MetaMateria
Environmental NanoTechnology

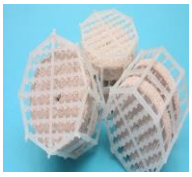
# Bio-Lair for Water Remediation


Bacteria are absolutely essential for natural recycling of nutrients throughout the environment and they biologically maintain healthy water by breaking down nitrogen, carbon, and other contaminants; they can even biologically incorporate phosphorus. This is nature's way of controlling contaminants, and for a normal environment, already existing bacteria can often do the job; however, when excess contaminants exist, such as proteins, oils or pathogens, or when oxygen is too low, water quality suffers and supplemental bacteria can provide the extra help needed. Often, special blends of bacteria can be used to handle a broader array of organic contaminants, which cleans water faster.

Bacteria reproduce on solid surfaces; therefore, the more surface area available for beneficial bacteria to multiply, the larger their colonies can be.

Because BIO-Lair media contains such high surface area for bacteria colonization and as long as nutrients are available, it can sustain much more bacteria in the water used to break down contaminants. Over 15,000 mg/L of bacteria were measured in water downstream of the media, as compared to 2500 mg/L typically found in waste water. Since bacteria break down contaminants, it makes sense that higher concentrations of bacteria accelerate cleaning of water, which is seen in many dirty water applications.

BIO-Lair is a **unique, highly porous ceramic** differentiated by its high surface area and open interconnected porosity. This allows water to easily flow through or into the media. It can pass 10 times more water than a sand filter at the same pressure. The porous media holds its weight in water, making bacteria colonies less susceptible to rapid environmental changes. The high surface area of BIO-Lair also allows multiple colonies of bacteria to co-exist. Aerobic bacteria for nitrification can multiply near the product surface, while anoxic zones are created inside for denitrification. Beneficial bacillus bacteria can be added to help break down and oxidize organic compounds. BIO-Lair enhances performance of biological waste treatment systems such as water with suspended microorganisms, trickle filters and sophisticated Membrane Bio-Reactors.



Product is available in many shapes and compositions; providing flexibility for use in existing or new systems. It can be packaged in durable plastic or in nets suspended in dirty water. It can be used in many water clean-up applications. Durability provides long life, it does not release harmful chemicals and can be washed clean, if needed. Typical properties are:

| | |
|---|---|
| Specific Surface Area | 12-15 $m^2$/gram (>40,000 $ft^2$/pound) |
| Bulk Density | ~285 g/cc (18 pounds/$ft^3$) |
| Typical Surface Area per Unit of Volume | 2,100,000 $m^2/m^3$ (700,000 $ft^2/ft^3$) |
| Typical Pore Distribution: Cell Wall | 0.5-5 microns |
| Connecting | 50-200 microns |
| Large | 200-500 microns |



MetaMateria • 870 Kaderly Dr. • Columbus OH 43228 • 614-340-1690 • metamateria.com

## BIO-Lair is available in different shapes and packaged in plastic or netting

***Pieces***

***Discs***

***Disc in Cage***

***Bricks***

***Packaged in Netting***

Since most process variables generating waste water cannot be changed, a treatment system is often more focused on Operational Variables, including the type of media used to host the microorganisms that can be used to break down organic and nitrogen contaminants. This also helps limit sulfur compounds from forming.

**Process Variables**
Flow past media
Contaminant concentrations
Process variability
Temperature
Dissolved oxygen
pH and alkalinity
Presence of toxic chemical inhibitors

**Operational Variables**
Internal recycle rates/ratios
Quantity of bacteria present per unit volume
Methods to contact contaminants with active bacteria
Type of bacteria present
Oxygen delivery mechanism(s).

### *High Specific Concentration of Bacteria*

The greatest limitation of any biological treatment system is the quantity of active microorganisms available to break down the contaminant(s). In an aerobic basin the quantity of bacteria depends upon the type and amount of bacteria for aeration/recirculation for operation under anoxic conditions. This is typically limited to about 2,500 ppm (approximately 2.5 kg of microbes per $m^3$ of system volume[1]) – above that, microorganisms begin to settle out and do not appreciably add to digestion. In an attached growth system (such as BIO-Lair), the limitation is a function of the surface area on which the microbes are attached. To reduce the footprint of a system, it is best to maximize the surface area per unit volume.

Commonly used media, such as Plastic Rings, Saddles, etc. have surface areas on the order of a 100 to 1000 square meters per cubic meter of media ($m^2/m^3$). Typical bacteria found in industrial treatment systems range from 2 to 5 microns in size, with a density near water (~1 gm/cc). A single layer of microbes covering this area provides about 2 kg of microbes per $m^3$ of system volume.[2] An active colony 5 layer thick reaches 10 kg per $m^3$.

