

Short Communication



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## 하천 퇴적토에서 분리한 *Citrobacter* strain SE4-1에 의한 아셀렌산염의 원소상 셀레늄으로의 환원

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### Selenite Reduction to Elemental Selenium by *Citrobacter* Strain SE4-1 Isolated from a Stream Sediment

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#### Abstract

**BACKGROUND:** Selenium is an essential element for all life forms but can be toxic above certain narrow levels. Prevalent forms of selenium in oxic environment are selenium oxyanions such as selenite and selenate, which may be contaminants in soils and water bodies. Bacterial reduction of more mobile selenium species (selenite or selenate) to less mobile elemental selenium may suggest a benign solution for alleviating toxicity and bioavailability of the selenium species.

**METHODS AND RESULTS:** A facultative anaerobic bacterium, *Citrobacter* strain SE4-1 was isolated from the contaminated stream sediments and found to effectively reduce selenite to elemental selenium. Aqueous phase of selenite was analyzed by inductively couple plasma spectroscopy and the precipitated sphere-shaped elemental selenium was observed by transmission electron microscopy.

**CONCLUSION:** The bacterial strain SE4-1 isolated in this study suggests a potential role in biogeochemical cycle of selenium by the selenite reduction in the stream environment, and potentials for biotechnological applications to

reduceselenium concentrations in selenium-contaminated systems such as wastewater, soil, and groundwater.

**Key words:** Bioavailability, Microbial reduction, Selenium, Soil, Toxicity

#### 서론

(selenium, Se)

(Nuttall, 2006).

가 (oxygenations;  $\text{SeO}_4^{2-}$ ,  $\text{SeO}_3^{2-}$ ) 가 (elemental selenium) (metal selenides) 가 (selenate,  $\text{SeO}_4^{2-}$ ) (selenite,  $\text{SeO}_3^{2-}$ ) 가 (bioavailability) (Se<sup>0</sup>)

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(Buchs *et al.*, 2013).  
 가 (bioavailable) 가 ,  
 (selenide) , ,  
 (biogeochemical)  
 (dissimilatory)  
 (Knight *et al.*, 2002; Lee *et al.*, 2007;  
 Oremland *et al.*, 1994).  
 (terminal electron  
 acceptor, TEA)  
 (detoxification)  
 (Dowdle  
 and Oremland, 1998).  
 가

**재료 및 방법**

배양 조건 및 아셀렌산염-환원 세균 분리  
 (enrichment) tryptic  
 soy broth (TSB; BD, Franklin Lakes, NJ, USA)  
 1/10 (3 g/L), (Na<sub>2</sub>SeO<sub>3</sub>)  
 1 mM 가 가 . 100 mL  
 (serum bottle) 50 mL , 100% N<sub>2</sub>  
 (purging)  
 (autoclaving)  
 가 resazurin .  
 1 g  
 (cannula) 100% N<sub>2</sub> . 28°C  
 , 1  
 Se (IV)  
 (anaerobic jar;  
 28029, Sigma-Aldrich, St. Louis, MO, USA)  
 (Atmospheric Generation System;  
 68061, Sigma-Aldrich)  
 10  
 SE4-1 ,

균주 SE4-1 확인 및 아셀렌산염 환원 실험  
 SE4-1 (phylogenetic)  
 (bacterial universal  
 primers; 27F, 1492R)  
 16S rRNA (sequencing)  
 ( , , ). BioEdit  
 (v. 7.2.5)  
 (phylogenetic tree) SILVA  
 Ref 99 release 128 (Quast *et al.*, 2013) ARB  
 6.0.6 (Ludwig *et al.*, 2004)  
 SE4-1 (Se<sup>4+</sup>; SeO<sub>3</sub><sup>2-</sup>)  
 1/10x TSB  
 1 mM  
 (0.20 μm, Advantec MFS, Inc.)  
 (ICP-AES; ICPS-7500, Shimadzu, Kyoto, Japan)  
 (elemental selenium,  
 Se<sup>0</sup>) (TEM; H-7650, Hitachi,  
 Tokyo, Japan)

**결과 및 고찰**

분리 균주 SE4-1  
 5  
 10 , SE4-1  
 . SE4-1 16S rRNA  
 NCBI GenBank BLAST EZBioCloud (www.  
 ezbiocloud.net) , 가 가  
 (taxon) *Citrobacter freundii* (ATCC 8090T) 99.5%  
 SE4-1 16S rRNA  
 NCBI GenBank accession no. MH511543  
 695,171 (SILVA)  
 neighbor-joining  
 (phylogenetic tree) (Fig. 1).  
 SE4-1 *Citrobacter freundii* MRB070408-1 (GU  
 126682) 가 가 , SE4-1 *Citrobacter  
 freundii* . *Citrobacter*  
 (Burton *et al.*, 1987)  
 (Theisen and Yee, 2014)  
 SE4-1 *Citrobacter*  
 가 가  
 , 5, 6 (As)  
 (Te)  
 가 가

