

News and opinions

Can microbes feed on environmental carbon nanomaterials?



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ABSTRACT

The rapid development of nanotechnology has created a variety of carbon nanomaterials (CNMs), such as cylindrical carbon nanotubes, two-dimensional graphene, spherical fullerenes, leading to revolutionary progress in biology, medicine, chemistry, and physics. CNMs are inevitably released into the environment during production, transportation, and use, which raises questions about the ecological safety and health risks of CNMs. Recently, environmentalists and researchers have suggested exploring the possibility that microbial biodegradation technology could be a reliable and efficient method for the removal of CNMs from the environment, because several types of microbes have been found to successfully degrade CNMs. However, we do not agree with this opinion at this point because this technology is immature, and is still very much at the experimental stage. Most importantly, environmental CNMs are highly stable, where the carbon is often difficult to extract and use by microbes.

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Microbial degradation of CNMs

CNMs are used widely, causing potential health and environmental risks [1–6]. There have been a number of studies demonstrating the ability of microbes to decompose CNMs [7–9]. Microbes can degrade carbon nanomaterials, mainly because they can produce CNM-degrading enzymes, such as Manganese peroxidase (MnP) from *Phanerochaete chrysosporium* [9] and lignin peroxidase (LiP) from *Sparassis latifolia* [8]. Taking multi-walled CNTs (MWCNTs) biodegradation by bacteria as an example, the degradation pathway is that MWCNTs are first decomposed into several intermediate products such as isophthalic acid, 2-methoxy naphthalene, cinnamaldehyde and 2-naphthol, and finally are transformed into CO₂ [10]. Recently, the biodegradation of CNMs by microbes has been reviewed, showing that both fungi and bacteria can degrade carbon nanotubes (CNTs), graphene (GRA), and their derivatives [11,12]. Known fungi for CNM biodegradation include *Sparassis latifolia* [8], *Phanerochaete chrysosporium* [9], and *Trametes versicolor* with naturally occurring microbial communities from aerated wastewater treatment plant sludge or field-collected sediment [13], while *Trabusiella guamensis* [14], naphthalene-

degrading bacteria, and a bacterial community composed of *Delftia acidovorans*, *Burkholderia kururiensis*, and *Stenotrophomonas maltophilia* [10] were found to be CNM-degrading bacteria. These fungi and bacteria can utilize CNMs as a carbon source, which leads to the degradation of CNMs. As a result, many researchers believed that microbial degradation could be a promising approach to environmentally eliminating CNMs. Moreover, most researchers considered microbial degradation as a better method to remove pollutants than traditional physicochemical methods because microbial degradation is a 'green' technology and avoids secondary pollution.

CNMs as a "terrible" carbon source for microbes

Environmentalists brought the findings about the microbial degradability of CNMs to light because of concerns about the risks of these materials in the environment [15]. Unfortunately, however, it is too premature to remove CNMs by microbes in practical applications at present. This is, in part, because CNMs are not a good carbon source for microbes (Fig. 1), although they are rich in carbon. For example, MWCNTs cannot be used as the sole carbon source to enrich CNM-degrading microbes [10]. Additional carbon sources such as glucose are often needed, which triggers the degradation of CNMs via co-metabolism. Previous studies on the microbial degradation of CNMs were mainly carried out under lab conditions [11]. Field conditions are largely different from those of lab. There are