[1] 5000 ppm by wt. * 1,000 kg/m3 = 5kg/m3
[2] Using 1,000 m2/m3 of media: 1,000 m2 * 2 micrometer microbe thickness * 1,000 kg/m3 = 2 kg microbes

***BIO-Lair*** has surface area typically over 2,000,000 $m^2/m^3$ with an average pore size for biofilm growth of 25-50 microns. This pore size is large enough to efficiently conduct water at a low pressure drop and will support a thick bio-film. A single layer of microbes covering this area would provide about 300 – 800 kg of microbes per $m^3$ of system volume.[3] Even with a very conservative assumption that most of the pores are unavailable; this provides 30 – 80 kg of microbes per $m^3$ of system volume, which is an order of magnitude higher than competitive media systems. Thus, BIO-Lair can be expected to provide higher volumetric efficiency, which can in significantly reduce capital equipment, increase output and operating costs for many systems.

## ***Contact Efficiency***

The reaction mechanism for converting $NH_3$-N, organics, and other compounds is common technology, because most biological processes employ similar microorganisms. An advantage of using the BIO-Lair porous substrate comes from deployment in circulation patterns to constantly sustain bacteria in the surrounding water (imagine a cloud of bacteria continually leaving the porous substrate. Bacteria in the media have time for denitrification and other reactions. The hydraulic retention time (HRT) is the average time required for wastewater to be held within the system volume to provide sufficient contact for contaminant reduction. This is a statistical average of time for a contaminant to have a reactive contact with a microbe. In a suspended system, water and microbes are circulated and aerated (for an aerobic system) which can be very time consuming to ensure a sufficient quantity of contaminant is reacted. In a packed bed or other attached growth system, water is circulated by or passed over the media, which improves the HRT. Some low efficiency systems, such as a simple aerated basin, may have HRTs on the order of days, but more efficient designs will include attached growth systems that have shorter HRTs, but will still typically be on the order of several hours or more. With BIO-Lair, HRTs as low as 10 minutes have provided an 80% reduction in ammonia concentration. HRTs of only 6 minutes for denitrification have consistently yielded reductions of 30 ppm (laboratory testing).

Fast reaction times can occur with the use of blends of bacillus and other types of bacteria at the high concentrations of active bacteria provided by BIO-Lair. These enzymatic bacteria are particularly suited for handling a broader array of contaminants. Soaking BIO-Lair with such blends enhances inoculation and start-up of bioremediation. For waste water containing many different types of contaminants and even cyanobacteria, a proper blend containing Bacillus, Pseudomonas and other strains of beneficial facultative anaerobic bacteria can be especially useful. These bacteria strains complement each other to provide all-around treatment by generating enzymes that target degradation of specific organic substances (e.g. oils, grease, carbohydrates). This lowers BOD-COD levels and reduces sludge buildup. It provides a balanced biological population that is supported on the BIO-Lair media. This type of bacteria often performs well in low dissolved oxygen environments. A combination of BIO-Lair and such bacteria blends will break down cyanobacteria (blue-green algae). In a suspended system, BIO-Lair acts as a ***Bacteria Multiplier*** constantly replenishing microbes in water as water circulates by the media.

One effective Bacteria blend used effectively with BIO-Lair to treat waste water is pureBacteria EB™. This consumes inorganic nitrogen and generates enzymes (lipase, protease, amylase, cellulose, and urease) that target animal and vegetable fats, oils, grease and phenolic compounds and helps lower BOD-COD levels. It will lower overall sludge buildup. It performs well even in low dissolved oxygen environments, although more rapid degradation occurs under aerobic conditions. It will reduce odors associated with organic loading and hydrogen sulfide gas production. It is active from 4°C to 60°C, with optimal range of 25°C to 40°C and a pH of 5.5 – 9.0. It is an environmentally safe formulation and contains no pathogenic bacteria.

[3] Using 100,000 m2/m3 of media: 100,000 m2 * 2 micrometer microbe thickness * 1,000 kg/m3 = 200 kg microbes

## *Nitrification - Oxidizing Ammonia and Nitrite*

Biological conversion of ammonium to nitrate nitrogen (NO3-N) is called nitrification. It is a stepped process that uses aerobic bacteria to convert ammonia (NH3-N) to nitrite (NO2-N), which is converted to nitrate (NO3-N). Oxygen availability is important, as is maintaining alkaline conditions for active bacteria. The high surface area provided by BIO-Lair media allows more growth of large active biocolonies than alternative media. BIO-Lair provides well over 2,000,000 $m^2/m^3$ of surface area, which is 100-900 times other media. It easily removes over 30 grams of total ammonia nitrogen (TAN)/$ft^3$ of media/day and can be even higher with BIO-DN. Plastic media provides only 200-800 $m^2/m^3$ of surface and even expanded sand filters are only 5,000-7,000 $m^2/m^3$ and remove only 5 grams TAN/day. Performance is usually limited by the availability of ammonia, oxygen and alkalinity. BIO-Lair provides unused capacity to handle rapid changes (spikes) in nitrogen levels.

A unique characteristic of porous BIO-Lair is the interconnected, hierarchical three-dimensional pore structure, ranging in size from millimeters to nanometers. This complex network provides an ideal substrate for both the development and the nourishment of many types of beneficial bacteria and because water easily flows into or through the structure, more of the available surface area is available for use.

