Electropositive Filtration Technology in Automobile Manufacturing Applications

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Argonide/Toyota – Electropositive Filtration Technology in Automobile Manufacturing Applications

Argonide Corporation began as an organization focused on the production and sale of nanopowders. By definition, nanopowders are extremely small particles (less than 0.1 micron) of materials such as nickel, copper, iron, alumina, gold, etc. These materials are in demand by research and development groups within both the public and private sectors. To date, the company is still involved in this active, although limited arena.

It became clear that the future success of Argonide was not in nanomaterials themselves, but in full-scale commercialization of a product based on nanotechnology. Through several years of extensive R&D, discussions with the U.S.E.P.A., and the use of several grants from NASA, we created a non-woven filter media.

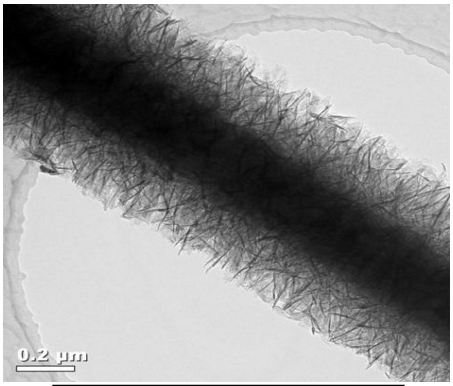
This media is naturally electropositive and doesn't require an outside electrical source or chemical additives to function. The next step in our continued evolution as a company was to incorporate this innovation into a product line which we have trademarked as NanoCeram®. The result is that in 2005, Argonide developed a full line of pleated NanoCeram® water filter cartridges based on our unique and innovative form of electropositive filtration technology. This innovation led to the induction of our filters into the exclusive Space Technology Hall of Fame.

In late 2006, Argonide licensed Ahlstrom Filtration for the worldwide rights to manufacture, market and sell filter media (as roll stock) based on Argonide's technology. Ahlstrom now produces this media under their tradename of Disruptor™. To date, this highly synergistic relationship has led to new innovations including the more recent NanoCeram-PAC™.

Argonide Technology:

As mentioned previously, Argonide sells nano powders for diverse applications. One of these is a nano alumina fiber only 2 nm in diameter, about the size of a DNA molecule. Argonide invented a novel water purification filter based on these fibers, utilizing their unique electropositive properties. Rather than filtering out particles by "sieving" as is done by membranes and fibrous filters, the new nano filter attracts and retains particles by electrostatic forces. The filter removes particles of all sorts including, humic acid, colloidal iron & manganese, bacteria and virus and at a high flow rate. As a pleated depth filter, its dirt holding capacity is extraordinary.

A line of standard-sized pleated cartridge filters are fully commercialized and are being manufactured in Argonide's Central Florida factory.

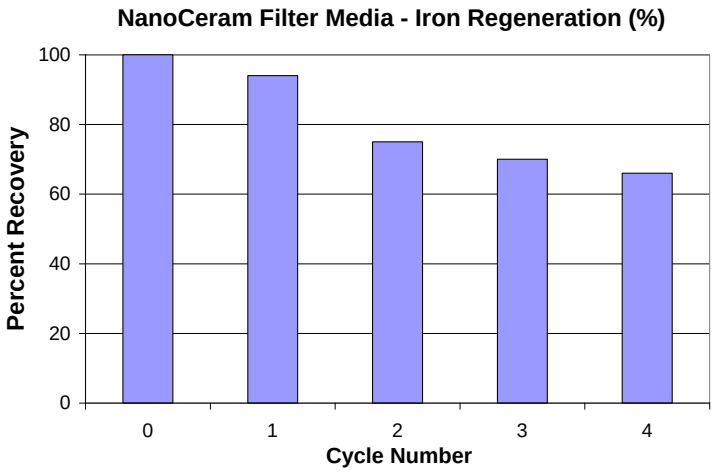


TEM of Nano Alumina on Microglass

Applications include purification of source water in industrial processes for manufacture of biotech/pharmaceuticals, food & beverage, chemical processing, purification of coolants in metal working, heating, ventilation & air conditioning chilling systems, colloid (haze) and bacteria removal in swimming pools and spas, and as a prefilter for extending the life of reverse osmosis filters as well as decreasing the frequency of cleaning cycles for those same systems. While the pleated version is not yet capable of certification for full protection against virus/bacteria/cysts, it is being sold for purification of drinking water.