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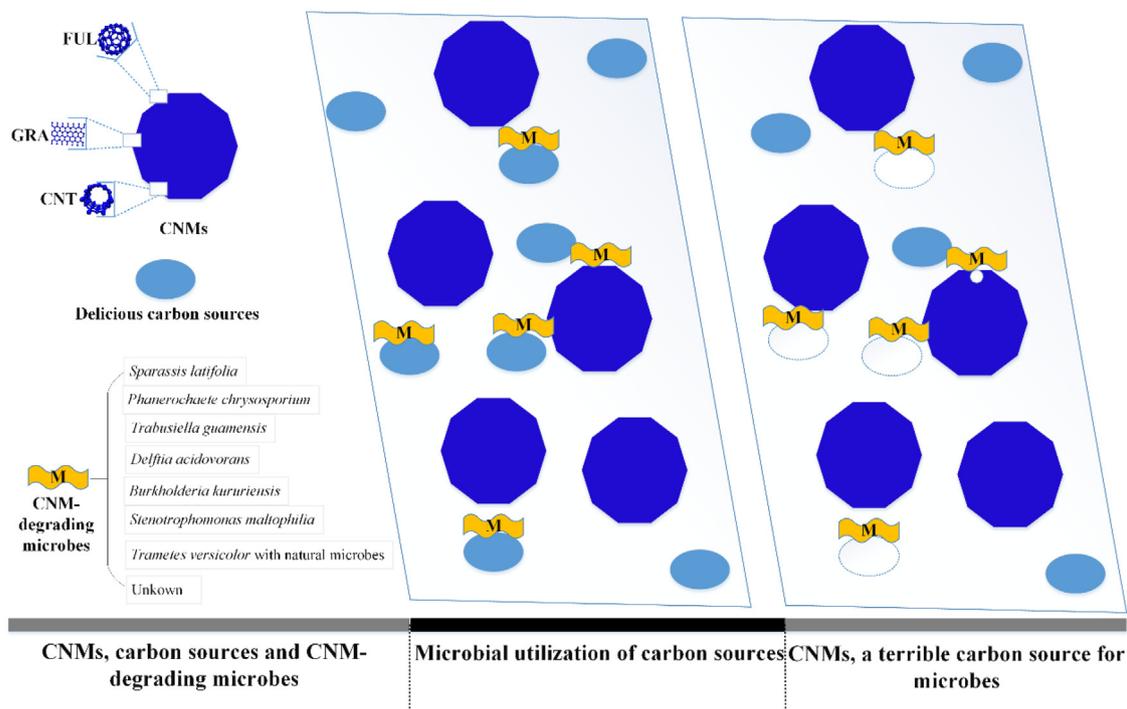


Fig. 1. CNMs as a terrible carbon source for microbes. CNMs mainly include carbon nanotube (CNT), graphene (GRA), fullerene (FUL), etc. Microbes prefer to utilize easily accessible carbon sources (delicious carbon sources), rather than CNMs. Dotted ellipse shows that the carbon sources have been consumed, while the small blank circle on CNMs indicates that only a minor part of CNMs have been utilized by microbes.

various carbon sources available for microbes in addition to CNMs under field conditions. Microbes generally prefer to utilize more accessible foods, rather than CNMs, because the carbon from CNMs is highly stable. In fact, despite claims by studies under lab conditions, CNMs show very low degradation rates by microbes under real environmental conditions. For example, it was reported that <0.1% single-walled CNTs (SWCNTs) were mineralized to carbon dioxide by *T. versicolor* together with naturally occurring microbial communities from aerated wastewater treatment plant sludge or field-collected sediment [13]. Moreover, the growth and reproduction of microbes are related to the conditions in their particular natural environment. Strong adaptability of the microbes to the CNM-containing environment is helpful to their survival by the utilization of CNMs.

Implications

The widespread applications of CNMs in numerous areas require removal strategies after they are disposed of in the natural environment because CNMs have been found to present toxic effects on many types of organisms. Although the current CNMs-degrading efficiency of microbes is low, but the ability of microbes to degrade CNMs can be improved by further studies. The methods to improve this ability include the development of a mixed culture consisting of multiple microbes at a reasonable ratio, the findings of new microorganisms or enzymes with very high CNMs-degrading potential, the adding of defects on the CNMs and modification to make them more reactive, the control of environmental conditions such as pH and temperature, and so on. Thus, microbial biodegradation technology could be a potential candidate for remediation of the environment contaminated with CNMs when various constrains such as weak ability to use CNMs as carbon source, dependence on the environmental conditions and limited number of known CNM-degrading microbes are addressed. Thus, we still have a long way to go to utilize microbial

degradation technology for cleaning up CNMs from the environment.

Notes

The authors declare no competing financial interest.

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