

PHOSLOCK®
Phosphorus Locking Technology

An Overview of Phoslock and Use in Aquatic Environments

What is Phoslock?

Phoslock is a patented phosphorus locking technology containing lanthanum (5%), a naturally occurring earth element, embedded inside a clay matrix (~95%). Phoslock was developed by the Australian national science agency, Commonwealth Scientific and Industrial Research Organization (CSIRO), to remove phosphorus from water bodies and restore water quality. Phoslock is produced through a patented ion exchange process whereby lanthanum ions displace sodium ions within the clay matrix. The formulation process of Phoslock absorbs lanthanum into a non-toxic carrier such that the lanthanum retains its capacity to bind phosphate when applied to aquatic environments and results in a non-toxic mineral that becomes an inert component of the sediments.

For over ten years, Phoslock has been successfully used in water resource restoration programs around the world to remove free reactive phosphorus (i.e. forms readily available for algae) and restore water quality. Although Phoslock is a new technology to the United States (2010), it is rapidly emerging as the most effective phosphorus inactivation and water quality restoration solution for ponds, lakes and reservoirs.

How does Phoslock work?

Following an application of Phoslock, the lanthanum ions sorbed to the clay matrix react preferentially with free phosphate compounds in water (removing free reactive phosphorus) and rapidly form a highly stable insoluble mineral. The resulting mineral complex becomes integrated as an inert component into the natural sediments of the waterbody and is not bio-available. Due to the specificity of Phoslock to phosphate, as long as binding sites are available, it will continually bind new incoming phosphorus from internal and external sources.

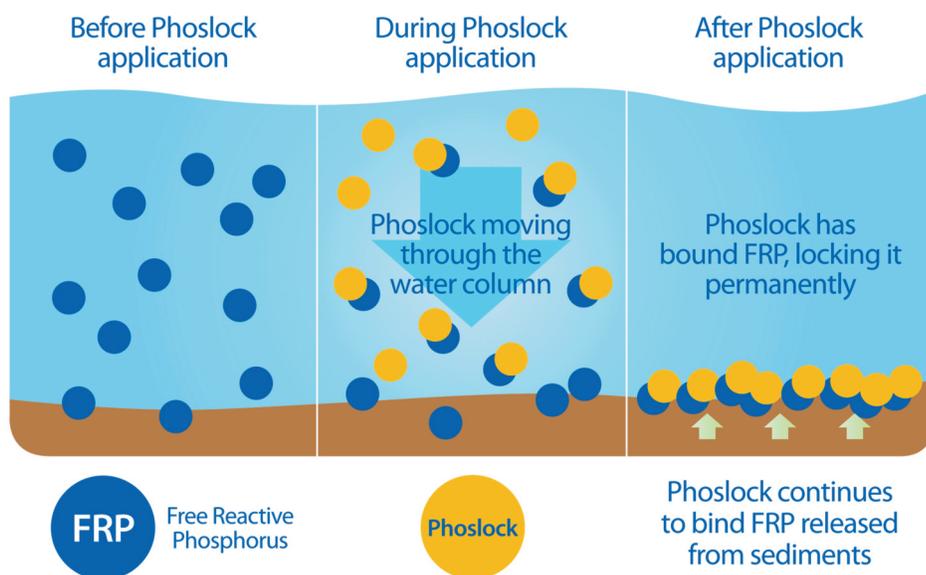


Figure 1. Illustration of the binding of Phoslock with Free Reactive Phosphorus (via phosphate bond) in water and as it is released from sediments.

¹Throughout this document, we use the phrase negligible risk. Risk is the probability of occurrence of an adverse effect from a given exposure to a substance. All substances have an inherent hazard (capacity to cause adverse effects). However, the risk of a potential adverse effect is managed by the product formulation, use directions, application rates and exposure. Phoslock at appropriate uses and dosing will result in negligible or insignificant risk.

Ecological Assessment

To assess and manage possible environmental impacts of a product, it is important to understand the potential risks associated with its use. The objective of the following information is to describe existing toxicity data on the product and assess any potential risks to the aquatic environment. Typical Phoslock application rates are < 100 mg/L. Phoslock applications may occur as a single event or over several days and also may be split over a season or multiple seasons depending on the site and management objective.

