Part Two: Lead/Copper Rule & Corrosion Control
Reduce Metal Levels – Minimize Phosphate

If you read my previous article on sequestering, I hope you were able to resolve mineral complaints while reducing or eliminating phosphate use. In part two, I want to point out that chemical use, phosphates in particular, may be unnecessary when addressing lead and copper issues. I do this within the framework of the lead and copper (PBCU) rule.

Rule Overview
The lead and copper rule took effect in 1992 when I began my water career with the DNR. In hind-sight, the industry, including those in the regulatory field, were largely unprepared for what was about to take place. Research papers were written, code was in place, and training was provided. What we did not have was experience, flexibility, time, and dollars. Unfortunately, we still deal with fall-out from the rule and repeat mistakes. Poor monitoring practices, non-chemical corrosion factors, ineffective treatment strategies, and limited regulatory flexibility work against us. While some of this may be addressed by rule revision, some will not.

The rule was written to detect and reduce lead/copper in the source-water and that contributed from pipe materials through chemical corrosion – uniform corrosion in particular. If more than 10% of your water customers, as measured by monitoring results, are above the lead or copper action level (15ug/l and 1300ug/l); chemical treatment, targeting uniform corrosion, is prescribed. Chemically controlling key water quality parameters or laying down barrier film may be an effective treatment strategy for this type of corrosion but it may not address other sources of metals (sediment) or other corrosive factors (i.e. microbial, thermal, electrolysis). Monitoring and sampling practices have a large influence over metal levels but are not a strategy to reduce it under the rule.

Monitoring Sites
When the rule took effect, water systems assembled a list of approved monitoring sites. The target metal was lead so utilities had to select homes that were likely to contain lead (i.e. lead service lines/goosenecks and homes built when lead solder may have been used - 1983 to September 1984).

Most homes did not fit the criteria so operators had to select pre-1983 homes with metal plumbing.

Everyone went through the motions of implementation. Site lists were assembled with some based on guess work or conjecture rather than building construction dates. They were submitted to the regulatory agency and filed with minimal review. Who had time to review hundreds or thousands of historical building records, if they could be found, and verify plumbing was original construction? Did anyone take the time to ensure federal site criteria were met before each subsequent monitoring round?

We now realize that monitoring site lists are a work in progress and need closer scrutiny prior to each monitoring event. Building dates may not be valid, pipe materials may have changed, “point of use” treatment or water softeners or new plumbing fixtures may have been installed, old construction records may have been found, and owners may have decided to opt in or out of the monitoring program. Even with a more robust evaluation, there is a certain amount of uncertainty and inconsistency in regard to using proper monitoring sites. While faucet location and pipe material is certainly important in properly implementing the rule, there is a shadow that lurks below.

Water turnover can have a pronounced effect on PBCU levels even though the rule puts little emphasis on it. How much water is the homeowner turning over each day and will they have good turnover leading up to the day of monitoring? Samples collected after returning from a two-week vacation, samples collected from a home using just enough water to flush the toilet each day, samples collected from unused buildings, or samples collected from a home with over-sized plumbing may contain high levels of PBCU. While elevated levels may be caused by uniform corrosion, some think that under these conditions microbes influence corrosion as well.

It is well known that micro-organisms pull nutrients from pipe (phosphorus from copper pipe and carbon from iron pipe), secrete acidic enzymes that dissolve metal, and result in pit corrosion. If you have nutrients and poor disinfection, you will have biological growth and likely microbial induced corrosion (MIC). It’s worse with stagnant, warm
Some utilities are conducting extensive evaluations to determine whether this occurs in plumbing systems carrying their water. They run special water quality tests (conductivity, chlorine, pH, and temperature), perform pipe and barrier film studies, and some are now using ATP (Adenosine Triphosphate) tests to measure total living biomass. If this sounds complex, let’s kick it up a notch and mention another possible cause for corrosion not addressed in the federal rule.

