Alumina Nanofiber Filters in Drinking Water Treatment

FACT SHEET 31-015-0211

What are Alumina Nanofibers?

Alumina nanofibers are very small fibers made from aluminum metal or aluminum containing materials. The fibers range in size from 1-100 (nm) in diameter and can be up to several micrometers in length (reference 1). To give perspective, a sheet of paper is about 100,000 nanometers thick. Alumina nanofibers consist of either aluminum oxide (Al_2O_3) or aluminum hydroxide, such as aluminum oxide hydroxide (AlOOH), commonly referred to as boehmite, or aluminum trihyroxide [$Al(OH)_3$], commonly referred to as gibbsite, bayerite or nordstrandite (reference 1).

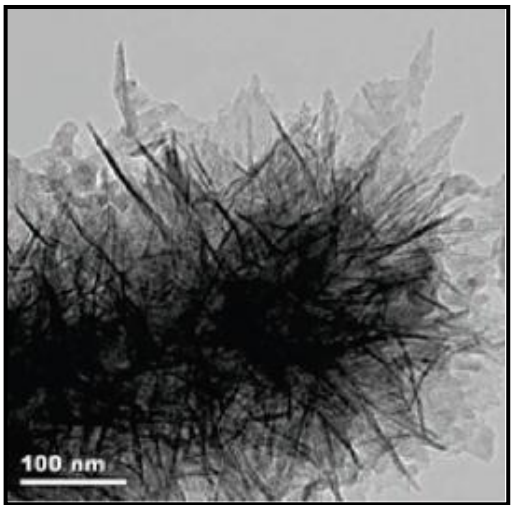

Figure 1. AlOOH nanofibers (reference 2).

How can Alumina Nanofibers be used for Treating Drinking Water?

Alumina nanofibers have been incorporated into cartridge filters to increase their ability to remove contaminants. The nanofibers have two particular attributes that make them attractive for use in drinking water filters – the proven capability of alumina to adsorb various contaminants in conjunction with the extremely high surface areas of the nanofibers allow for potential adsorption of significant amounts of contaminants (references 3, 4). This could extend the life of a filter. The electrostatic attraction allows for the potential adsorption (and thus removal) of viruses which are on the submicron and nanoscale. This would improve a filter's microbial pathogen removal capabilities. Research has shown the potential for Al_2O_3 alumina materials and Al_2O_3 alumina nanofibers to remove or reduce virus concentrations in water (references 5-8).

Currently, one company uses alumina nanofibers for drinking water treatment. The nanofibers are aluminum oxide hydroxide, or boehmite (AlOOH). The boehmite nanofibers are about 2 nm in diameter and 200-300 nm in length (Fig. 1). The nanofibers are incorporated onto submicron glass fibers which are then bonded onto a pleated filter medium (references 9, 10). The resulting filter has pore sizes of about 2-3 micrometers. However, due to the electrostatic attraction much smaller particles (e.g., viruses) could potentially be removed through adsorption, effectively making the filter function as though it had much smaller, submicron pore sizes similar to a membrane filtration technology such as ultrafiltration. With an actual pore size of about 2-3 micrometers, the filter could allow a high rate of flow with a low pressure drop compared to membrane technologies – an advantage over traditional membrane technologies. Some research shows Al_2O_3 alumina nanofiber filters of similar design to this company's filters performing effectively at high flow rates (references 8, 11).

Do Alumina Nanofibers used for Treating Drinking Water Pose any Human Health or Environmental Health Risks?

Alumina nanofibers used in drinking water treatment could be shed from a filter and be ingested or enter the environment.

U.S. Army Public Health Command (Provisional)
Water Supply Management
Aberdeen Proving Ground, MD 21010-5403
Commercial (410) 436-3919/DSN 584-3919
Email: Water.Supply@amedd.army.mil

Boehmite (AlOOH) nanofibers can generally be considered safe. Boehmite (AlOOH) has long been used as a vaccine adjuvant (i.e., an added ingredient to improve vaccine efficacy) and it has been used in analgesics (i.e., pain relievers). Boehmite adjuvants have been associated with severe local reactions (e.g., pain, tenderness, redness, swelling) only on rare occasions (references 12, 13). There are no environmental health effects data available on boehmite nanofibers, although these nanofibers have the same composition, size and aspect ratio as the boehmite used as adjuvants.