Evaluation of Lanthanum Toxicity

Lanthanum is a naturally occurring earth element. Lanthanum can occur in many forms. One such form, lanthanum chloride (LaCl_3) can be potentially toxic to aquatic organisms due to the dissolution of high levels of free lanthanum into water after application. This prohibits the use of LaCl_3 as an environmentally compatible phosphorus mitigation solution. However, when lanthanum is applied to surface waters in the form of Phoslock, the risk of potential lanthanum toxicity to aquatic organisms is negligible due to the unique formulation of Phoslock (absorbed to the clay matrix) and a limited potential for exposure to free lanthanum. When Phoslock is applied to water, lanthanum associated with the clay in Phoslock preferentially and rapidly binds with phosphate (PO_4), forming a highly stable mineral called rhabdophane (LaPO_4). This resulting rhabdophane complex has a very low solubility ($K_{sp} < 10^{-27}$) and is not influenced by changes in pH and redox reactions in waterbody sediments, thus is not bio-available. Lanthanum can only be extracted from rhabdophane in the laboratory using strong acid extraction methods.

Laboratory studies with Phoslock demonstrated that no lanthanum released within 24 hours when granular Phoslock (10 mg/L) was dissolved in de-ionized water; and only a small concentration of lanthanum (~0.016 mg/L or 3% of the total lanthanum in Phoslock) was released from the 10 mg/L concentration of Phoslock when dissolved in low alkalinity natural water or synthetic soft water (Yasseri and Nowak 2008).

Even if the total amount of lanthanum applied to a system following a Phoslock application became readily available in water (which it does not due to the Phoslock formulation and the fact that lanthanum binds to phosphates in water), the margin of safety associated with lanthanum toxicity is very high. For example, free lanthanum levels following an application dose of 75 mg/L Phoslock in Bareensee Lake, Germany resulted in a peak level of 0.130 mg La^{+3} /L shortly after application and <0.02 mg/L one month later. Toxicity tests from this Bareensee Lake project revealed an EC_{50} of 103 mg La^{+3} /L zooplankton (*Daphnia magna*) and EC_{50} of 150 mg La^{+3} /L for fish eggs (*Danio rerio*). The peak level of La^{+3} detected in the lake following application was approximately 800 and 1,150 times lower than the EC_{50} concentrations for zooplankton and fish eggs respectively.

The main potential for free lanthanum in water following a Phoslock application is in waters that have a very low alkalinity (< 20 mg/L) and/or low phosphate concentration (<0.005 mg/L). Typical Phoslock applications are not conducted in waters with low alkalinity and phosphate levels. Even in these low alkalinity aquatic environments, the concentration of dissolved lanthanum associated with the product is very low and below predicted toxicity thresholds. In these systems, risks can be further mitigated by several other assessment and management strategies such as conducting pre-application laboratory "jar tests" using lake water and lowering and/or splitting the Phoslock dose over time through a series of applications. Due to the ability of organisms to readily process lanthanum (through the liver) and the low level of free lanthanum that potentially becomes available for a short period of time following Phoslock applications, the aquatic toxicity risk and hazard to

aquatic organisms is negligible.[†] While free lanthanum can be used in tests to assess the toxicity to organisms, lanthanum in Phoslock, or bound as rhabdophane, is not free and unlikely to become available or achieve concentrations of toxicological concern in the natural aquatic environment.

Exposure to water column biota

The phosphorus removal capacity of Phoslock does not change drastically under different chemical or environmental conditions. From a water chemistry standpoint, the binding and removal of Phoslock is a straight forward process. Phoslock binds to phosphates over a pH range of 4 to 11, and binds to phosphates under aerobic and anaerobic conditions. Water analysis during and after application reveals no significant change in pH and no need to buffer treated waters during or after a Phoslock application. A pH change in the water column, sediment water interface and bottom sediments will not result in a release of lanthanum from Phoslock and phosphorus bound as rhabdophane. Since Phoslock rapidly settles to the sediments, the potential exposure duration to organisms in the water column is relatively short. Also, due to the unique formulation of Phoslock, the lanthanum remains sorbed to the clay until it is displaced by phosphates, and subsequently only disassociates a minimal amount of free lanthanum to the water.

Invertebrates

Data were compiled from numerous different testing agencies on a range of sentinel water column invertebrates. Responses of these zooplankton species, including both mortality and reproduction, were evaluated throughout Phoslock exposures. The data show a wide margin of safety associated with Phoslock (Table 1) applications at predicted use rates and environmentally relevant concentrations.

