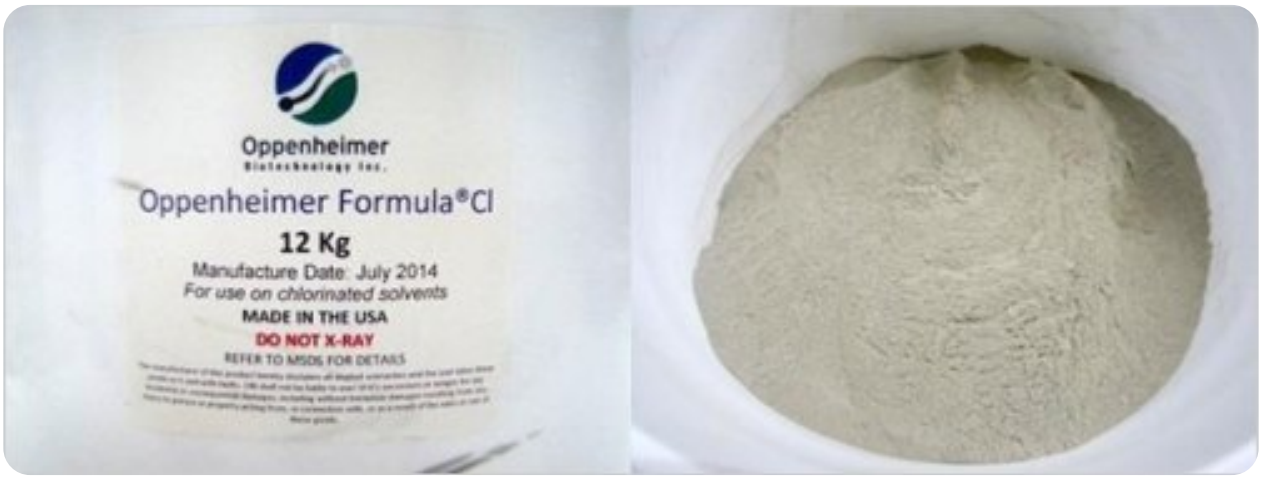
• ARTICLE — VOL. 3

Remediating volatile organochlorine contamination with a multi-microbial agent

Bioaugmentation that detoxifies VOC contamination such as trichloroethylene without generating secondary waste



BioRangers

• Overview

Introduction — the background to VOC contamination

Volatile organochlorine compounds — typified by trichloroethylene and tetrachloroethylene — are carcinogenic organic compounds bearing chlorine that readily volatilise at normal temperature and pressure. In Japan, widespread groundwater contamination came to light in the 1980s; chloroethylene and 1,2-dichloroethylene were added to the groundwater environmental standards in fiscal 2009, and chloroethylene was added to the soil environmental standards in April 2017. All of these are substances that can be generated by the degradation of trichloroethylene and the like.

Target substance **VOCs such as trichloroethylene**	Agent used **Oppenheimer TCE Formula™**
Reaction mode **Oxidative degradation under (micro)aerobic conditions**	Key feature **Detoxification that generates no secondary waste**

• Approach

Remediation with a multi-microbial consortium agent

Bioremediation is a technology that uses microbial metabolism to break down contaminants, and it requires far less input energy than conventional excavation removal or thermal treatment. However, biostimulation — which activates the indigenous microbes already present at a site — leaves uncertainties around its effectiveness and the remediation period. To address a wide variety of contaminants, we apply a multi-microbial consortium agent (microbial consortium).

Oppenheimer Formula™ is a consortium developed by the late Professor Emeritus Carl Oppenheimer of the University of Texas, an authority in marine microbiology, and it is registered in the EPA (US Environmental Protection Agency) NCP Product Schedule. Of these, Oppenheimer TCE Formula™ efficiently dechlorinates organochlorine compounds and then uses the resulting hydrocarbons again as a carbon source, ultimately breaking them down to water and carbon dioxide. Because multiple microbes with differing degradation characteristics work in succession, no harmful intermediate metabolites accumulate and no secondary waste is generated.