I recently spoke to a community that has been struggling with copper issues since the rule took effect. They are now finding high copper levels at sites with energized plumbing systems. One site, with copper levels close to the action level, had 2.5 amps of current in the plumbing. The neighbor had about the same amount with similar water quality problems. Copper levels dropped after the electric utility replaced the transformer with an isolation transformer. Did the current affect corrosion rates? Possibly, according to test results. They are now finding that electrical problems are more common than thought.

Plumbing in another home had 2 amps of current when the furnace ran because the heat ducts were in contact with the plumbing line. Evidently, poor grounding practices are at work. Yet another home had pulsating current (0.02 to 1.9 amps) from a homeowner installed, electronic demineralizer. This system used current to induce a magnetic field around and through a small section of water pipe. The manufacturer claims that it prevents pipe scale and will dissolve scale. Does it dissolve metal pipe as well? Since there are hundreds of ways to energize plumbing systems, the question becomes whether or not electric current causes internal corrosion of plumbing materials?

I am loathe opening this can of worms but will mention that the effect of electric current on iron/steel has been studied for years and used extensively by the water, gas, and oil industry. Impressed cathodic protection, using DC current to protect metal surfaces, has extended the life of iron/steel materials in many applications and results in a net economic benefit when used correctly. This requires one to identify and control the anode (sacrificial metal), cathode (metal to be protected), connection media between them, and, when using impressed cathodic protection, the amount of current to maintain electron equilibrium. What happens when electron equilibrium is not maintained and you do not have control over the flow path? Given the complexity and uncertainty of this issue, it may be best to avoid energized plumbing systems for PBCU monitoring.

While selection of monitoring sites is a complex task and needs to be understood before samples are collected, sample collection itself is no different.

Sample Collection
Too often utilities are contacting the homeowners a couple days before the big sampling day to ask them to collect a sample. They do not ask about possible plumbing changes, give minimal sample collection instructions, and do not document important sampling information. Worse, sometimes instructions are incorrect, sample right after flushing in the morning, or the operator fails to give acceptable stagnation times. Even with good instructions, we are finding that samples are being collected at the wrong locations or stagnation times are either too low (less than 6 hours) or exceptionally high.

Some water systems are addressing poor sampling protocol by working closely with the homeowner to refresh the water the night before and arriving early to collect samples. Other utilities give the homeowner a monitoring form and explain the criteria for sample acceptance (i.e. 6 to 10 hours of stagnation). Important information includes: flushing time, stagnation and sample times, and location on where they took the sample. When mistakes are made, no crime is committed. Throw the sample out and request that it be collected correctly the following day.

The monitoring day should not be the beginning of your lead
and copper monitoring program. Similarly, good operation and maintenance practices can also reduce metal levels before the first sample is collected.

**Fundamentals of Reducing Metal Levels and Corrosion**

Water is the universal solvent and we all know what solvents do. It is corrosive to some extent but this solvent has other important properties that increase metal levels. Water not only dissolves pipe/fixture material, it removes film and scale and then transports the metal containing solids to your customers. Some of these solids may seem innocuous, like iron and manganese, but these two in particular can absorb other metals, such as lead, concentrate it, and then give it free transportation to a location you might not like. While this can be a disaster for your PBCU monitoring program, it gets worse.

Our universal solvent, with a few nutrients mixed in, like nitrogen and phosphate and carbon, provide essential nutrients for micro-organisms. As previously mentioned, these critters form colonies on metal pipe and cause pitting. This is one reason why WDNR code requires disinfection when adding phosphates.

So what does all this mean?

Good O&M practices need to be a part of your utility’s everyday routine. This not only prevents lead and copper from finding its way into your water but also prevents its accumulation and transportation to your customer’s faucet. With that said, there are several O&M practices you can incorporate into your work schedule that will reduce PBCU levels.

**First**, ensure your source and treated water is low in PBCU, low in minerals that have an affinity for absorbing and transporting PBCU, and low in nutrients such as nitrogen, phosphate, and carbon.

