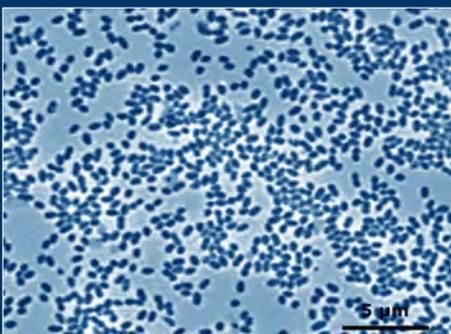


Fluidized Bed Bioreactor

- *Cost-Effective*
- *Environmentally Safe*
- *Compact & Portable*





create: value | quality | response

With more than 20 years of experience, Cardno ERI provides safe, environmentally sound, and cost-effective treatment for gasoline constituents.

Cardno ERI has years of proven success providing our customers and partners with environmental solutions that exceed expectations and protect the environment. Our team has extensive expertise in earth sciences, engineering, research, information technology, and construction.

Cardno ERI and faculty from the University of California at Davis (UC Davis) have collaborated to develop a line of compact, practical, and effective bioreactor systems to treat contaminated groundwater. Bioreactor-based water treatment involves pumping groundwater out of the ground, mixing it with active microorganisms in a bioreactor system, and discharging the newly treated water. The treated water is either sent back into the ground, to a municipal sewer system, or into surface water.

The bioreactor groundwater treatment technology developed by Cardno ERI and UC Davis includes an aboveground tank containing trillions of microorganisms, primarily bacteria that attach themselves to the surfaces of fine grains of sand. The grains are distributed throughout the tank by the upward flow of the water passing through the tank for treatment. As the contaminated water mixes with them, the microorganisms consume methyl tertiary butyl ether (MTBE), tertiary butyl alcohol (TBA) and other dissolved gasoline components as food.

Cardno ERI bioreactors can treat a wide range of contaminant concentrations because of the way their distinct water recycle loop dilutes the incoming process water. Cardno ERI's bioreactors have handled extremely high concentrations (up to one million micrograms per liter of gasoline constituents), reducing them to non-detectable levels.

Applicable Compounds

The microbes used in the Cardno ERI system biodegrade ethers such as MTBE, TBA, diisopropyl ether (DIPE), tertiary amyl methyl ether (TAME), and ethyl tertiary butyl ether (ETBE). They also biodegrade gasoline petroleum hydrocarbons such as benzene, toluene, ethylbenzene, and xylenes (BTEX). The bioreactor can be used to treat fuel oxygenates and petroleum hydrocarbons. However, if extremely high concentrations of petroleum hydrocarbons are present, the water should be pretreated using more conventional technology such as activated carbon or air stripping; ethers and alcohols will break through the pretreatment process for subsequent removal in the bioreactor.



Ancillary Equipment

Sufficient oxygen must be provided for the aerobic microorganisms to consume the VOCs. Use of an oxygen booster can double the bioreactor capacity by elevating dissolved oxygen concentrations. Dissolved oxygen concentrations as high as 38 milligrams per liter have been achieved.

When the water is oxygenated, dissolved iron, manganese, and hardness can form nuisance precipitates that can cause clogging and other problems. Moderate concentrations of these precipitates are removed by means of a bead filter or filter pad. If concentrations are extremely elevated, pretreatment may be necessary. In addition to food (VOCs) and oxygen, the biomass requires nutrients – particularly nitrogen, phosphorus, and potassium. A nutrient solution can be metered into the feed tank to satisfy this need.

A flow switch and autodialer are included in Cardno ERI bioreactor systems to notify the operator should the recirculation flow be interrupted. Water temperature and pH must be maintained within a normal operating range. When necessary, Cardno ERI bioreactors can be equipped with systems for pH adjustment.

Cardno ERI bioreactors can treat a wide range of contamination concentrations because of the way their distinct water recycle loop dilutes water coming out of the ground.



Cardno ERI-500 Fluidized Bed Bioreactor

- Light and portable.
- Includes bioreactor tank with sand media, feed tank, recirculation pump, oxygenator tower, filter pad, and flow switch on a 4' x 4' skid.
- Auto-dialer, plastic drum, and pump for nutrient solution are included but are not located on the skid.
- Can treat 0.2 pound per day of VOCs.
- If oxygen booster is added, can treat 0.4 pound per day of VOCs.

Cardno ERI-4000 Fluidized Bed Bioreactor

- Includes bioreactor tank with sand media, feed tank, recirculation pump, oxygenator tower, bead filter, and flow switch on a 6' x 10' skid.
- Auto-dialer, plastic drum, and pump for nutrient solution are included but not located on the skid.
- Can treat 1.3 pounds per day of VOCs.
- If oxygen booster is added, can treat 3 pounds per day of VOCs.





