Technical Report

nextSand Filter Media

A report on the performance advantages of high purity nextSand over conventional filter media for pressure and gravity filtration applications.

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Background: Enhanced Particle Removal.

Improving water filtration performance translates to improved water quality and bottom-line cost savings. The dominant factor for particle removal from water using granular filter media is physical inertial impaction [i.e., direct, physical interception of the particle(s)]. Over the past 50 years, improvements in granular-media water filtration have been achieved by: a) using smaller mesh size sand to remove finer particles, b) by combining sand with garnet or garnet and anthracite (i.e. "multimedia" beds) which resulted in a lower nominal filtration range of 12-15μ for multimedia; and c) by improving the fluidics design of beds and vessels. Further enhancements in performance for granular filter media can be achieved by modifying the particle characteristics in the feed water stream or increasing the filter media surface structure and/or surface area to enhance particle inertial impaction.

Clinoptilolite Mineral Structure & Properties

Mineralogically, there are about forty known types of natural zeolites (hydrated silicates) known in the world. Clinoptilolite is one of these types but varies greatly in both structure and purity. It is recognized that *high-purity* clinoptilolite has ideal characteristics for use as water filtration media. In 2002 there were seven, open pit, clinoptilolite mines in the Western USA producing ~46,000 metric tons of product, with varying mineral composition used for agriculture, soil-amendment and other uses (Verta 2002). In 2003 only three clinoptilolite mines in the Western USA produced granular media for water filtration applications. Only *one* of these mines produces *high purity* clinoptilolite, and is the sole supplier of **nextSand** filter media.

The clinoptilolite used for **next-Sand** is mined, crushed, sieved (e.g. 14 x 40 mesh) and kiln dried. Natural, *high purity* **nextSand** filter media has the high surface area and high porosity in addition to surface micro-crystals that makes it an ideal filter media. The ultra-high surface area and surface micro-structure of nextSand significantly increases the probability for inertial impaction of particles for particle removal from water compared to conventional filter media.

High purity clinoptilolite silicate structures are characterized by low solubility in water and acid; low to moderate Specific Gravity, with comparatively high hardness. Based on crystallography, the basic atomic structure of **nextSand** media consists of four (4) atoms of oxygen equally spaced. With this tetrahedral crystal structure (Si2O4) oxygen atoms are shared with other Si2O4 structure to form the unique crystal framework (Fig. 1).

Fig 1. nextSand crystal structure.

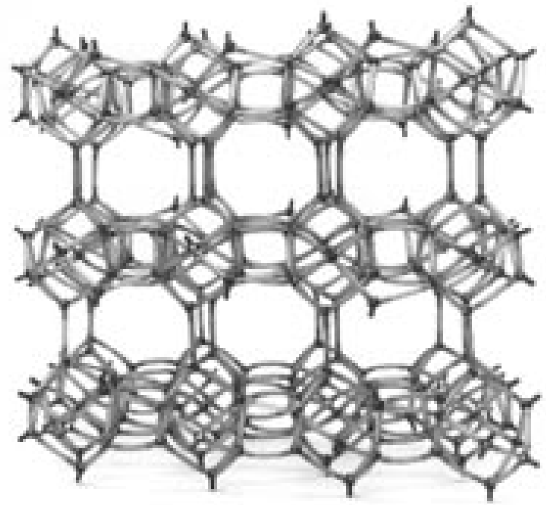


Table I lists characteristics for the high purity, hard **nextSand** filter media used in the water filtration tests outlined in this report. Figure 2 illustrates the typical micro-crystal structure (0.1 to 1μ spacing between surface crystals) of **nextSand**.

Mineralogically, clinoptilolite is classified as a crystalline aluminum oxide/silicon oxide, mineral consisting of hydrated Ca_2 (Na_2 or K_2) $Al_8Si_{28}O_{72}$•24 H_2O (Berkhout review; Rempel, 1996). Based on X-Ray Diffraction Analysis (XRD) of the mineral purity of natural clinoptilolite filter media sold in the USA the mineral content ranges from ~70 wt/% to >95 wt%. High surface area is important for the nextSand filter media. Unpublished surface area measurements in 1999 for clinoptilolite filter media from the Western USA, based on analytical measurements (Gemini Model 2360, Micrometrics, Inc., Norcross, GA) indicated: a) that the clinoptilolite used for water filtration ranges from 14 to 29m2/g; and b); the presence of mineral contaminants negatively impacts the surface area. The surface area of nextSand shown in Table I is indicative of **nextSand's** high purity.