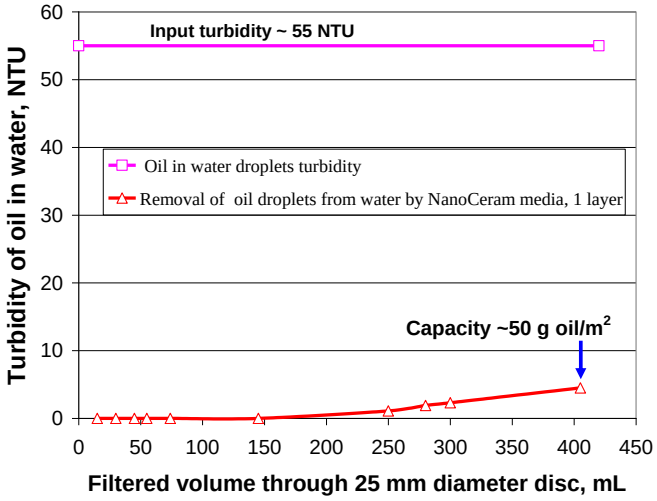
Areas of Specific Interest for Toyota

Colloidal Iron



Iron, particularly in colloidal form, is a significant challenge in virtually every filtration scenario. The electroadhesive properties of Argonide's technology have proven to be extremely effective in the adsorption of these sub-micron particles. This efficiency is documented and has proven to be a challenge as well due to the limiting factor it places on the lifespan of a typical NanoCeram® filter cartridge. These filter cartridges are considered dead-end filters and typically must be discarded when they reach terminal pressure drop. However, Argonide is developing a process whereby a NanoCeram® filter cartridge can be partially recharged in regards to iron adsorption. Laboratory results show a 90% recovery of the filter media per cycle. The result of this process can extend the life of a standard NanoCeram® filter cartridge by 4, 5 or even more times in an iron reducing role.

Oil Emulsion & Trace Oil



Low levels of oil or oil emulsions can often present additional challenges in waste water processes. Recent work has shown a significant advantage in this area as well. Technology exists for oil skimming and coalescing systems, but polishing the water after such systems can be expensive in terms of water waste and energy consumption. A NanoCeram® filter cartridge (either a standard NanoCeram® or the newer NanoCeram-PAC™) can be inserted into an existing system and provide the efficiency desired to reduce these contaminants to a much more manageable level.

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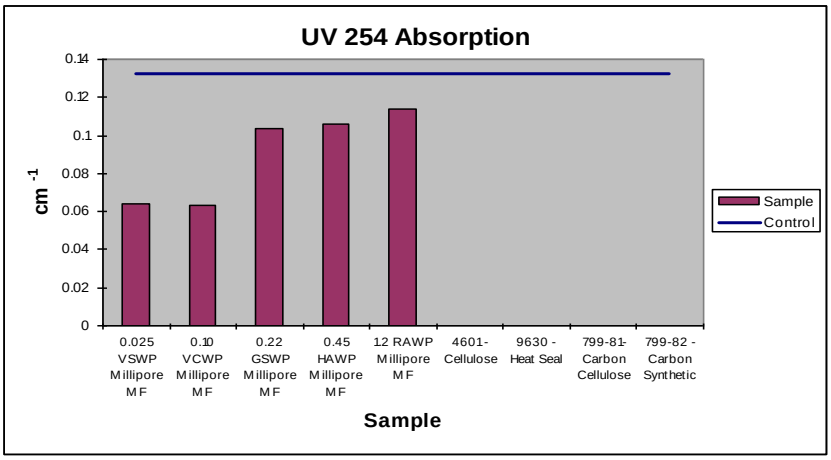
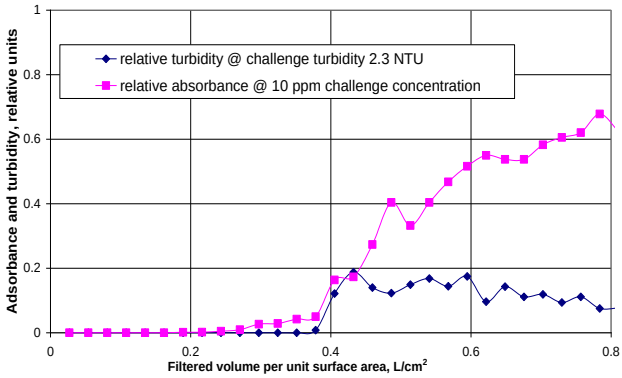
TOC & NOM

A significant challenge for virtually every filtration device and system on the market is that of total organic carbon (TOC) or natural organic matter (NOM). These extremely small particles exist in large numbers wherever there is a biological breakdown of organic matter. This includes virtually all surface and many subsurface sources. The figure seen to the right shows that NanoCeram® (Disruptor™ #4601) and NanoCeram-PAC™ (Disruptor™ #799-81) media are both far more efficient than even 0.025 micron ultraporous membranes for retaining humic acid. The data came from testing five MF Millipore 38mm diameter filters ranging from 0.025 micron to 1.2 micron and four versions of Ahlstrom's Disruptor™ filter media (two of which Argonide uses in their filter cartridges. Each filter was challenged with 150 mL each of the prepared humic acid solution in a Seitto filter holder set-up.



