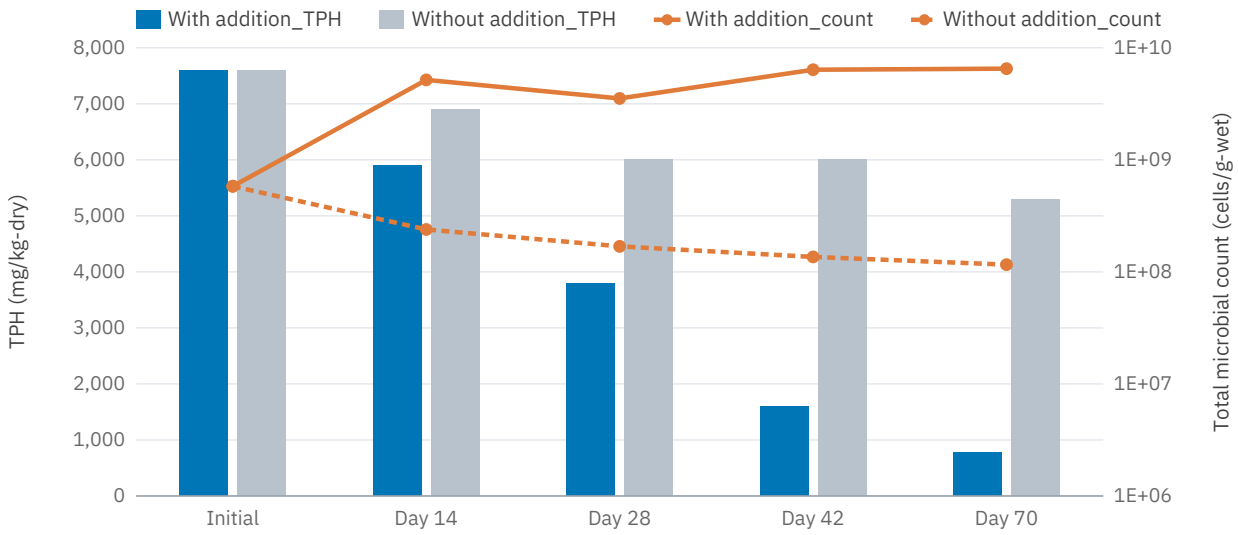

Figure 2 Changes in TPH concentration and total microbial count in the medium-concentration test (with / without addition)

Assessment: In both tests a reduction in TPH concentration and an increase in total microbial count were confirmed. There was no growth inhibition of the microorganisms by these soils, and regardless of soil type or TPH concentration, oil remediation of soil using the multi-microbial consortium agent is fully feasible.