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Isolation of a thermophilic bacterium, *Geobacillus* sp. SH-1, capable of degrading aliphatic hydrocarbons and naphthalene simultaneously, and identification of its naphthalene degrading pathway

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HIGHLIGHTS

- A thermophilic bacterium SH-1 could degrade aliphatic hydrocarbons and naphthalene.
- The C12–C21 *n*-alkanes in crude oil could be degraded almost completely in 8 days.
- 100 mg L^{-1} Naphthalene could be degraded to non-detectable level within 72 h.
- A biodegradation pathway of naphthalene under thermophilic condition was proposed.

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ABSTRACT

A thermophilic naphthalene- and aliphatic hydrocarbon-degrading bacterium SH-1 was isolated from a deep oil well and identified as *Geobacillus* sp. *n*-alkanes from C12 to C33 in crude oil and naphthalene were effectively degraded by strain SH-1, and this strain could readily utilize these compounds as its sole carbon and energy resources. During the degradation of naphthalene, strain SH-1 initiated its attack on naphthalene by a monooxygenation at its C-1 to give 1-naphthol and further monooxygenation at C-2 to produce 1,2-dihydroxynaphthalene. The ring of 1,2-dihydroxynaphthalene was cleaved to form trans-*o*-hydroxybenzylidenepyruvate. Subsequently, trans-*o*-hydroxybenzylidenepyruvate was transformed to (2E)-3-(2-hydroxyphenyl)prop-2-enal by losing a carboxyl group. Additionally, benzoic acid was identified as an intermediate in the naphthalene degradation pathway of this *Geobacillus* strain. This study highlights an important potential use of the thermophilic degradative strain SH-1 in the cleanup of environmental contamination by naphthalene and crude oil and presents a mechanism for naphthalene metabolism.

1. Introduction

Oil pollution is now a common phenomenon and has caused ecological and social catastrophes. Polycyclic aromatic hydrocarbons (PAHs) have long been on the US Environmental Protection Agency (US EPA) list of priority pollutants due to their toxicity, carcinogenicity, and teratogenicity and their recalcitrance in the environment (Song et al., 2011). Naphthalene is one of the PAHs that has been classified as a potential human carcinogen by international agencies (the International Agency for Research on Cancer [IARC], the US EPA, and the Deutsche Forschungsgemeinschaft [DFG]) (Preuss et al., 2003). Naphthalene is among the most toxic components in the water-soluble fraction of crude oils. Because of its toxicity and chemical persistence, this compound is an extremely dangerous environmental contaminant (Bamforth and Singleton, 2005), and the remediation of naphthalene pollutants has been a matter of growing concern among environmental scientists.

During the past 30 years, many remediation technologies have been tested in efforts to remove these contaminants. Among them, bioremediation is a safe and cost-effective option (Samanta et al., 2002). Microorganisms that degrade various components of petroleum are readily isolated from the environment, particularly from petroleum-contaminated sites. Microorganisms that can utilize saturated hydrocarbons (*n*-alkanes) are widely distributed in nature (Atlas and Atlas, 1991; Zhang et al., 2011) and include members of at least 60 genera of aerobic bacteria and five genera of anaerobic bacteria (Prince, 2005), including *Acinetobacter* (Sakai et al., 1994), *Rhodococcus* (van Hamme and Ward, 2001), *Alcanivorax* (Liu et al., 2010), *Bacillus* (Zhang et al., 2010), *Streptomyces*

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