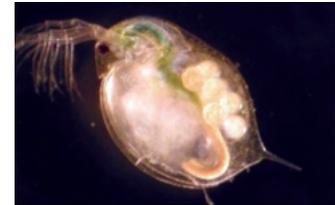


Table 1. Description of Phoslock toxicity experiments with sentinel zooplankton species.

Species	Endpoint	Test Duration	Lowest Observed Effect Concentration (LOEC)*	Water	Reference
<i>Ceriodaphnia dubia</i>	Mortality	48 hours	> 50mg/L Phoslock	Field water	Ecotox 2008
<i>Ceriodaphnia dubia</i>	Reproduction	7 days	> 1mg/L Phoslock	Field water	Ecotox 2008
<i>Ceriodaphnia dubia</i>	Mortality	7 days	> 1mg/L Phoslock	Field water	Ecotox 2008
<i>Ceriodaphnia dubia</i>	Mortality	48 hours	> 12,500 mg/L Phoslock	Synthetic soft	Stauber, 2000
<i>Daphnia magna</i>	Mortality	48 hours	> 50,000 mg/L Phoslock	Synthetic soft	Martin & Hickey, 2004

* Due to the amount of Phoslock needed to result in impacts to biota, many studies did not test concentrations high enough to result in significant impacts, thus toxicity endpoints are reported as greater than the highest concentration tested and does not indicate the actual lowest observed effect levels.

intake. These large volumes of water could not be consumed by a person per day. Drinking Phoslock treated water directly after an application would pose negligible risk to human health.

Exposure via Fish Consumption

The risk via consuming Phoslock/lanthanum in fish harvested from Phoslock treated water after application was negligible as shown in a fish health investigation, after three successive applications of Phoslock in Lake Okareka, New Zealand. The Lake Okareka fish health monitoring report (*Landman et al., 2007*) demonstrated that trout and koura accumulated lanthanum only in the liver and hepatopancreas tissues, not in the flesh/muscle following the application of Phoslock. It was also demonstrated that lanthanum was removed from the fish liver and hepatopancreas tissues within a few months and the concentrations of lanthanum returned to baseline before another Phoslock application one year later, suggesting a biological capacity to depurate lanthanum (*Landman et al., 2007*). This is also consistent with the findings that the main excretion route for absorbed lanthanum in humans or animals is via the liver into bile (*Dammert & Pennick, 2007*). The highest concentration of lanthanum measured in the liver of male and female trout in Lake Okareka after one and two months of Phoslock application was 1.2 and 0.8 mg/kg. Similarly, the highest concentration of lanthanum in the hepatopancreas tissues of male and female trout was 0.8 and 1.0 mg/kg respectively (*Landman et al., 2007*). Therefore, in total the highest concentration of lanthanum in one trout was 2.0 mg/kg. Thus, a person would need to consume 826 pounds of fish per day to ingest the minimum dose of La that corresponds to the lowest Fosrenol daily intake. The average person would need to consume 3,306 pounds of fish per day to consume the maximum daily dose of La from Fosrenol. These large quantities of fish would not be consumed by a person per day. If a person consumed 2 pounds of fish this would result in consuming La levels 400 times lower than the minimum daily dose of Fosrenol. Moreover, fish liver and hepatopancreas tissues are not generally consumed by humans. Even consumption of large quantities of fish liver and hepatopancreas tissues harvested from Phoslock treated waterbody would pose negligible risk to human health.

Lanthanum is not a Hazardous Substance

Phoslock is not considered hazardous by the Occupational Health and Safety Administration (OSHA) Hazard Communication Standard (*29 CFF 12910.1200*). Lanthanum and the clay used in the formulation are not listed on the USEPA Toxic Substances Control Act inventory list. Lanthanum is not on the Australian National Occupational Health and Safety Commission (OHSC) List of Designated Hazardous Substances (*NOHSC, 1999a*).

No risk has been associated with contact of Phoslock. The main potential for human exposure to Phoslock is during the application process. Due to some small particulates in the formulation, there could be some potential eye irritation and inhalation for applicators and handlers associated with an application. Applicators and handlers should follow suggested personal protective equipment guidelines found on the package label and material safety data sheet.

Summary

Phoslock is patented phosphorus locking technology that has been specifically formulated to decrease potential exposure to aquatic biota. Phoslock poses a negligible to very low risk to the aquatic environment while providing a high affinity to bind and remove phosphorus that results in improvements to water quality. A review of toxicity data has shown a large margin of safety to aquatic organisms and humans that may be exposed to Phoslock treated water during and following application.

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