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PHOSPHATES AND WATER QUALITY

Introduction

The removal of phosphates is seen by some as a key component in maintaining water quality in aquatic venues. Understanding how phosphates contribute to water quality issues allows the qualified operator to make informed decisions in regards to the prevention and treatment of algae growth. This knowledge, when applied correctly, becomes a powerful tool in maintaining clear, balanced, and healthy water. Lanthanum-based phosphate removers have firmly established themselves as a key component for phosphate removal.

Phosphate removers have been available for pool use since the mid-to-late 1990s. It winds through water chemistry equilibria, phosphonate-based pool chemicals, lanthanum precipitation, and the realities we all face in managing pools. Phosphonate sequestrants, such as aminotrimethylene phosphonic acid (ATMP) and 1-hydroxyethylidene-1,1-diphosphonic acid (HEDP), eventually degrade under chlorine and solar UV exposure into orthophosphate. This phenomenon has been documented in recent studies. That means some of the very products intended to control metals can end up contributing to the nutrient load that we later measure in our water.

Factors Causing Phosphate Build Up

Phosphates, also known as orthophosphates, do not exist in one single form. There is a whole family of species. The pH drives speciation because different pHs have different amounts of hydrogen available to interact and form the various species of phosphates. Very high pH water has almost no available hydrogens and thus phosphate (PO_4^{3-}) exists. As the pH decreases, more hydrogens become available forming hydrogen phosphate (HPO_4^{2-}), then dihydrogen phosphate ($H_2PO_4^-$). At very low pH only phosphoric acid (H_3PO_4) exists.

At pH values maintained in aquatic venues, the vast majority of phosphate exists as dihydrogen phosphate ($H_2PO_4^-$) and hydrogen phosphate (HPO_4^{2-}). The dissociation constants of phosphoric acid tell the story: $pK_{a1} = 2.15$, $pK_{a2} = 7.20$, $pK_{a3} = 12.35$. At a pH of 7.5, roughly 67% is HPO_4^{2-} and 33% is $H_2PO_4^-$, with almost no PO_4^{3-} present. At 7.8, it skews further—about 80% HPO_4^{2-} and 20% $H_2PO_4^-$ [1]. This speciation pattern affects the solubility and reactivity of phosphate in water, which, in turn, influences the effectiveness of phosphate removal strategies.

To understand its impact, add calcium: Calcium and phosphate readily form calcium phosphate scale, which is sparingly soluble and can foul heaters and chlorine generators; utilities have documented Ca–P scale formation under phosphate treatment.[2] Once calcium phosphate deposits form, scrubbing alone will not suffice. Up to 20% of the heater or chlorine generator efficiency can be easily lost, and recovery is challenging. Preventing it in the first place is far more effective.

Where do all these phosphates come from? City water dosing, landscaping runoff, fertilizer runoff, leaves decomposing, bird droppings, pollen, swimmer waste, and even the addition of sequestrants. A single quart of sequestrant can result in hundreds of parts per billion (ppb) weeks later. In routine testing of outdoor aquatic venues, phosphate spikes of 200–400 ppb from leaves left to rot have been measured, and 50–100 ppb after heavy weekend use.

Phosphate is not just a local contaminant—it can also arrive by air. NASA and other atmospheric studies have documented that Saharan dust storms carry phosphorus-rich particles across the Atlantic, depositing measurable amounts throughout the Caribbean, Florida, and parts of the southeastern United States.[3] While these events do not affect every pool or region, they can temporarily elevate phosphate levels in outdoor pools following major dust incursions. Because rainfall, pool size, and storm intensity vary, the actual concentration jump differs each time. However, for facilities in affected regions, this is a real and recurring factor.

How Algae Actually Uses Orthophosphate

Phosphorus is not just "extra food" for algae—it is an essential component of growth and algal blooms. Algae species use phospates to produce ATP, to build DNA and RNA, to form cell membranes, and to regulate enzymes. Without phosphorus, algae growth is severely stymied.[4]

When orthophosphate is present, however, algae growth accelerates, utilizing special proteins on their cell walls that act like little doors, allowing phosphate to be pulled into the cell where the phosphate is converted into ATP—the energy fuel that powers growth and rapid multiplication.

Phosphate itself does not create algae problems—poor water quality practices such as low DPD-FAC, lapses in disinfection, and maintaining high pH. When phosphate levels are high, even a short drop in DPD-FAC values or an increase in UV degradation can be enough for algae growth and biofilms to occur.