Features and Benefits:

The effectiveness of the technology has been proven by successful full-scale use of Cardno ERI bioreactors at dozens of gasoline release sites.

- Naturally occurring microorganisms are employed.
- The microorganisms permanently destroy the contaminants rather than merely transferring them to another medium (such as to air or activated carbon).
- The treated water has very low or non-detectable contaminant concentrations.
- The biomass is extremely resilient, adapting well to changes in contaminant concentrations, temperature, and other conditions.
- The bioreactor system has a partial recycle loop that provides operational flexibility and enables the bioreactor to operate at peak efficiency under varying conditions.
- The equipment is compact, quiet, and odor-free.
- Cardno ERI bioreactors are minimally impacted by clogging and precipitates compared to other technologies. In particular, high manganese concentrations are well tolerated.
- Removal efficiency is high under a wide range of water temperatures.
- Discharge of effluent (containing bacteria and high levels of dissolved oxygen) back to groundwater can be used to promote *in situ* bioremediation and flush the smear zone.
- Groundwater extraction makes hydraulic control possible, and contamination plumes can be pulled back from sensitive receptors.

- Small volumes of waste are generated.

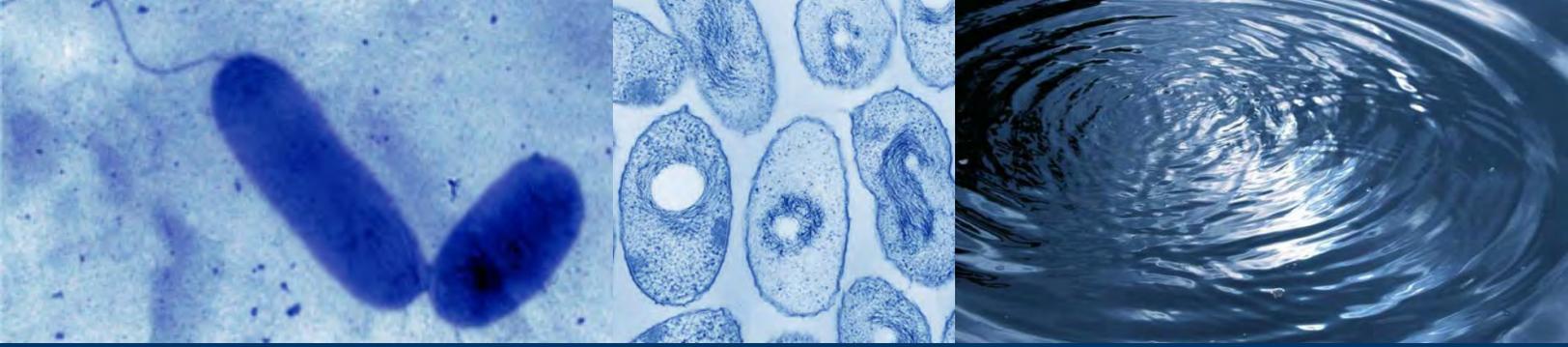
- When remediation is complete, the bioreactor can be reused at another site.

Mass Loading

Cardno ERI bioreactors are sized to treat a specific mass loading which is equal to the total flow rate of water to be processed times the total volatile organic compound (VOC) concentration in the recovered water. In a well-executed remediation project, initial VOC concentrations typically decrease over time as the site is remediated.