Table I.
Physical properties of nextSand filter media.

Dry Bulk Weight	*55 lb/ft³*
Mesh Size	*14 x 40*
Color	*Light green-gray*
Surface Area	*26-27 m²/gm*
Surface Charge	*Net Negative*
Bed Void Volume	*55-58%*
Thermal Stability	*500°C*
Binding Material	*Opal $SiO_2 \bullet {}_nH_2O$*
Uniformity Coefficient	*> 2.0*

The *high purity* clinoptilolite used for nextSand is classified under 21CFR Part 182.2729 & 40 CFR Part 180 as GRAS (Generally Recognized As Safe), and is listed under NSF/ANSI 61.

nextSand Hardness & Media Longevity

The hardness, i.e., resistance to abrasion of zeolite filter media is determined by the clinoptilolite mineral purity, where higher purity is a favorable characteristic. In addition, the binding (or cementing/bonding) properties of the mineral impurities in the **nextSand** granules are important for abrasive resistance and water insolubility. Table II lists some of the common mineral impurities detected in clinoptilolite from the Western USA. Mica is ubiquitous in clinoptilolite deposits in the Western USA, but if the wt % is <0.25, then this would not be expected to compromise the granule hardness. On the contrary, mineral granules with 2.5 wt% or higher, would be expected to "break down" in the filter bed. Generally, if: a) the clinoptilolite purity is >85%; b) the smectite (e.g., clay) and mica are undetectable; c) calcite is <0.25 wt%; and d) the mineral is void of water soluble and/or "weak" shear-force mineral contaminants; and e) the clinoptilolite crystals are strongly bonded, then the media would be expected to be resistant to abrasion. Conversely, when significant clay, mica quartz and/or water-soluble impurities are present the mineral hardness is compromised. Table II lists the common mineral contaminants found in Western USA clinoptilolite deposits and the expected effects on abrasion resistance. ***The rare high purity of the nextSand mineral sets it apart from all other known clinoptilolite deposits and the presence of Opal in nextSand's mineral structure provides superior strength and stability.***

Table II.
Common clinoptilolite contaminants and effects on media abrasion resistance.

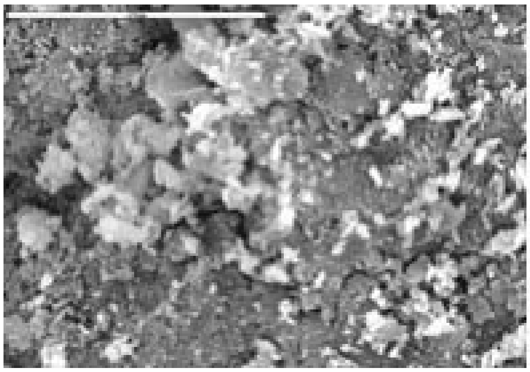
Mineral Contaminant	Effect on Abrasion Resistance
Calcite: (Calcium Carbonate)	*Low water solubility, acid soluble, porr abrasion resistance.*
Feldspar: aluminum silicate of soda, potash or lime.	*Water soluble, glassy crystals, low abrasion resistance.*
Mica: Hydromica, <1 %	*Relatively inert, but soft; poor zeolite bonding, poor abrasion resitance*
Opal C-T: amorphorus silica, quartz. (green color)	*Water insoluble, strong binding, abrasion resistant.*
Quartz Translucent, hexagonal, silicate quartz.	*Water insuluble, moderate zeolite binding, abrasion resistant.*
Rutile: fine, mineral crystals, golden to black or red color.	*Brittle crystals; low abrasion resistance.*
Smectite: "Clay", monomorillonite.	*Water Soluble, weak binding, low abrasion resistance.*

The authors have not observed a single case of *high purity* **nextSand** media undergoing bed loss (attrition) in pressure vessels or gravity flow beds over the past several years representing ~10 water filtration projects and numerous test evaluations.

However, we are aware of "breakdown" occurring for clinoptilolite from other Western USA clinoptilolite deposits. These breakdowns were attributed to the presence of smectite (clay), calcite and/or weak shear-force mineral contaminants. These findings support the claim that the high purity mineral used in **nextSand** is a unique form of clinoptilolite with ideal properties for water filtration.

Only *high purity* **nextSand** media has the quality and purity needed to achieve reliable filtration performance and filter bed longevity.

Figure 2.
High magnification SEM showing micro-crystals (0.2 to 0.9μ spacing) on nextSand media.



Performance & Advantages of nextSand Filter Media.