Lanthanum in Action

Lanthanum ions (La^{3+}) and phosphate ions (PO_4^{3-}) bind to form lanthanum phosphate ($LaPO_4$). The solubility product of this compound is about 3.7×10^{-23}, which is extremely low. Once it forms, it is essentially locked away, unavailable as a nutrient. That is what makes lanthanum-based phosphate removal so effective.It is a preventative tool, not a curative one. Algae is starved of “fuel” before growth has a chance to occur.

In real-world applications, lanthanum-based phosphate removal has proven its usefulness in water treatment. It is used extensively in lake restoration projects to reduce harmful algal blooms and improve water quality for both wildlife and humans. The reason is simple: lanthanum binds phosphate harder than the usual alternatives.

Aluminum and ferric phosphates are sparingly soluble, with solubility products typically reported in the range of 10^{-19} to 10^{-21}. For reference, aluminum phosphate ($AlPO_4$) has a Ksp of approximately 6.3×10^{-19} at 25 °C (University of Rhode Island, Department of Chemistry 2025), while ferric phosphate dihydrate ($FePO_4 \cdot 2H_2O$, known as strengite) exhibits a pKsp near 26.4—equivalent to a Ksp of about $10^{-26.4}$ [5]. These values confirm that both aluminum and iron phosphates are highly insoluble under the conditions of pool water. However, lanthanum phosphate is even less soluble, making it the dominant phosphate binder where lanthanum-based removers are used.

In pool water, carbonate and hydroxide ions are also present and can react with lanthanum. Competition can reduce phosphate removal efficiency unless a slightly higher dose is used. Even with that, lanthanum still has significant advantages: it works better across different pH levels, it will not stain a pool, and the solid it forms stays in place rather than breaking down.

Operationally, lanthanum should be dosed when total alkalinity is on the lower end of the acceptable range. Higher carbonate concentrations increase the likelihood of lanthanum forming temporary carbonate or hydroxide precipitates, which can cause short-term turbidity and heavier filter loading. These effects are typical and subside once the lanthanum has bound available phosphate.

Lanthanum-modified clays can be effective at locking up soluble reactive phosphorus and reducing internal P loading, but performance is context-dependent. Field and lab studies show clear reductions in P flux—especially under anoxic conditions—yet responses vary by lake and season, and gains are not guaranteed under all oxygen regimes. Effectiveness can be weakened by competing anions (e.g., carbonate), higher alkalinity, and dissolved organic carbon that complexes La, all of which can reduce practical binding capacity. Post-treatment, water-column La generally remains low, but bioaccumulation in biota has been observed, warranting routine monitoring even where acute toxicity is not evident. In short, it works best when matched to site chemistry and oxygen dynamics, paired with pre- and post-treatment assessments, and tracked with follow-up data rather than marketing promises.[6,7,8,9].

Residential pools v. Commercial and Institutional Aquatic Venues

In residential pools, lanthanum-based phosphate removers are considered an appropriate treatment protocol for regular water quality maintenance. Unlike commercial and institutional aquatic venues, residential pools are designed for much slower turnovers, smaller filters, and see less use of automated controllers and dedicated disinfection and pH control systems. Additionally, with the popularity of residential-based chlorine generators the use of phosphate removers is generally considered to aid in cell maintenance.

In commercial and institutional aquatic venues, the use of phosphate removers is significantly less utilized. Properly designed and maintained filtration and disinfection systems renders phosphate build up largely a non-issue. Instead of use in a regular water quality treatment protocol, the qualified operator should consider phosphate removal products if properly installed, and maintained, filtration and disinfection systems are having difficulty maintaining algae free water or proper water clarity.

Practical Use of Phosphate Removal Products

Before using, read all product labels and dose as directed. While many manufacturers suggest a lower maximum phosphate level of 100-125 ppb, the qualified operator should target less than 500 ppb[10].That threshold is considered an industry best practice. Many qualified operators see diminishing returns below 100–500 ppb, absent chronic fouling of heaters and chlorine generators[11]. Always plan for filter loading and backwash after treatment. If necessary, use a flocculant and vacuum solids to waste. Treatment effectiveness should be closely tracked and if a measurable improvement is not seen, the qualified operator should stop the treatment protocol.

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