The degradation of trichloroethylene and the like is widely known to proceed via the anaerobic dechlorination reaction of bacteria of the genus Dehalococcoides (Fig. 1), but dechlorination all the way to ethylene is difficult, and there are concerns about the accumulation of harmful intermediate metabolites such as vinyl chloride monomer. Our experimental results to date show that our agent works in a manner closer to an oxidation reaction under (micro)aerobic conditions, which differs from the anaerobic reaction (Fig. 2).

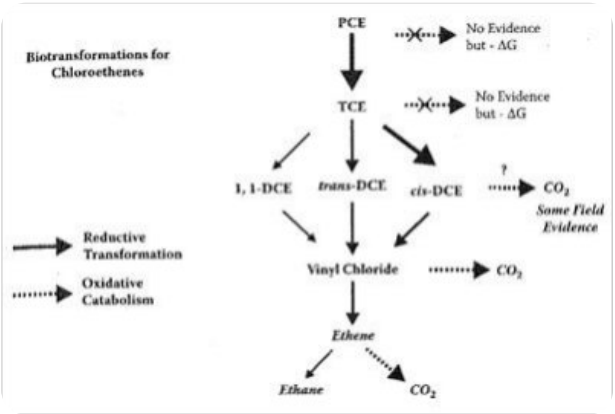


Fig. 1: Dechlorination reaction by anaerobic microbes

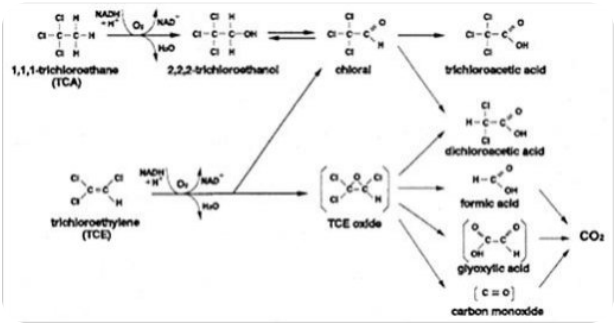


Fig. 2: Cometabolism by aerobic microbes

• Lab trial

Simulated contaminated-water degradation test

We dispensed 200 mL of simulated trichloroethylene-contaminated water into each 250 mL medium bottle, setting up a control series and a bio-treatment series to which a nutrient agent, an essential-element aqueous solution, and Oppenheimer TCE Formula were added. After shaking culture, on days 1 and 7 a third-party analytical institution analysed trichloroethylene and cis-1,2-dichloroethylene, and we measured the total microbial count (direct microscopy) and pH.

Series / item	Initial value	Day 1	Day 7
Control TCE (mg/L)	0.19	0.2	0.14
Bio-treatment TCE (mg/L)	0.19	0.08	0.06
cis-1,2-DCE (mg/L, both series)	<0.004	<0.004	<0.004
Bio-treatment total microbial count (cells/ml)	3.22E+07	4.69E+07	2.65E+08