Data courtesy of Heather Mowers, Ahlstrom Filtration



The filtrate was collected in clean, sterile containers and sent to an external laboratory for UV254 testing according to the Standard Methods for the Examination of Water and Wastewater 5910 Ultraviolet Absorption Method.

Breakthrough curves (above) confirm the ability of the filter to remove this class of contaminants. In this case, NanoCeram® filter discs (25 mm diameter) were challenged with humic acid. Breakthrough was detected by both optical turbidity & spectrophotometric methods. Note the high filtration efficiency until the filter is exhausted at about 0.4 L of fluid/cm^2 of filter area.

Biofouling

Membrane biofouling is a significant challenge for industry. Chemical treatments, physical cleanings, and even membrane replacement in extreme cases costs industry in terms of financial expenditure, labor, and water waste. Physical reduction of biological contamination elements in RO membrane feed waters is a goal shared by virtually all membrane operators.

Media	Thickness, mm	Basic weight, g/m^2	Challenge water			B. Diminuta removal, %		
			pH	TDS g/L	BD, CFU/ml	0-10 ml	60-70 ml	130-140 ml
NanoCeram®	0.8	200	7.2	0	$7 \cdot 10^5$	99.997	99.97	99.93
			9.2	0	$1.3 \cdot 10^6$	99.99	99.9	
			7.2	30	$1.2 \cdot 10^6$	99.9	99.7	
			9.2	30	$5.1 \cdot 10^5$	99	98.5	
Other Electropositive media	0.8[d]	210[d]	7.2	0	$7 \cdot 10^5$	98.6	97.7	97.7
			9.2	0	$1.3 \cdot 10^6$	93.8	73	
			7.2	30	$1.2 \cdot 10^6$	92	72	
			9.2	30	$5.1 \cdot 10^5$	92	84	

NanoCeram® filter cartridges will retain >99.9999% of most bacteria. B. diminuta is a very small (~0.3 micron) bacteria, only slightly larger than a smallpox virus. Data are shown comparing adsorption of B diminuta, by NanoCeram® versus another electropositive filter. Aliquots (10 ml) are taken at 3 intervals. When scaling this data to that of standard filter cartridges, the tests represent a flow rate of 15 gpm through a 2.5" x 10" cartridge.

The TOYOTA Water Management Group: Toyota has a long standing history of being environmentally conscious. Toyota North America has received the Energy Star award and maintained its Energy Star status for manufacturing facilities every year since 2004. From the Toyota Energy Management Organization (EMO) has grown another work group called the Toyota Water Management Group. The focus of the Toyota Water Management Group is to support the 3 Key Performance Indicators of COST, QUALITY and RELIABLE OPERATION in the area of water and waste water treatment.

Kaizen is the activity of making continuous, small improvements to a process. Water Kaizen activity is a core responsibility of the Toyota Water Management Group. After successful kaizen, Yokoten (implementing at like processes across the company) takes place. The Water Group is instrumental in Kaizen and Yokoten activities. At Toyota's North American Engineering Group (TEMA) Rick Lancaster heads up this effort. With over 1,300 million gallon of water purchased per year and over 300 million dollars in capital equipment in contact with this water, Kaizen and Yokoten activities must be constantly pursued. Proper water treatment program management consists of both good maintenance as well as kaizen. In 2007 Toyota set a target of 15% water reduction by year 2011. Currently Toyota assembly plants average *900 gallon*/vehicle which is already well under the industry average.

