



AQUADENE® BLENDED PHOSPHATE

Corrosion/Lead Control

AQUADENE® SK-7661 blended phosphate is a water soluble liquid, specifically formulated to control a multitude of problems in surface water applications. This unique formulation has proven to be beneficial in controlling lead leaching and is an effective corrosion inhibitor for use in multi-metal systems. The blended phosphate compounds are engineered to resist reversion, ensuring that the product remains active throughout a municipal distribution system.

I. THREE MAJOR FACTORS AFFECTING CORROSION

Corrosion is an electrochemical process in which the metals commonly used in water systems are dissolved and ultimately fail. Some types of corrosion cause a fairly uniform attack on metals, gradually thinning the entire metal surface, often causing “red water” from iron systems, or blue stains from copper or brass systems. Another type of corrosion, oxygen corrosion, concentrates its attack in small areas, developing deep pits which can penetrate the wall of the water tank or pipe. This type of corrosion usually does not significantly contribute to iron, lead or copper levels in the water, but even a single hole in a length of pipe or tank can destroy its usefulness.

Corrosion is a perfectly natural process. Man has learned how to convert naturally occurring ores into useful metals, but all these metals have a tendency to revert back to their naturally stable forms. Some metals are highly resistant to corrosion, but these are usually too costly to be used in municipal or private water systems.

All waters are corrosive to some degree. However, the rates of corrosion produced by different waters vary widely, depending upon a number of factors. Some of the major factors which govern the rate of corrosion include acidity, electrical conductivity, and oxygen concentration. Each of these factors is discussed in the sections below.

1. ACIDITY OR LOW pH

The pH scale is used by chemists to express the balance between the materials in water, which on one hand tend to make it acid, and on the other hand tend to make it alkaline. On the pH scale, 7.0 is the neutral point, indicating a perfect balance between acid and alkaline materials. pH values below 7.0 indicate an increasing overbalance of acidic materials, and pH values above 7.0 indicate an increasing overbalance of alkaline materials.

As water falls to earth in the form of rain, it picks up carbon dioxide from the air. As this same water trickles through the earth, decaying vegetation adds more carbon dioxide to the water. This carbon dioxide combines with the water to form $(\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3)$ carbonic acid. In areas where the ground water trickles through limestone (calcium and magnesium carbonates), the carbonic acid and limestone combine to form soluble bicarbonates, neutralizing the acid in the process. The resulting waters are usually hard, somewhat alkaline, having low carbon dioxide concentrations, and pH values in the range of 7 to 8.

Where the ground strata does not contain limestone, the ground waters retain their acidity, giving pH values in the range of 6 to 7, increasing the corrosivity to metals commonly used in municipal water systems.





2. ELECTRICAL CONDUCTIVITY

When two different metals such as copper and iron are in contact with each other and with a solution which will conduct electricity, a galvanic cell is established. In this cell, electricity is generated and one metal will dissolve or corrode in proportion to the electricity generated. This galvanic corrosion occurs very close to the joint between the dissimilar metals. Absolutely pure water is a very poor conductor of electricity, but many dissolved minerals and gases separate into charged particles called ions which are capable of conducting electricity. Thus, water supplies which have few dissolved minerals are poor conductors, but waters containing high mineral concentrations are relatively good conductors.

It is rare that an entire water system is constructed of a single metal. Galvanized pipe systems often use brass valves, and a zinc (galvanized) surface, which is broken at the ends of the lengths of pipe, at the threads. Copper plumbing systems often use solder at the joints, and valves are made of a different alloy. Even if a single metal were used throughout a system, corrosion cells can exist due to spot impurities at the surface, and by differences between bare metal and metal covered by scale or other deposits from the water.

Under these circumstances, every water system has a number of potential galvanic cells and sites for possible corrosion. Where the water has low mineral concentrations, this type of corrosion does not present a major problem. However, in some areas the mineral concentration and conductivity of the water is so high that corrosion does create major problems.

3. DISSOLVED OXYGEN

The combination of oxygen and water provides an excellent environment for the occurrence of corrosion. When water is exposed to oxygen in the air, dissolution of oxygen into the water occurs readily. As water falls to the earth as rain, or flows across the land's surface into lakes and streams, it quickly becomes saturated with oxygen. However in ground water, oxygen is consumed as the water seeps into the ground through layers of decaying organic matter. Thus deep wells are usually free of dissolved oxygen. Exceptions can occur, of course, in areas where the ground contains little organic matter. Furthermore, the air cushion in a pneumatic pressure tank can contribute to oxygen in a deep well water supply.

When the electrochemical reaction of corrosion occurs, a very thin film of hydrogen forms at the surface of the corroded metal. If this film could be retained, it would service as a barrier to protect the metal from contact with the water, and corrosion reactions would stop. However, when oxygen is present in the water, it combines with the hydrogen film, and removes the film from the metal's surface. Thus corrosion will continue, causing deeper and deeper penetrations into the metal.

