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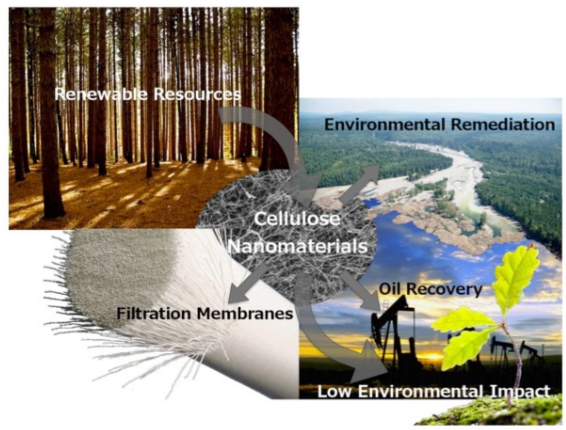
Cellulose Nanomaterials in Environmental Cleanup Technologies

Nanomaterials made of cellulose – a natural polymer used mainly to produce paper – hold great promise in environmental remediation applications and water filtration membranes, according to Duke University Superfund Research Program (Duke SRP) researchers. In a compilation of research findings, Duke SRP researchers led by Mark Wiesner, Ph.D., outline the physical and chemical properties, production costs, and current use of cellulose nanomaterials.

Cellulose, the most abundant organic polymer on earth, is an important structural component of plants. As analytical instrumentation has improved, scientists have discovered naturally occurring nanoscale cellulose structures that range in size from nanometers to microns and demonstrate strength properties comparable to Kevlar.

According to the authors, cellulose nanomaterials represent a new class of sustainable materials with recognized potential in improving paper and packaging as well as the automotive, construction, personal care, and textile industries. The use of cellulose nanomaterials in environmental engineering applications is much less explored but has great untapped potential for water treatment and remediation technologies.



Duke SRP researchers describe the potential benefits of advancing the use of cellulose nanomaterials in water filtration and environmental remediation technologies. (Image by Charles de Lannoy)

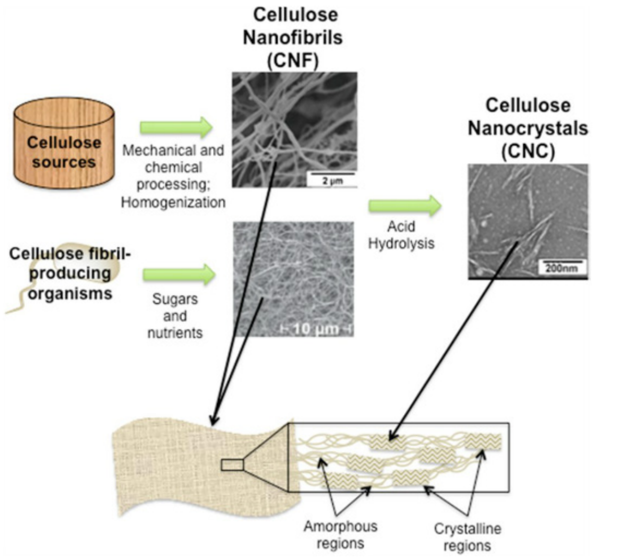
Environmental Remediation

Because cellulose nanomaterials have a high surface area-to-volume ratio, low cost, and high natural abundance, and are inherently environmentally inert, they offer a promising alternative to activated carbon for sequestering contaminants. Scientists have demonstrated that the sorptive capacity of cellulose nanomaterials can be increased using carboxylation, a chemical reaction that adds acid structures. Some forms of cellulose nanomaterials derived from bacteria have proven suitable to absorb heavy metals. Modified cellulose nanomaterials can also absorb a wide range of organic contaminants.

Although scientists have found that the materials are effective in sequestering contaminants, more research is needed to ensure that chemical modifications do not alter the nontoxic nature and biodegradability of cellulose nanomaterials. Studies are also required to determine if the higher cost of cellulose nanomaterials, as compared to the popular activated carbon, will be offset by potentially lower deployment costs.

Water Filtration

Membranes can be created from cellulose nanomaterials because of their dimensions and strength. Although the biodegradability of cellulose nanomaterials is an advantage in many applications, there is concern that they may degrade easily when incorporated into membranes that interact with bacteria. One way to circumvent this is to use cellulose nanomaterials as an additive to polymer membranes, which would most likely protect the cellulose from degradation. Small loadings of cellulose nanomaterials on polymer membranes can increase the strength of the membrane by up to 50 percent.



Cellulose nanomaterials are categorized into two groups – cellulose nanocrystals (CNCs) and cellulose nanofibrils (CNFs). CNFs are isolated by breaking down cellulose feedstocks or they can be directly produced by certain types of bacteria. CNCs are produced using acid to extract only the crystalline region of the nanomaterials. Reprinted with permission from (Carpenter et al. 2015 Cellulose Nanomaterials in Water Treatment Technologies. Environ Sci Technol 49:5277-5287). Copyright (2015) American Chemical Society.

Advantages of Cellulose Nanomaterials

By comparing the properties and application of carbon nanotubes with cellulose nanomaterials, the authors conclude that the latter may be a suitable replacement for carbon nanotubes used in water treatment technologies. Cellulose nanomaterials are much cheaper and less energy-intensive to produce than carbon nanotubes. Unlike carbon nanotubes, they are also biodegradable and a naturally occurring renewable resource.

According to the authors, cellulose nanomaterials' inherent fibrous nature and remarkable mechanical properties, coupled with their low cost, biocompatibility, and sustainable source, suggest huge potential as a component in water filtration membranes and environmental remediation applications. The success of these materials is evident in the exponential growth in cellulose nanomaterial-related patents in the last 10 years, with a rush to stake claim on the cellulose nanomaterial market. However, the authors urge those interested to maintain open communication during this process in order to develop these materials to their full potential.

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To learn more about this research, please refer to the following source:

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