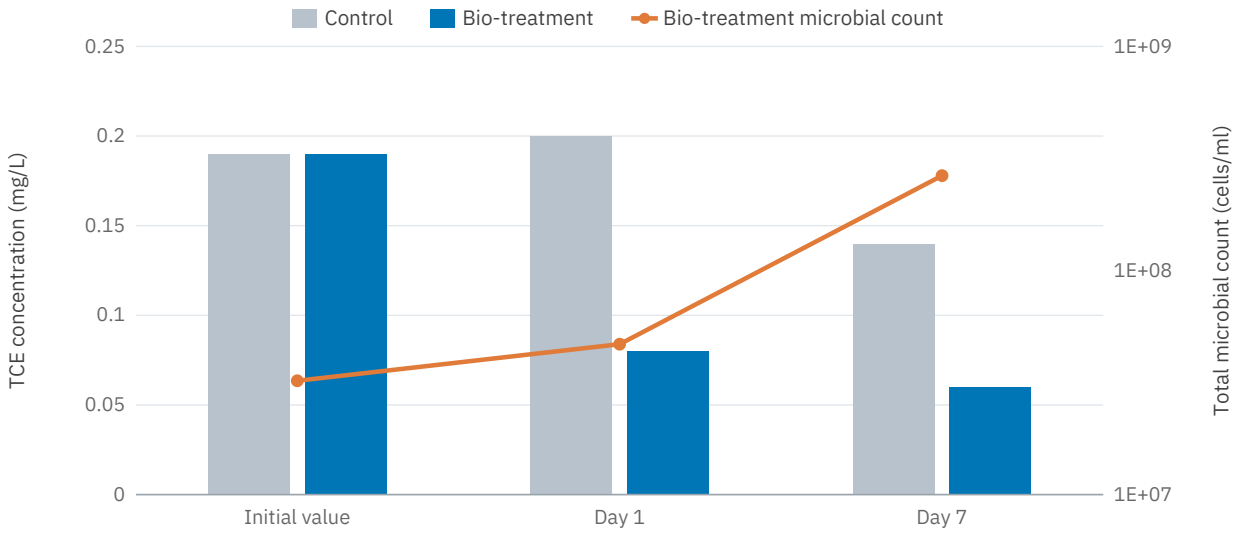


Fig. 3: Trends in trichloroethylene concentration and total microbial count

With the addition of the agent, trichloroethylene fell from an initial average concentration of 0.19 mg/L to an average of 0.06 mg/L on day 7. Whereas the control was at 0.14 mg/L, the bio-treatment series showed clear degradation accompanied by an increase in the total microbial count.

• Field trial

Groundwater field demonstration at a site in N Prefecture

For the trichloroethylene groundwater contamination identified at a site in N Prefecture, we carried out remediation with a system that combined the multi-microbial consortium agent with a device (bioreactor) that draws out the microbes' degradation capacity to the maximum. In this configuration the raw water passes through an oxidation tank → a sedimentation tank → a sand filtration tank to become discharge water, while the sludge is returned and recirculated.

The bioreactor in operation

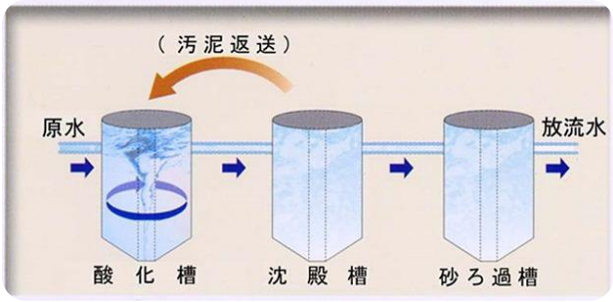


Fig. 4: Schematic of the bioreactor system

Item (mg/L)	Raw water	Treated water
Trichloroethylene	400	0.17
1,1,1-trichloroethane	9.9	0.0026
1,1,2-trichloroethane	0.17	0.0017
1,1-dichloroethylene	0.3	<0.001
cis-1,2-dichloroethylene	130	0.15
dichloromethane	14	<0.001
1,2-dichloroethane	0.62	0.0039
tetrachloroethylene	1.2	<0.0005
benzene	0.36	<0.001

As shown by the analytical results before and after treatment (table), every substance fell below its wastewater standard value. Trichloroethylene was substantially reduced from 400 mg/L in the raw water to 0.17 mg/L in the treated water.

In closing

At industrial sites (and former sites) used by dry-cleaning businesses and manufacturers, soil and groundwater contamination by trichloroethylene and the like is expected to continue in the years ahead. Even at industrial sites still in operation or nearing closure, taking in-situ remediation measures early can be expected to lower remediation costs. Building on the bioaugmentation in which we specialise, we will continue working to establish more efficient remediation methods through hybridisation with various construction methods and additives and through the development of new products.

Ministry of the Environment website (https://www.env.go.jp/)
Jeffrey W. Talley, Bioremediation of Recalcitrant Compounds.
Hashimoto, A. et al. (2002) Degradation pathways of trichloroethylene and 1,1,1-trichloroethane by Mycobacterium sp. TA27.