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PermeOx[®] Plus Frequently Asked Questions (Release 2.0)

1. What is the history of PermeOx[®] Plus?

Calcium peroxide, the main ingredient in **PermeOx[®] Plus**, is manufactured by FMC Corporation for a variety of industries including the food industry, and the agricultural industry to promote seed germination. **PermeOx[®] Plus** is a special formulation of calcium peroxide developed for use in the environmental industry for enhancement of phytoremediation, municipal and industrial wastewater treatment and odor control, as well as to accelerate the bioremediation of soil and groundwater contamination.

After originally developing and manufacturing a magnesium peroxide-based slow release compound in the early 1990's, FMC elected to review and improve its original formulation. **PermeOx[®]** was developed as an optimum replacement for magnesium peroxide for its ease of handling, increased solubility, and primarily for its improved oxygen content. The original formulation of **PermeOx[®]** was further refined in 2001 into **PermeOx[®] Plus**, a product with less dust, higher oxygen content, longer oxygen release rates and available at a lower cost than other competitive products.

2. Is literature, including case studies and technical information available on PermeOx[®] Plus?

A wealth of information exists on **PermeOx[®] Plus** and its parent compound calcium peroxide which documents its superior oxygen release rates. Case studies are being developed daily. Numerous studies are available that were completed as long ago as 1993 on the original **PermeOx[®]** formulation, including successful applications at petroleum sites, diesel spills, and creosote contamination. Regulatory agencies across the country have been provided with up to date information on **PermeOx[®] Plus** and have approved hundreds of sites for in-situ and ex-situ applications. **PermeOx[®] Plus** has been used in many states across the USA, Canada and internationally. Substantial studies have been performed by FMC's Princeton Research Facility as well as by third party laboratories over the last two years, comparing **PermeOx[®] Plus** to the leading magnesium peroxide product on the market. These studies demonstrate that significant improvements in oxygen release over longer periods of time have been demonstrated by **PermeOx[®] Plus**, all for a lower cost.

3. What are the primary benefits/advantages of PermeOx[®] Plus over competing products (magnesium peroxide)?

- a. Sustained Oxygen Release - **PermeOx[®] Plus** provides much greater oxygen release over a longer period of time than competing products. Based on recent laboratory data, **PermeOx[®] Plus** has been shown to continually release oxygen over a period of 350 days or more, where magnesium peroxide showed a much lower release of oxygen over the same period in hundreds of laboratory tests. These data also indicate that the magnesium peroxide formulation locked up upon hydration, preventing release of all its available oxygen.



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- b. Percent Oxygen – The active oxygen content of **PermeOx[®] Plus** is more than 18% as compared to less than 10% for magnesium peroxide based on tests performed by FMC’s Princeton Research Laboratory. As a result, for every pound of **PermeOx[®] Plus** product placed in your application, 80% more oxygen will be released.
- c. Cost - The cost per pound (lb) of product is substantially less than that of competing products. While actual costs are based on the quantity ordered, a current savings of up to 20% over competing products will be realized (assuming \$10 per lb for the leading competitor versus \$8 per lb for **PermeOx[®] Plus**). More importantly, the cost per pound of oxygen delivered is greater than 50% less than the cost of competing products (\$100 per lb oxygen for the leading competitor as compared to \$44 per lb oxygen for **PermeOx[®] Plus**).

4. What are the differences in pH between magnesium peroxide and PermeOx[®] Plus? How does it affect the pH of groundwater?

Based on recent testing conducted in FMC’s Princeton Research Laboratory, the pH of a 1% magnesium peroxide product solution is approximately 11.0 pH units, as compared to 11.5 pH units for a 1% **PermeOx[®] Plus** product solution. **PermeOx[®] Plus** has a rate of hydration 2 to 3 times faster than magnesium peroxide. When placed into an advective current, such as with groundwater flow in the subsurface, the pH rise in the formation will depend upon the amount of product used and the buffering capacity of the surrounding soil and groundwater. Field studies have shown groundwater pH to be only slightly elevated immediately surrounding injection locations (for both products). Overall pH increases for both products are negligible, and biological activity is not adversely affected when placed in a typical hydrogeologic system.

5. Do oxygen-releasing compounds lock-up?

Lock-up refers to a physical shell or coating forming around the outside of the product, inhibiting the product’s ability to release all of its active oxygen (AO) over a given period of time. Data obtained during hundreds of tests at FMC’s Princeton Research Laboratory show that **PermeOx[®] Plus** released more oxygen over longer periods of time than magnesium based products, without the lock-up phenomenon exhibited by magnesium peroxide.

