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*Evaluation of Use of Polyphosphates  
in Water Industry*

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## Evaluation of the Use of Polyphosphates in the Water Industry

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*A contribution to the Journal by Thurston E. Larson, Head, Chemistry Section, Illinois State Water Survey, Urbana, Ill.*

THE statements in this attempt to separate fact from fancy in the sale and use of polyphosphates in water treatment derive from findings which have been described in reliable scientific literature. Several comments are contrary to the implications of sales representatives who lack either adequate training or the capacity to resist the temptation to oversell. Such deficiencies have resulted in misapplications which have not benefited the reputation of polyphosphates in water treatment.

In a broad general sense, all polyphosphates show the same characteristics—with some notable exceptions which are of minor consequence in this discussion. These polyphosphates include the crystalline pyrophosphate, metaphosphate, and tripolyphosphate, as well as a number of glassy polyphosphate blends. Polyphosphates behave chemically in a manner quite different from the well known orthophosphates. In many ways the polyphosphates are remarkable as a class of chemical compounds.

Many claims have been made; some are adequately supported by data, but others are often misinterpretations or inferences which cannot be substantiated by suitable records. In each case the circumstances of the application must be considered. Inferences from

favorable data acquired in one application are not necessarily applicable to another. The first need in any application is a statement of the end to be accomplished.

### Softening of Household Water

Data are available to show that about 5-10 ppm polyphosphate are required to counteract 1 ppm hardness. Thus, for example, water with a hardness 300 ppm will require an application of, 1,500-3,000 ppm of polyphosphate to soften it, or 6-12 tons per million gallons. On the other hand, considering smaller quantities, 1 oz of polyphosphate would be required to soften 10 gal of water of 300 ppm hardness. Thus, a household job such as dishwashing represents a practical application. Such softening is accomplished by a process called sequestration, or by the formation of soluble calcium polyphosphate and magnesium polyphosphate complexes.

This should not be confused with what is normally considered as threshold treatment—a stabilizing or inhibiting treatment which is designed for another purpose when treating municipal or industrial water supplies. Threshold treatment refers to the application of polyphosphate in a concentration of about 2-4 ppm. This concentration theoretically reduces the

hardness of the water by about 0.5 ppm—for example, from 300 ppm to 299.5 ppm.

Polyphosphates are normally an integral ingredient in dishwashing compounds for restaurants and household use, as well as in many synthetic detergents. A typical dishwashing machine compound contains about 40 per cent polyphosphate, 40 per cent sodium silicate, and 20 per cent soda ash.

Thus, the use of polyphosphate for softening water for domestic purposes is practicable, but exceeds the bounds of ridiculousness when it is implied that the same applies to municipal softening of hard-water supplies.

### **Cleaning of Wells**

As cleaning and wetting agents, polyphosphates have achieved frequent notable success when used for cleaning screened sand and gravel wells. When confronted with a well problem, it is important to be sure, first, that the problem results neither from pump inefficiency, lack of water in the aquifer, nor failures in the column pipe. Where it has been determined that lack of water is due to clogged screen or a clogged water-bearing formation in the immediate area of the screen, treatment with about 30 lb of polyphosphate per 100 gal of water in the well bore has been found successful. Such treatment is often accompanied by the use of 1-2 lb of chlorine or chlorinated lime and, on a few occasions, has been in conjunction with a wetting agent of the non-ionic type. The practice of surging the well periodically during the several hours following the application of the treatment is recognized as highly beneficial. For continued success, it is desirable to repeat the application at scheduled intervals dictated by experience so that incrustation does not reach

the point where this nondestructive type of treatment can no longer be applied with success.

### **Red Water**

Rusty water may occur as the result of the natural presence of iron in the water pumped from ground water wells or it may result from iron dissolved in the water as a product of corrosion.

Iron in well water is normally present in the soluble (ferrous) state. The water is clear until, upon exposure to air or to chlorination, it is converted to the insoluble (ferric) state which reacts with water to form ferric hydroxide, or rust.

Polyphosphates have the property of being able to combine with or sequester soluble iron. They do not combine with or sequester insoluble ferric hydroxide. In view of this property, the more effective use of polyphosphate requires the application of this treatment to the water before it is exposed to air or before chlorination. Subsequent oxidation by air or chlorine will convert the iron to the ferric form, but it remains dispersed until the polyphosphate has lost its dispersing property by reversion to orthophosphate.

The amount of polyphosphate required for this purpose is about 2-4 ppm per 1 ppm of iron in concentrations up to about 2-4 ppm. At higher concentrations of iron, more than 9 ppm polyphosphate is not always beneficial.

As it has been recognized that polyphosphate is an excellent source of phosphorous for the growth of bacteria, it is normally recommended that the concentrated solution of polyphosphate for injection into the water be treated with about 50 ppm chlorine each time the solution is prepared. This prevents the development of a breeding ground

for possible coliform organisms in the polyphosphate treatment solution.