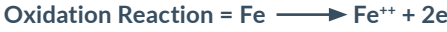
II. MECHANISM OF CORROSION CONTROL

From the previous paragraphs, it is apparent that corrosion is not a simple problem, and in most systems, is related to more than one factor. Further, it is impossible to completely halt corrosion where water contacts metals, but we do have some methods which will reduce corrosion to tolerable levels. It is for these reasons that we provide corrosion control, not corrosion prevention.

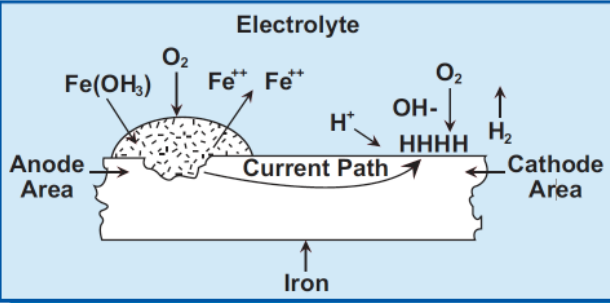
Although it is not feasible to remove all the dissolved minerals and gases from the water, there are materials available to control their corrosive nature. The two materials most commonly used, for corrosion control in potable water systems are poly-orthophosphate blends and zinc orthophosphate. The later has fallen out of favor for several reasons, the most prominent being the addition of zinc to drinking water. This addition, for health and waste water zinc removal, is being closely scrutinized by local and federal government agencies. Therefore, the focus of this bulletin will center on the addition of poly-orthophosphate blends to water systems as a means of corrosion control.

Although complex chemistry is involved, the mechanism in which poly-orthophosphate blends inhibit corrosion can be looked at simply. Much as paint and a coat of wax are applied to your car to protect the metal from corrosion, phosphate blends form a film on the inside of pipe surfaces, thus protecting them from corrosion.

We use the term "corrosion inhibition", because on a molecular level the combination of poly and orthophosphates inhibit the basic electrochemical reaction of corrosion. The two basic reactions are oxidation and reduction. Using the example of iron pipe, the chemical equations would be:



These reactions occur on two separate sites on the metal's surface. The oxidation reaction takes place at the anode. This is where the actual metal is dissolved, and with secondary reactions, corrosion by-products (rusts) are formed. The reduction reaction occurs at the cathode. No evidence of corrosion is seen at this site. However, it connects the electrochemical circuit which allows corrosion to take place.





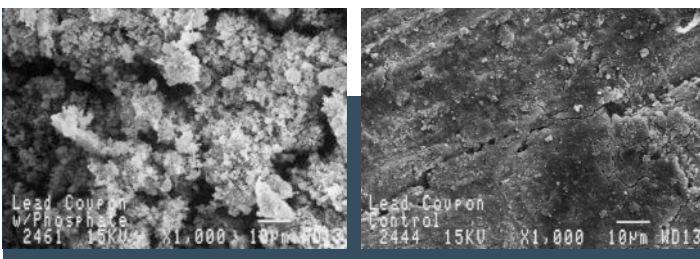
CORROSION CELL DIAGRAM

The electrochemical circuit must have an anodic site, cathodic site, a connection between the two (in our case the pipe wall itself), and an electrolyte solution. For our purposes, the electrolyte solution consists of water and the dissolved minerals and gases present within the water system.

It is not feasible to remove the pipe or the water from the system for obvious reasons. Poly-orthophosphates are chemically engineered to block both the anodic and cathodic corrosion reactions. In theory, if either of these reactions, oxidation at the anode or reduction at the cathode, is interfered with, the corrosion process itself will be inhibited.

Orthophosphate acts as an anodic inhibitor, forming a film on the metal which acts as a barrier to the oxidation reaction. Polyphosphates chemically block the electron flow to the cathode, thereby inhibiting the reduction reaction. Polyphosphates also block some secondary reactions at the anodic site of the corrosion cell. In addition to this, polyphosphates prevent some corrosion by-products (oxidation of metal ions) from forming through a conditioning process known as crystal modification.

With the aid of recent technological advances, and continuing research into film formation, we have been able to photograph the actual phosphate film on treated metal surface. The following photos, or more specifically scanning electron micrographs, were made of lead coupons treated with one of our **AQUADENE®** blended phosphate products. The coupons (treated and control) were Au/Pd coated for electron beam conductivity, and then examined using a JEOL 840 scanning electron microscope show the effect of the conditioning process, allowing for corrosion inhibition to take place.



WHY BLENDED PHOSPHATE PRODUCTS?

Water system managers often ask if blended poly-orthophosphate products are definitely better than straight orthophosphate products. Most test results continue to verify that the blending of several polyphosphates with orthophosphate is advantageous. The addition of polyphosphate not only inhibits the cathodic reaction of the corrosion cell, but also blocks secondary rust forming reactions on the anodic side. This three pronged corrosion control program, from one chemical addition, by far outperforms orthophosphate alone.