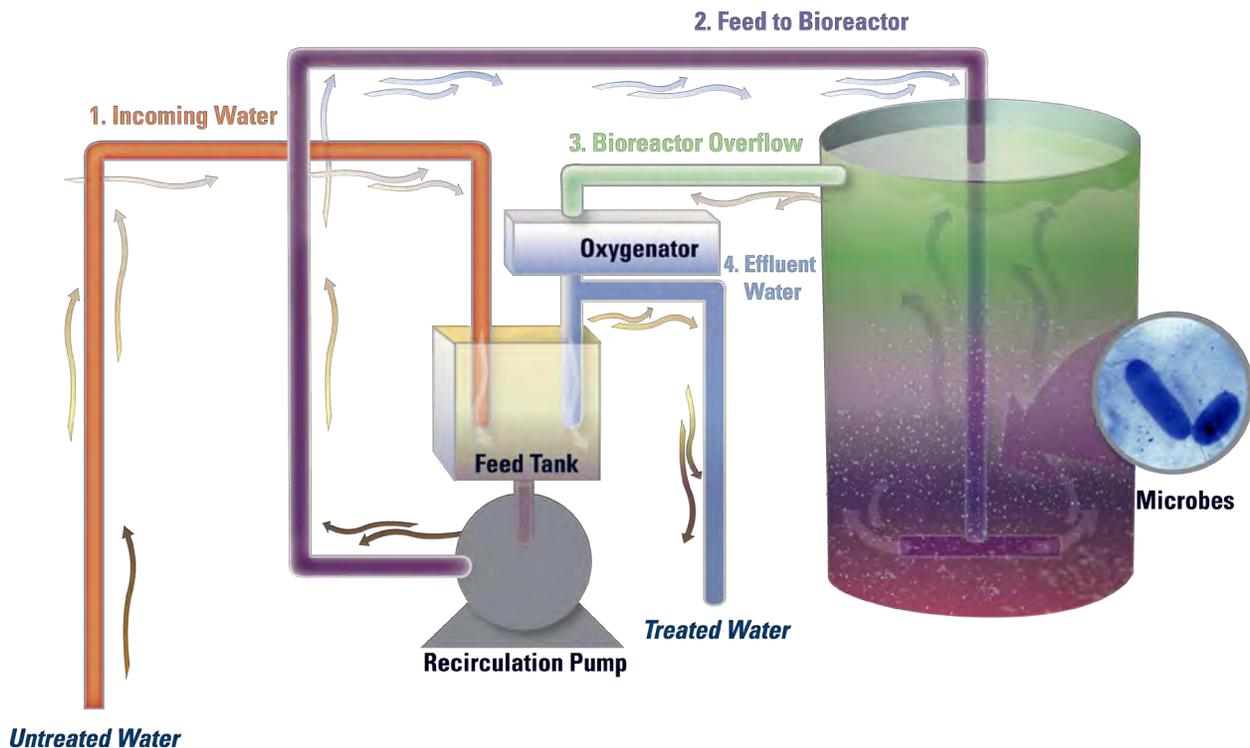
As VOC concentrations decrease, the influent flow rate of water from the recovery wells can be increased such that a constant mass loading enters the bioreactor system for treatment, thus allowing more water to be processed.





Schematic Operation of Fluidized Bed

1. Water from the site recovery wells enters the feed tank where it is diluted with treated water exiting from the bioreactor.
2. The mixed water stream is pumped to the bottom of the bioreactor where it flows upward through the sand medium, which is colonized by microorganisms. The microorganisms consume VOCs present in the water, converting them to carbon dioxide and water and using dissolved oxygen in the process.
3. Treated water with a decreased dissolved oxygen content flows from the bioreactor through an oxygenator where it is reoxygenated to near saturated levels (typically around 8 milligrams per liter).
4. Much of the treated water is recycled to the feed tank to dilute the incoming well water; while an amount equal to the incoming well water is discharged from the system. The treated water typically has effluent VOC concentrations that are at, or below, detection limits.



Handling of Bioreactor Effluent

The water exiting the bioreactor is often filtered and then passed through a pair of activated carbon canisters before final discharge to groundwater, surface water, or municipal sewer system. Since the gasoline constituents have been consumed, the carbon is not necessary for treatment under normal conditions but merely serves as a backup should there be a sudden increase in influent VOC concentrations from the site or an upset in the bioreactor.

An alternate strategy is to discharge the oxygenated treated water directly to groundwater without final carbon polishing. This provides oxygenated, treated water containing bacteria to the subsurface, thus promoting *in situ* bioremediation at the site at the same time that the *ex situ* treatment is taking place. In some cases, discharge of this effluent to the source area can also be used to flush the smear zone, making gasoline constituents more amenable to *in situ* bioremediation.



Specifications for Standard Cardno ERI Fluidized Bed Bioreactors

Parameter	Units	Cardno ERI-500	Cardno ERI-4000
<i>Flow Rates and Mass Loading</i>			
Maximum VOC mass loading without oxygen booster	µg/L-gpm (pounds/day)	20,000 (0.2)	110,000 (1.3)
Maximum VOC mass loading with oxygen booster	µg/L-gpm (pounds/day)	40,000 (0.4)	250,000 (3.0)
Fixed recycle flow rate	gpm	10	50
Maximum hydraulic loading	gpm	7	30
Hydraulic residence time in bioreactor tank	minutes	15	15

<i>Dimensions</i>			
Tank diameter	feet	2	5
Tank height (with fittings)	feet	10.5	11.5
Capacity of tank	gallons	250	1,500
Skid for tank, feed tank, filter, O ₂ tower	feet x feet	4 x 4	6 x 10

<i>Weight</i>			
Empty	pounds	400	3,800
Loaded with media, biomass, and water	pounds	3,000	19,000

<i>Optimal Water Parameters</i>			
Temperature	°F	50 - 95	50 - 95
pH	std. units	6.5 - 8.5	6.5 - 8.5

<i>Operation & Maintenance Requirements</i>			
On-site labor	hours/week	1.5 - 2.5	2 - 3
Power (for bioreactor only)	kilowatts	0.9	1.5
Materials, chemicals, parts, sludge disposal	US\$/month	100	200

In addition, Cardno ERI bioreactors can be custom designed for virtually any mass loading by varying the size of the bioreactor tank footprint.

For information about the Cardno ERI Fluidized Bed Bioreactors:

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