Unlike boehmite, aluminum oxides (Al_2O_3) do not have a history of use in human health protection. Based on limited research of aluminum oxide nanoparticles, there are concerns that they may increase the risk of cardiovascular disease and adversely affect certain types of brain cells (references 14, 15). Research on environmental health risks is also limited but suggests that aluminum oxide nanoparticles may have a minor adverse impact on environmental health (references 16 – 18). Aluminum oxide nanofibers may cause adverse human or environmental health effects but further research is necessary to determine the impact, if any, they may have on humans and the environment.

Author's Note: In the previous version of this factsheet there was no differentiation made between aluminum oxide and aluminum hydroxide nanofibers.

References

1. Noordin, M.R. and Liew, K.Y., (2010). Synthesis of Alumina Nanofibers and Composites, Nanofibers, Ashok Kumar (Ed.), ISBN: 978-953-7619-86-2, InTech, Available from: http://www.intechopen.com/articles/show/title/synthesis-of-alumina-nanofibers-and-composites (accessed 8 Nov 2010).

2. "Water filtration media: Talking about a revolution?", *Filtration + Separation Magazine*, Jun 2007, http://www.ahlstrom.com/index.asp?id=21eb02349d7543a2abcb761ff632780a (accessed 8 Sep 2009).

3. MWH, revised by Crittenden, J., et.al., Water Treatment Principles and Design, 2nd ed., John Wiley & Sons, Inc., New York, NY, 2005.

4. Lu, P., and Ding, B., (2008), "Applications of Electrospun Fibers", *Recent Patents on Nanotechnology*, Vol. 2, pp. 169-182.

5. Zhao Y., Sugiyama S., Miller T., Miao X., (2008), "Nanoceramics for blood-borne virus removal", *Expert Review of Medical Devices*, Vol. 5, No. 3, pp. 395-405.

6. Brown J., Sobsey M., (2009), "Ceramic media amended with metal oxide for the capture of viruses in drinking water", *Environmental Technology*, Vol. 30, No. 4, pp. 379-391.

7. Lau B., Harrington G., Anderson M., Tejedor I., (2004), "Removal of nano and microparticles by granular filter media coated with nanoporous aluminum oxide", *Water Science and Technology*, Vol. 50, No. 12, pp. 223-228.

8., Ke X., et.al. (2009), "Ceramic membranes for separation of proteins and DNA through in situ growth of alumina nanofibres inside porous substrates", *Chemical Communications (Cambridge, England)*, Vol. 14, No. 10, pp. 1264-1266.

9. Tepper F., et.al, "Nanosize electropositive fibrous adsorbent", United States Patent 6,838,005, 4 Jan 2005.

10. Argonide Corporation, http://www.argonide.com/nanoceram.htm (accessed 8 Sep 2009).

11. Ke X., et.al. (2008), 'High-flux ceramic membranes with a nanomesh of metal oxide nanofibers", *Journal of Physical Chemistry B*, Vol. 112, No. 16, pp. 5000-5006.

12. "Common Ingredients in U.S. Licensed Vaccines", Oct 2009, U.S. Food and Drug Administration, http://www.fda.gov/BiologicsBloodVaccines/SafetyAvailability/VaccineSafety/ucm187810.htm (accessed 8 Nov 2010).

13. Toxicological Profile for Aluminum, U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, Sep 2008.

14. Oesterling E., et.al. (2008), "Alumina nanoparticles induce expression of endothelial cell adhesion molecules", *Toxicology Letters*, Vol. 178, No. 3, pp. 160-166.

15. Chen L., Yokel RA., Hennig B., Toborek M., (2008), "Manufactured aluminum oxide nanoparticles decrease expression of tight junction proteins in brain vasculature", *Journal of Neuroimmune pharmacology*, Vol. 3, No. 4, pp. 286-295.

16. Doshi R., et.al. (2008), "Nano-aluminum: transport through sand columns and environmental effects on plants and soil communities", *Environmental Research*, Vol. 106, No. 3, pp. 296-303.

17. Wang H., Wick R., Xing B., (2009), "Toxicity of nanoparticulate and bulk ZnO, Al2O3, and TiO2 to the nematode Caenorhabditis elegans", *Environmental Pollution*, Vol. 157, No. 4, pp. 1171-1177.

18. Zhu X., et.al. (2008), "Comparative toxicity of several metal oxide nanoparticle aqueous suspensions to Zebrafish (Danio rerio) early developmental stage", *Journal of Environmental Science and Health Part A, Toxic/Hazardous Substances and Environmental Engineering*, Vol. 43, No. 3, pp. 278-284.