Lock up, which apparently prevents the release of oxygen, was identified in tests performed on magnesium peroxide. During the course of these studies performed over a 12-month period, magnesium peroxide was found to release less than 14 mg/l active oxygen over a 360-day period while **PermeOx[®] Plus** released 215 mg/l of active oxygen over that same 360-day period. The fact that **PermeOx[®] Plus** is more soluble assists in the release of more oxygen over a longer period, and will maintain the permeability of the formation in which the material is being placed.



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6. What soil moisture content is required to activate the oxygen release and can it be used in the vadose zone?

The amount of soil moisture necessary to activate the release properties of **PermeOx[®] Plus** is very low (10-25%). As such, **PermeOx[®] Plus** is well suited for applications involving vadose zone treatment, ex-situ biological treatment piles and land farming. **PermeOx[®] Plus** can also be applied where the targeted treatment zone straddles the soil/water interface, thus maximizing biological activity and contaminant reduction in these areas.

7. What are the by-products of PermeOx[®] Plus when it has reacted?

After the active oxygen is released, the remaining product is lime, similar to that used in lawn care. It is non-hazardous and does not present any dissolved phase issues as a result of its injection into groundwater or treatment in soil. Further, the need for magnesium monitoring is eliminated when using **PermeOx[®] Plus**.

8. What quantity of PermeOx[®] Plus is required for treatment of hydrocarbon plumes?

Based on published studies regarding the bioremediation of petroleum hydrocarbons, an approximate ratio of oxygen to hydrocarbon mass of 3 to 1 is required to support enhanced bioremediation. As with other products, a factor for additional oxygen demand must be incorporated into the equation to account for oxygen that may be consumed by non-targeted compounds. As such, and to provide an easy evaluation of cost savings when using **PermeOx[®] Plus** over its leading competitor, it is recommended that an additional factor of up to 8 be included in hydrocarbon calculations depending on how well the system is understood. It should be noted, however, that these factors apply to implementing a goal of remediating and degrading all hydrocarbon mass present. Applying a reduced volume or using lower oxygen-demand factors may still achieve a very favorable result in stimulating natural biological activity and creating downward trends in overall concentrations, which often is the primary goal of enhanced natural attenuation.

What this means is that for every pound of hydrocarbon mass present, up to 24 pounds (after factors of 3 and a maximum of 8 are applied) of oxygen should be applied for maximum effect. The primary difference is that **PermeOx[®] Plus** contains 18% oxygen per pound (compared to 10% with the leading competitor). As an example, if a site has 10 lb of hydrocarbon mass present, 240 lbs of O₂ or 1,333 lbs of **PermeOx[®] Plus** at a cost of \$8 per pound is required (\$10,664 total cost), compared to 2,400 pounds of magnesium peroxide at a cost of \$10 per pound (\$24,000 total cost). This results in a cost savings of over 50% to apply the same amount of active oxygen, which will be released and sustained over a longer period of time. When calculating product needs and comparing products, make sure that the same input factors are being used.



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9. What applications is PermeOx[®] Plus used in?

PermeOx[®] Plus can be used in numerous treatment applications from direct tank excavation placement in the vadose zone to slurry injection via direct-push drilling equipment. The application techniques are very flexible. FMC has manufactured the product to be much more user-friendly than competing products as **PermeOx[®] Plus** is granular like a fine sugar, and not prone to airborne dust problems. Further, the material will not set up like magnesium-based products.

PermeOx[®] Plus is typically applied at a rate of 0.1% to 1.0% by weight of the soil matrix for dry applications (3 to 30 pounds per cubic yard average) and 20% to 50% slurry for injection applications. We are always available to provide technical support for specific applications.

10. How can I get PermeOx[®] Plus and/or more information?

Product information is available through several outlets. General information and questions regarding the product can be found on FMC's web site <http://www.fmcchemicals.com/>, under Green Team environmental applications, and then under **PermeOx Plus[®]** for product info, MSDS sheets and technical contacts from FMC for product information. Additional product updates can be found on **Panther Technologies, Inc.**'s web site at <http://www.panthertech.com>, click PermeOx[®] Plus. To purchase product and/or obtain support on product applications, contact **Panther Technologies, Inc.** **PermeOx[®] Plus** is offered by FMC only through select distributors nationwide. **Panther Technologies, Inc.** serves as FMC's service partner and product distributor for both small and large orders along the eastern United States from Maine to Florida, as well as in Texas and California. **Panther** can be reached at (609) 714-2420 during normal business hours or via email at permeox@panthertech.com. Product inventory is maintained in distribution warehouses in Medford, New Jersey; Trenton, New Jersey; and Chicago, Illinois and other geographical areas for immediate availability. Technical questions can be directed to either FMC Technical Support at (866) 860-4760 or to **Panther** at the above number.