In certain areas where sufficient concentrations of ammonia, methane, or both may be present in the well water, some iron removal water treatment plants are rendered ineffective by bacterial growths in the filter bed. Such growths deplete the oxygen which was dissolved in the water by aeration for the purpose of oxidizing the soluble iron to the insoluble ferric hydroxide prior to filtration. In fact, even though chlorination is subsequently applied to the water effluent, the water mains themselves may be so infected with such growths that chlorine is destroyed by the growths faster than the reverse can occur. Subsequently, such insoluble iron as may be deposited in the mains is redissolved as ferrous iron because of the anaerobic conditions created by the bacterial growths.

Chlorination before filtration has proved to be successful in many cases. In persistent situations it may be desirable to use copper sulfate in conjunction with polyphosphate for the purpose of inhibiting the growth of bacteria while the polyphosphate keeps in soluble form such soluble iron as may be picked up from the mains. The economics of such treatment is not prohibitive for small water plants. Normally, a treatment with 1 ppm copper (2.5 ppm anhydrous copper sulfate) is adequate when applied with more than 2-4 ppm and less than 9 ppm polyphosphate.

### Scale Prevention

Scale is defined here as a deposit from hard water and does not refer to either rust deposits or corrosion products. Threshold dosage of polyphosphate in water has the unique power of preventing crystal growth of calcium

carbonate. Although either calcium or magnesium may be responsible for the scale, polyphosphate is effective against calcium carbonate deposits *only*; it has no effect on redissolving or preventing the magnesium hydroxide deposits so frequently encountered where lime softening plants are not operating properly.

The first of four points where calcium carbonate deposits can be controlled is the sand filter. Lime softening plants without sufficient recarbonation to prevent calcium carbonate deposition on sand frequently acquire an accumulation of calcium carbonate on the sand grains. Continuous treatment with polyphosphate in threshold concentrations (2 ppm) has frequently been reported to prevent such depositions. Magnesium hydroxide deposits which may occur at this point are no problem because they do not accumulate on the sand grain and are easily removed during backwashing.

Distribution systems constitute a second point of scale accumulation because lime softening plants with insufficient recarbonation may also deposit a rather heavy calcium carbonate scale in the main as the water leaves the plant. Again, threshold treatment with polyphosphate will prevent this accumulation at this point. However, such plants frequently also produce a water at or near saturation with magnesium hydroxide. Such lime-softening effluents are usually high in magnesium and pH and low in calcium and alkalinity or both. Deposits of magnesium hydroxide in the water main *cannot* be removed or prevented by the use of polyphosphates. There is no record in the literature to indicate the successful use of polyphosphate for this purpose.

Magnesium hydroxide or magnesium silicate, singly or mixed with calcium carbonate or residual alum form a wavy, rippled deposit that has a very serious effect upon carrying capacity. Records are available where the Hazen-Williams *C* value has been reduced from 120 to 90 or 80 with as little as a  $\frac{1}{16}$ -in. deposit of this rippled nature. Because polyphosphates will, not prevent such a deposit and no chemical is known for postcorrective treatment, the cure is one of prevention and not of treatment.

A third point of scale accumulation is in apartments, hotels, hospitals, and similar places, where three kinds of hardness can be considered :

1. Completely softened water which will not deposit calcium or magnesium scales

2. Unsoftened hard water which usually does not scale in cold water lines (At drinking fountains or faucets, however, scale deposits may build up. Polyphosphates should correct this deposition of calcium carbonate for such hard waters. Scales in hot-water appliances and hot-water lines are usually calcium carbonate. Treatment of this condition with polyphosphate in threshold concentration should also be of benefit if the retention time at the heating point is not sufficient to revert the polyphosphate to orthophosphate.)

3. Lime-softened water, which rarely produces heavy scales in cold water lines (In fact, some calcium carbonate scale is desired for corrosion prevention. Scales in hot-water lines are common, and if the scale is calcium carbonate, polyphosphate can be of benefit, particularly if applied in recirculated systems. If, however, the scale is magnesium hydroxide, which is highly insoluble in hot water, polyphosphate treatment is worthless.)

Another property of polyphosphate that should be considered lies in its behavior when exposed to high temperature and to high pH. High temperature and, to a lesser extent, high pH in hot-water tanks and at the heating point, cause a significant reversion of polyphosphate to orthophosphate within a few hours. A number of overdose instances are on record where the orthophosphate has reacted with calcium to form a calcium phosphate or calcium hydroxyphosphate scale which actually did more harm than good. The rates for reversion for various polyphosphates vary, but there is no record of any polyphosphate that possesses desirable useful properties which is not subject to partial or complete reversion to orthophosphate within a matter of hours under high-temperature conditions.

Magnesium hydroxide scale with or without adsorbed silica in hot-water tanks can easily be removed by flushing with a hose. When such flushing of this highly heat-insulating deposit becomes necessary on a weekly or monthly basis, the water user is justified in complaining.