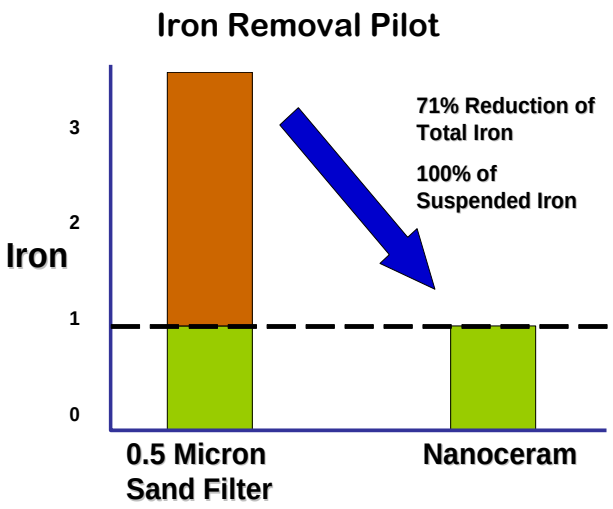
KAIZEN: A new process developed in house at Toyota, called the ***R3 Analysis*** utilizes basic Toyota Production System (TPS) tools to study and kaizen processes that use water. It is a zero-based analysis of the entire facility on a process by process basis, identifying opportunities to REDUCE/REUSE/RECYCLE (R3). By analyzing each process as an independent component and studying its influent and effluent volumes and qualities and building an overall water map for a facility it is easy to identify opportunities for reduction and reuse. Reuse of water often would require nothing more than simple filtration to make the waste stream from one process adequate for makeup to a neighboring process. Often, traditional water filtration (down to 1 micron) would not be adequate to remove submicron particles and a waste stream would be considered unusable. Submicron filtration would make the water usable, but ultrafiltration was rather cost prohibitive.

MAINTENANCE: Proper water chemistry management on a large scale is often less than perfect. Stagnation, dead legs, inadequate mixing and other factors yield mild corrosion (under 1 mil/yr is typical) in water systems. One mil/yr in a 5 million gallon system can add as much as 50 lbs of iron oxide to the water. If the system is tight, over time this will add up quickly. In many cases, filtration is required to maintain satisfactory suspended solids levels in cooling towers, closed loops and other process waters. Iron corrosion product (iron oxide) offers a particularly tough challenge for filtration as it tends to be sub-micron and colloidal. If iron corrosion product is not removed, risk of fouling of heat transfer surfaces (COST) or more aggressive Iron Reducing Bacteria growth can occur. Removal of iron is a serious challenge for industrial closed loops.

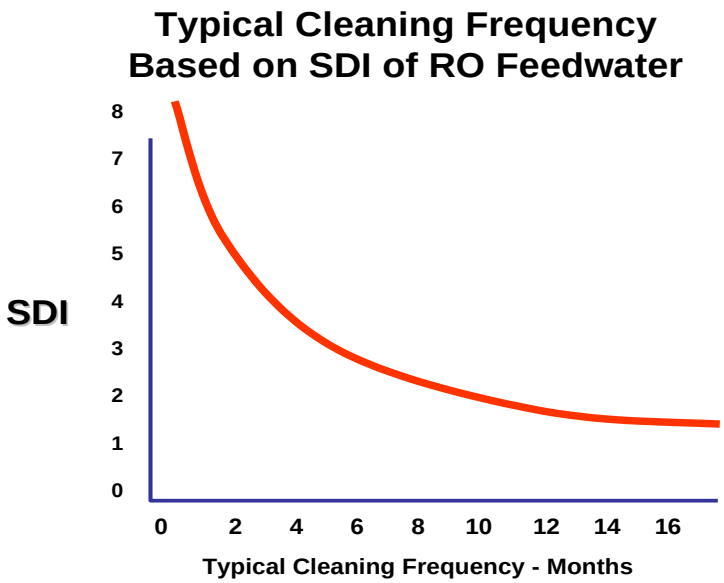
To prevent major maintenance and membrane replacement costs, often feed water used for Reverse Osmosis must be polished with activated carbon and very fine filtration systems to reduce the Silt Density Index to acceptable levels, less than 3. Municipal water sources across North America, recycled waste streams, rain water and other supply waters are not always consistent in many cases and prefiltration is less than perfect. Even what could appear to be the cleanest water (turbidities under 1 NTU) can result in SDI's as high as 5 or 6 due to humic acid and other soluble organics, well above the accepted levels for RO feed.

Kaizen + Maintenance = Opportunity : In mid-2006, Argonide received an inquiry from Rick Lancaster regarding a press a press release he had seen about the NanoCeram® submicron filters. Having struggled with submicron iron issues in closed loops for years, this product caught his attention and pilot activities were initiated at a North American facility in a maintenance capacity.