Since the mid-1970's lab and field test data has been accumulating in the USA that demonstrated the utility of *high purity* clinoptiolite as a water filtration media. **nextSand** has out-performed conventional sand and sand/anthracite media for both pressure vessels and gravity filtration beds (Foreman, 1985, McNair et al, 1987; Hansen, 1997; Johnson et al, 1997; Johnson & David 1999). Generally, the **nextSand** filter beds operate at less than half the hydraulic loading rate of 20 x 40 mesh sand and 50% of sand/anthracite or multimedia. Interestingly, **nextSand** media has proved effective for removal of Giardia lamblia cysts and E. coli bacteria, where sand failed (McNair et al, 1987; Foreman, 1985). Since 1985 scattered reports and numerous technical and engineering studies have demonstrated the utility of *high purity* **nextSand** as a water filter media.

Since the mid-1990's, **next filtration technologies inc.** (NFTI) has conducted >100 **nextSand** filter media lab and field tests. **nextSand** has been successfully used for well water, drinking water, surface water, pre-reverse osmosis (R/O) and industrial wastewater filtration applications. The NFTI water filtration tests used 14 x 40 mesh **nextSand** media vs. 20 x 40 mesh sand, sand/anthracite (1:2 ratio) or multimedia. Two-thirds of the tests utilized pressure vessels at 12-20 gpm/ft^2 and one-third of the tests, gravity flow at 2-4 gpm/ft^2 flow rates. Table III Summaries the NFTI filtration test results obtained for *high purity* **nextSand** vs. conventional, filter media. The test results indicate the following.

First, that the solids loading capacity of **nextSand** media was superior, with declining performance as follows; >multimedia>sand/anthracite>sand. **nextSand** had 1.5-2X higher solids loading capacity per ft3 than multimedia beds.

Second, **nextSand** is a superior water filtration media, particularly for removing fine particles in the 0.5μ to <10μ range that escape conventional media.

Third, **nextSand** functions as a true depth filter.

Fourth, **nextSand** beds reduce the backwash frequency compared to conventional granular media and,

Fifth, the superior solids loading capacity and filtration performance of *high purity* **nextSand** applies to both pressure vessel and gravity flow beds.

Table 2.
nextSand vs. conventional media performance (pressure vessels)

Filter Media	Filter Rating (nominal)	Solids Loading Capacity
Sand (20x40 mesh	~20 micron	1X
Sand/Anthracite (20x40 mesh & Anthracicte	~15 micron	~1.4X
Multimedia[1]	~12 micron	~1.6X
nextSand (14x40)	<5 micron	~2.6X

[1] Multimedia bed volume-#12 garnet (9%), #50 garnet (18%), 20x40 mesh sand (30%), GAC (43%)

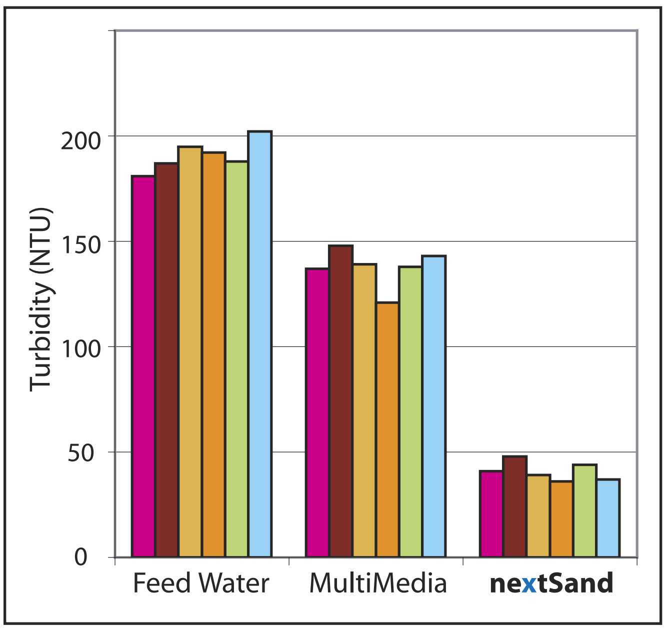
Real-World Performance of nextSand

An example of the superior fine particle filtration performance of **nextSand** is provided in Figure 2. The histogram plot shows filtration results for turbidity (NTU) removal of river water clay & TOC particles for **nextSand** vs. multimedia.

The mid-2004 field tests were conducted in

Houston, TX testing NTU for six consecutive filtration days (8 hrs filtration per day with backwash cycles at the end of each day). The **nextSand** filtrate averge NTU was 70% *less than* the multimedia filtrate indicating that nextSand more efficiently removed the turbid particles. Several other **nextSand** applications are provided below.