Scale is also frequently encountered in cooling towers where polyphosphate is frequently a part of the chemical treatment. Continuous treatment by application of polyphosphate alone is usually not completely effective. Such water use and accompanying treatment is complicated by the rate of blowdown, the pH of the water, the general water quality, the reversion rate of the polyphosphate, and the temperature of operation. The problem is frequently one of treatment to prevent corrosion, scale, and slime. Polyphosphate treatment is usually an adjunct to other treatment or is supplemented by pH adjustment, by the addition of chromates, or

zinc salts (or both), by ferrocyanide or organics for corrosion control, and even by chlorine or chlorinated phenols for slime control.

### Corrosion

Corrosion is defined as the loss of metal and may be evidenced by failure of a structure, conduit, or container. In the case of ferrous metals, it may be detected by the appearance of iron in the water from the solution of ferrous metal. It may also be detected by the appearance of rust deposits on the water side of the metal. These deposits may be uniform, as in general corrosion, or knobby growths, as in pitting and tuberculation.

The appearance of iron (red water) as a result of corrosion may not be in significant quantities at high velocities because of dilution, but can be considerable at low velocities because of the longer contact time. On the other hand, the corrosion rate necessary to induce structure failure may be greater at high velocities but insignificant at low velocities.

The presence of iron in the water is not necessarily an indication of corrosion, because it may have been present in the water before contact with the metal vessel. The appearance of a rusty scale is not always evidence of corrosion because it may be a deposition of hardness together with iron which was originally present in the water.

Polyphosphates have been reported to be effective in reducing corrosion by domestic waters. The reliable data show this effectiveness only under certain conditions and with certain types of waters. Corrosion prevention cannot be claimed, even though the red water effects of natural iron in the water have been lessened by the use of

polyphosphates, nor can prevention be claimed where red water is avoided by sequestration of this iron corrosion product. Improvement but not prevention can be claimed in situations where pitting-type corrosion is altered to generalized corrosion.

The effectiveness of polyphosphates is progressively greater at increasing turbulent velocities and at increasing concentrations. Under essentially no conditions are polyphosphates effective in stagnant or nearly stagnant water, such as in dead ends or service lines. The only data available on its effectiveness at low velocities appear to indicate a slight increase in corrosion at 0.5 fps. It should be recognized that conditions of 2-5 fps or more of turbulent flow velocities are not experienced continually in all parts of almost any distribution system, and certainly not in communities where the grid has been designed with 5-10 miles of 4- and 6-in. pipe for a 30,000 gpd consumption. Considerable embarrassment could be avoided if vendors as well as superintendents would calculate the velocity of flow in 4-in. dead ends at normal domestic consumption rates by a limited number of families.

In hot-water systems, the corrosion rates are usually greater than in cold. Recirculation improves the effectiveness of polyphosphates or of any inhibitor in hot-water systems, but, because of the low velocity, not in hot water tanks. It can, however, improve the ability of the treatment to maintain such iron as is dissolved by corrosion in solution.

There is room for definition of water quality as related to its corrosive properties. All waters are not equally corrosive and it should be recognized that the quantity of polyphosphate required may vary depending on the water

quality as well as the specific conditions of use. Any large-scale application and most small-scale applications for corrosion control, warrant well planned and complete corrosion testing to establish data on effectiveness at the specific applications and velocities involved.

### **Cleaning of Water Mains**

Reported experiences vary with regard to the effectiveness and even the desirability of using polyphosphates for water main cleaning. The usual procedure consists of mechanical removal of bacterial slime, debris, mineral deposits, or corrosion products. On occasions, little discussed in scientific journals, polyphosphates or other chemicals have been used as an adjunct to mechanical cleaning. No clear, reliable assessment of the value of this function is available, nor is it reasonable to expect a valid evaluation without more exact data than have been published to date.

The use of polyphosphates as an adjunct to mechanical cleaning must be followed by effective water treatment if the cleaning is to have a lasting effect. If the subsequent treatment is done with polyphosphates for corrosion control, the limitations inherent in low-velocity mains must be recognized.

Nonmechanical removal of corrosion products and deposits other than calcium carbonate has been proposed and attempted, often with embarrassing results. It would appear that the primary problem is that of defining the deposit to be removed and the quantity. These unknowns are further complicated by a butcher's guess on the quantity and method of application of polyphosphate. When it is recognized that even the manner of action of polyphosphate on the various unknown deposits or corrosion products is not clearly established, nonmechanical water main cleaning with polyphosphates must be considered as nothing more nor less than a calculated risk. There is no established and proved plan or specification for nonmechanical removal of noncalcareous deposits.

### **Conclusion**

Polyphosphates are a truly remarkable class of chemicals. Their effectiveness for many purposes has been demonstrated in the laboratory and by practice. Their ineffectiveness for other purposes has also been established in the laboratory as well as by experience. It is unfortunate that no specific data are available for the cure-all misapplications which have resulted in disastrous failures and chaotic difficulties.