Opportunity 1: The first area of concern was a 5 million gallon chilled water system that had a history of mild corrosion. Iron levels in the recirculating water had peaked at 3.5 ppm, well over the 1.0 ppm target. Suspended iron in chilled water systems can settle and cause deposition, encouraging further corrosion and bacterial growth. Particle analysis data showed that the bulk of the iron particles were submicron and in the 0.1 to 0.2 micron range. The current 0.5 micron sand filter had been working well, but the particle sizes were just too small for its capabilities. The NanoCeram® filter was able to remove iron to < 1.0 ppm with great success. Economic analysis, however, made the clean up of this massive system unfavorable with a one-use filter. Unless the filter could be regenerated, it was likely not going to be a good fit. Today, Argonide is actually developing just such a process to make the filter regenerable for iron particulate. Currently it looks like the filter can be cleaned up to 5 times with as much as 90% recovery per cleaning cycle.

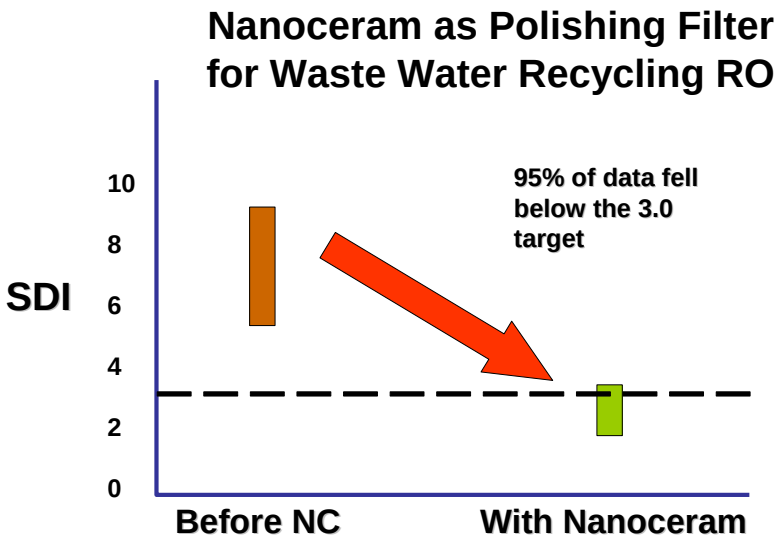


Opportunity 2: The next challenge involved the prefiltration portion of an R.O. system that recycled storm water runoff from a stormwater retention pond on their site. The existing hollow-fiber membrane system being used as the final RO membrane prefilter was unreliable and would lead to unacceptable spikes in both turbidity and SDI (silt density index) levels, caused by leakage in the membrane bundles. Both of these parameters are crucial for an RO membrane's efficiency and lifetime. For best cleaning frequency, an SDI of less than 3.0 is recommended.



Due to the extreme cost of replacement of the UF membranes, alternative polishing methods were investigated.

Toyota installed a filter system containing Argonide's electropositive filters downstream of the hollow-fiber membrane. When operating properly, this new configuration produced very positive results; with the hollow-fibers providing the lion's share of the particulate reduction. However, broken fibers and internal failures allowed ever so slight leakage of solids around the UF. SDI readings were as high as 8.0 at times. Argonide's filters "polished" this water further providing SDI values of < 2.0. This also provided the entire RO system with a level of reliability that was missing prior to the NanoCeram® installation.



Opportunity 3: The next challenge involved the Prefiltration portion of an R.O. system located at Toyota which utilizes municipal water. Prior to installation of NanoCeram® filters, the SDI on the system's feed water averaged approximately 4.42; after installation of the NanoCeram® filters, the SDI now averages approximately 1.19. Initial pilot scale testing utilized 2.5" x 10" NanoCeram® cartridges with 5-micron pleated polypropylene cartridge prefilters. This configuration yielded approximately four (4) days of effective life for the NanoCeram® filters. After replacing the 5 micron filters with 1-micron pleated filters, the effective life of the NanoCeram® filters increased

to 6 - 7 days. Toyota has now installed HyFlo™ housings to incorporate 4.5" x 20" NanoCeram® filters and 1-micron prefilters.

Although the revamped system has not run long enough to determine any kind of life expectancy, cleaning cycles on the RO membranes have begun to extend out slowly.

The goal is to reach at least 6 months between cleanings. Toyota was actually replacing their membranes every 6 - 9 months due to premature fouling of the membranes beyond cleaning.

More Opportunities: Initial success in these applications has led to installations and/or pilot programs at other Toyota sites in North America. While data is still being collected at these other pilot sites, the early data is very promising. These include:

Chilled Water Loop Iron Removal
RO Prefiltration (Well Water)
RO Prefiltration (Municipal Water)
Die Cooling Iron Removal

Future testing is planned at:

Rinse Water Recycling
Weld Water Loop Iron Removal
Low-Level Oil Removal (using NanoCeram PAC)
RO Prefiltration
Metals Recovery from Waste Water