Figure 2.
nextSand vs. multimedia removal of surface water turbidity (NTU). Feed water & filtrate are plotted for nextSand vs. multimedia representing six 24 hr, D) pressure vessel runs @ 12 gpm/ft2.



Bottled Water Plant

A major bottled water plant in Mexico, pumped ground water to four, parallel filtration vessels (48"dia/ea, 3 ft bed ht) that serve as pretreatment to two RO units. A two month, "on-line" test was carried out using two of the filter vessels filled with nextSand and two filled with multimedia tracking the feed water and filtrate SDI's. The results indicated that **nextSand** reduced the SDI by 50% while multimedia reduced the SDI by just 5%. The **nextSand** media provided superior pre-filtration for the RO equipment for one year without any problems or bed loss.

Drinking Water Plant

A resort on San Juan, Island, Pacific Northwest installed a new drinking water plant to supply drinking water to the resort and local residential customers. The design engineers conducted pilot tests and worked with the Washington State Public Health Department, then installed a 220 gpm system to remove colloidal and micro-particles from lake water (4-19°C). Three parallel gravity-flow, **nextSand** filter beds (3 ft bed ht, with 12" under gravel) have operated at ~4 gpm/ft2 flow rate for two years, filtering DAF decant water and providing high quality (<0.25 NTU, <1 mg/l TOC's) drinking water.

Cooling Tower Makeup Water

A major chemical plant in South Texas pumps river water for cooling tower make-up water but had periodic turbidity problems due to rain events. Filter pilot tests indicated that the turbidity was predominantly colloidal and that **nextSand** filter media removed >98% of the turbid particles. The customer replaced the sand and garnet media in a gravity filter unit with 30,000 lbs (545.5 ft3) of **nextSand**. The **nextSand** media continues to provide superior filtration performance after several years operating at 2-3 gpm/ft2 flow rate, including periods of high turbidity "spikes".

Boiler Feed Makeup Water:

An electric power plant in Louisiana installed a well water pumping station water treatment facility and new RO equipment to provide boiler feed make-up water. Multimedia was specified for use in two carbon steel pressure vessels (750 gpm/ea, 3 ft bed ht) as pretreatment to the RO equipment. The plant start-up was delayed several months due to failure of the multimedia system to meet the RO filtrate volume and SDI specifications. The two multimedia beds were replaced with equivalent volumes of 14 x 40 mesh nextSand media. The **nextSand** media has consistently performed to the original strict design specifications for the RO feed water and low SDI for over two years. No significant **nextSand** bed loss has been observed.

"Produced Water" Filtration

An oil company operating in Texas and New

Mexico wanted to convert unusable oil production produced water into reusable irrigation water. Early in 2004 a water treatment and filtration pilot test was conducted at the oil product site. The produced water was processed for oil/water separation, flocculation, clarification then filtration using two, parallel pressure vessels (72 inch dia.), with **nextSand** operating at ~10-12 gpm/ft^2. The filtrate was used directly as feed water for an RO unit which recycled the water as agricultural irrigation water.

Summary & Conclusions

The unique *high purity* clinoptilolite used for **nextSand** has the physical and mineral properties needed for reliable and efficient water filtration applications. **nextSand** is a direct replacement (volume for volume) for sand, sand/anthracite or multimedia in pressure vessels or gravity beds. **nextSand** has a lower dry bulk weight of 55lb/ft3 than sand or garnet, which translates to lower freight costs.

nextSand performs as a true depth filter–the water flows through the porous crystalline matrix as well as around the **nextSand** granules in the filter bed. Based on published reports and NFTI lab and field data the following conclusions can be made for **nextSand** filter media. First, **nextSand** is a superior filter media compared to sand, sand/anthracite, sand/garnet or multimedia. Second, **nextSand** is cost-competitive with multimedia and eliminates the requirement for warehousing, shipping and loading multiple media layers into the vessel. Further, **nextSand** has several other advantages vs. conventional granular media, which are:

- **nextSand** operates at lower differential pressure with superior performance at high flow rates.
- **nextSand** has higher solids loading capacity.
- **nextSand** filters reduce the backwash frequency by ~50%.
- **nextSand** more effectively removes fine particles (<10μ).

nextSand is inert and stable over pH range <1 to <12. The unique *high purity* of **nextSand** ensures superior hardness and abrasion resistance for longest media life.

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