Orthophosphate when added alone for corrosion control purposes, is usually accomplished with the addition of phosphoric acid (H_3PO_4). The use of this hazardous chemical may at first seem like a cost saving approach to corrosion control, however through careful scientific and fiscal studies, this proves not to be true for the following reasons. It has been widely understood that it takes three to four times as much phosphoric acid (as measured in PO_4 content) to achieve the same film forming abilities as that of **AQUADENE** blended phosphate products. The added engineering costs of working with a hazardous material (i.e.; storage, feed equipment, and shipping) can be cost prohibitive. Many plant managers look at the added liability alone of working with such a material as just not being worth it, when considering the safety of operating personnel.

Other beneficial effects are realized by the addition of polyphosphate to an aqueous system. The effectiveness of polyphosphates include control of red water, black water, (sequestering capabilities) and scale. Red and black water are caused by the presence of iron and manganese in the water. These metal ions along with calcium carbonate are common in many well waters. Polyphosphates remove the stain causing abilities of the Fe and Mn metal ions through the chelating process. Polyphosphates not only keep scale forming $CaCO_3$ in solution, but also gradually dissolve existing scale deposits.

WHAT BLEND IS RIGHT FOR YOUR SYSTEM?

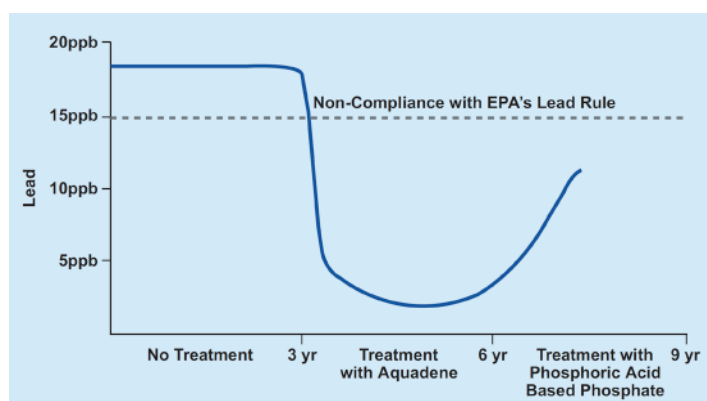
Clearly, the choice for corrosion control additive today is that of a poly-orthophosphate blend. But what blend should be used in my system? No two water systems are exactly alike. Differences in water chemistry, purification process, and metallurgy are just some of the variables involved in choosing a blend. Beware of one or two blend companies, trying to fit one chemical into all systems. This can prove to be a costly mistake for an uninformed water manager. Therefore, the species of phosphate use, concentration and percentage of polyphosphate to orthophosphate should be tailored to your system's particular needs.

WHY AQUADENE BLENDED PHOSPHATE PRODUCTS?

Are all blended phosphate products the same? Are other companies' phosphate products the same as Carus' AQUADENE® blended phosphate products? These are a couple of commonly asked questions from water managers when choosing a phosphate product. The answer to both of these questions is "no". Differences in source materials and the manufacturing process can greatly alter the end phosphate product. AQUADENE's product stability, solubility, and effectiveness remain the benchmark for the industry.

In AQUADENE products, only food grade sodium and potassium phosphate salts are used as the source of PO_4 . This is contrary to several of our competitors, who use cheaper fertilizer grade phosphoric acid as a source of orthophosphate. It is less expensive to produce a phosphate blend this way; however the resulting product effectiveness for corrosion control is decreased. This can be best illustrated (see graph below) by the amount of lead present in the water of a large water system that switched to a phosphoric acid base material.

AQUADENE PERFORMANCE VS. PHOSPHORIC ACID BASED BLENDED PHOSPHATE



Fiscal responsibility is a must when it comes to water management, but at what cost? The EPA's lead and copper rule of 1991 mandates the optimization of metal control in potable water. **AQUADENE** blended phosphates continually meet the goals of major municipalities throughout the world. In addition to this, **AQUADENE's** end use cost generally outperforms most other treatment programs available in the market place.

CARUS VALUE ADDED

LABORATORY SUPPORT

Carus has technical assistance available to answer questions, evaluate treatment alternatives, and perform laboratory testing. Our laboratory capabilities include: consulting, treatability studies, feasibility studies, and analytical services.

FIELD SERVICES

As an integral part of our technical support, Carus provides extensive on-site treatment assistance. We offer full application services, including technical expertise, supervision, testing, and feed equipment design and installation in order to accomplish a successful evaluation and/or application.

CARUS

During its more than 100 year history, Carus' ongoing emphasis on research and development, technical support, and customer service has enabled the company to become the world leader in permanganate, manganese, oxidation, and base-metal catalyst technologies.



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