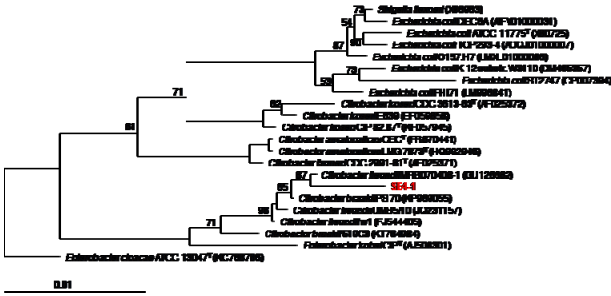


Fig. 1. Unrooted neighbor-joining phylogenetic tree based on 16S rRNA gene sequences showing the phylogenetic relationships of the isolated strain SE4-1 among the species of the genera *Citrobacter*, *Enterobacter*, *Escherichia*, and *Shigella*. Distance correction was done by Jukes-Cantor model. *Enterobacter cloacae* ATCC 13047 was set as the outgroup. The bootstrap scores are expressed as percentages, the estimated confidence levels for the positions of the branches. The scale bar indicates the evolutionary distance value between sequences, determined by measuring the lengths of the horizontal lines connecting two organisms.

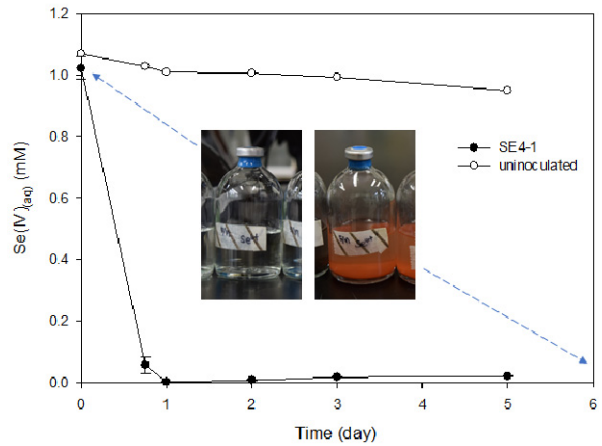


Fig. 2. Concentrations of aqueous selenite during the incubations. The closed and open circles indicate the average concentrations of the triplicates from the bacterium-inoculated and uninoculated incubations, respectively. Subset photos show one of the inoculated incubations at time 0 and 6-d, respectively.

SE4-1에 의한 아셀렌산염 환원

SE4-1	(selenite)
1/10x TSB	1 mM Se(IV)
, 18 h	(aqueous selenite)
0.056±0.028 mM	94.5%가
, 24 h	0.001±0.001 mM 99.9%가
(Fig. 2).	
가	
SE4-1	
.5	가
0.019±0.002 mM	가
(selenide, Se(-II))	Se(0)

(Fig. 2 subset).

(sphere) (Lee et al., 2007; Oremland et al., 1994). (TEM)

(Fig. 3).

TEA 가 (Lee et al., 2007; Ludwig et al., 2004).

(Se<sup>0</sup>)

X-

SE4-1

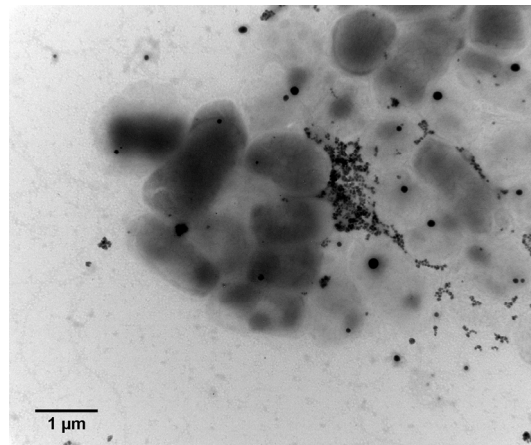


Fig. 3. Transmission electron micrograph of the strain SE4-1 coprecipitated with the elemental selenium (Se<sup>0</sup>) reduced from selenite.

8×10<sup>5</sup> cells/mL (optical density)

가 (Fig. 3). TSB TEA, SE4-1 TEA

SE4-1

## 요약

(selenite,  $\text{SeO}_3^{2-}$ ) SE4-1

*Citrobacter freundii* 가

(elemental selenium,  $\text{Se}^0$ )

가

## Note

The authors declare no conflict of interest.

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