The composition of BIO-Lair can include other useful materials (such as carbonates, zeolites, sulfur, etc.). This provides flexibility in both product shape and composition, making it suitable for bio-trickling filters, fixed bed filters and even moving bed reactors, where media is protected in plastic. The BIO-Ca product contains aragonite as a calcium source, which provides regulation of pH drops due to active bacteria.

Testing of BIO-Lair products show NH3-N can be reduced from 6 mg/L to <0.1 mg/L in a few minutes and 30 mg/L of NO2-N dropped to under 5 mg/L in 15 minutes. In one industrial application, ammonia in water was lowered from 300-700 mg/L to under 10 mg/L, with a short liquid residence time, using BIO-Lair to hold bacteria colonies in plastic located in circulating water. Oxygen and alkalinity were regularly added to the water.

## De-Nitrification

All types of BIO-Lair products have been used for years for biological conversion of nitrate (NO3-N) to nitrogen gas (denitrification) in waste water and aquaculture systems. A higher performance is seen compared with most other commercial products. Testing shows that anoxic conditions can develop within the thickness of the material, while aerobic bacteria on the surface layer removes any residual oxygen. A new composite product (BIO-DN) was developed that also contains electron donors to support autotrophic bacteria colonies and the carbonate buffer to control pH. This product will also supports aerobic bacteria near the surface to lower oxygen so heterotrophic bacteria colonies will exist inside. The DN product operates with low dissolved carbon for standard nitrate reduction, but needs higher carbon when bacillus bacteria are used.

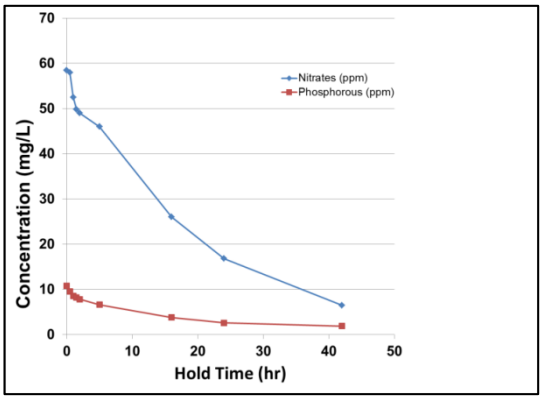
Testing of BIO-Lair media in a recirculating aquaculture environment (3000 liters) showed nitrates reduced 10 fold (from 225 to 20 mg/L) once denitrifying bacteria colonies were established (6 grams of nitrate-nitrogen (NO3-N) per 1500 gram media). Lab testing in an up-flow column filter, filled with 1.6 cm BIO-Lair balls and a 12 min residence time, removed over 450 gm of NO3-N per cubic foot/day.

The BIO-DN product removed significantly more nitrate than regular BIO-Lair media. Testing in an up-flow column filter filled with 1.6 cm balls, over 900 grams of ($NO_3$-N) were removed per cubic foot/day. Water contained carbon at 0.5:1 C:N ratio.

The DN product tested at higher influent levels **removed over 35 Kg/$m^3$ media/day**, some three times higher than reported values. DN contains a carbonate buffer to balance acidic conditions and an electron donor (sulfur) for autotrophic bacteria.

## Phosphorus Nutrients

MetaMateria also manufactures a highly effective porous product (PO4 Sponge) for removing soluble phosphorus (P) from water. MetaMateria's PO4 Sponge product absorbs considerably more P than competitors, especially at very low P concentrations. PO4 Sponge represents a cost effective alternative to chemicals that are expensive and represent increased complexity in the treatment process.




P can also be tied up biologically in bacteria and other living creatures and chemically. When anoxic conditions are created within the porous BIO-Lair (low-oxygen), some of the calcium ions in the composition are made available by a lower pH caused by bacteria and this will also remove some phosphorous. This graph shows BIO lowering both nitrate and phosphorus. When BIO products are used with MetaMateria's PO4 Sponge, some additional phosphorus will be removed from water.

Contact us for additional information on PO4 Sponge products.

## ***Benefits of BIO-Lair for Waste Water Treatment***

- Biomass will multiply rapidly on submerged BIO products with very high surfaces, limited by nutrient availability
- High surface area allows lateral biomass growth rather than thick films
- Shape allows use of product packaged in a variety of plastic shapes or netting
- Can function at moderate dissolved oxygen concentrations (typically DO of <5 ppm)
- Can works at lower C:N or BOD:N ratio, typically under 2BOD:N; higher for bacillus bacteria
- Sulfates or excess biomass do not clog the porous BIO product under normal operating conditions
- High denitrification rates exist relative to alternatives – 8 to 35 Kg/m$^3$/day achieved
- Residence time (EBCT) is typically 15-60 minutes, much shorter than needed with other media

## *For additional information:*

**Dr. Richard Schorr, CEO**
jrschorr@metamateria.com
614-599-0939 (mobile)

**Tim Marth, VP**
tmarth@metamateria.com
614-499-2617 (mobile)

**Dr. Suvankar Sengupta, CTO**
ssengupta@metamateria.com
614-596-6842 (mobile)