**Second**, flush your water system out on a regular basis. This not only eliminates metal containing solids from building up in your system but it also reduces the presence of biofilm. Removing solids and scales will likely require unidirectional flushing. Water velocity not only needs to be high enough to move this material, the water needs to be moved in one direction and that is your flow hydrant.

**Third**, maintain adequate disinfection residual to reduce the potential for biofilm and microbial induced corrosion. I am not talking about maintaining chlorine just above detect either (0.1mg/l). It may take many times that to inactivate micro-organisms to achieve biostability. If your system does not practice continuous chlorine disinfection, you likely have substantial biofilm to cut through.

If you are unsure about the stability of your water, run a few ATP tests to determine total living biomass present. These tests are becoming more popular and some manufacturers have portable test units you can use.

**Fourth**, stop injecting additional food (nutrients) into your water. That guy who uses a smidgen of water a week to flush the toilet, the gal who is out of town most of the week on business, or the McMansion with oversized plumbing undoubtedly have warm water and zero disinfection residual. They likely have a googol of complex biological communities living on all the available, internal surfaces of their pipes.

**Fifth**, be sure treatment is optimized. If you are using caustic to raise pH or laying down barrier film with orthophosphate, ensure the feed system is operating correctly and you have a consistent dose. If dose is jumping around, fix the feed system problem (see the article called “Dose Variability” in the Winter 2014 issue of the WWA publication for more information). Also, if you are testing any of these water quality or chemical parameters yourself; you need to be running standards on a regular basis to ensure your test method is accurate.

So what happens if you scrutinized your operation and maintenance practices, used sites with correct plumbing material and had good water use, ensured samples were collected correctly, but still exceed the action level? Can you avoid having to public notice the violation? Can you avoid getting
funneled into a corrosion control study? Can you avoid additional monitoring requirements that are poised to come fast and furious? Can you avoid expensive treatment that may not work? It depends.

**Evaluating 90th Percentile PBCU Results**

Most operators are collecting water samples toward the end of the monitoring period and will not have time to react to the negative news. If you collected early, you have a couple months to sort things out and take appropriate action.

Systems that have additional, approved monitoring sites will be in the best position to respond. Compliance with the lead and copper action levels is based on the results of all valid samples collected in the compliance period. If the system collects more than the required number of samples, the results of all the compliance samples will be used in determining the 90th percentile values. As long as the site is approved and has not been sampled yet in the monitoring period, it can be used to increase the number of samples used in calculating the 90th percentile.

Several years ago a small system called me about a lead exceedance. They collected 5 samples, took the highest two results and averaged them for the calculated 90th percentile, and found that they exceeded the maximum contaminant level. One sample was very high. While allowed by code and cost effective for a small utility, five results is not a large sample size to get an accurate picture of what is occurring in a water system. I advised them to collect five additional samples at the remaining, approved sites. They collected the additional samples, used the 9th highest value as their 90th percentile, and came under the lead standard. While I admit that this is more difficult for larger water systems, the same concept of improving monitoring accuracy with larger sample sizes holds.

Before someone holds me in contempt, I better explain myself. We are not in the business of trying to get around a Federal rule. We are in the business of accurately assessing PBCU concentrations. From a statistical standpoint, a larger sample size is more accurate. It works both ways though. It may bring your calculated result down but it could also increase it. Either way, we increase our confidence in the calculated result so everyone wins.

Are there other options? Basically no and this demonstrates one of the downfalls of the rule - inflexibility. Once you submit your results to the regulatory agency, you are certifying they are accurate and meet the monitoring and sampling criteria. Regardless of the gross mistakes you or your sampler made, you own the results. The only exception is laboratory error.

With that said, what happens when you exceed the action level and there is no monitoring recourse?

**Action Level Exceedance**

A violation sets in motion a number of requirements. While not the end of the world, it will take work, time, and dollars to work through. The regulatory agency will issue a notice of noncompliance that requires the following:

- Implement a public education program, including public notice the action level exceedance every 6 months until compliance is achieved.
- Collect PBCU samples at your entry points.
- Collect water quality parameters (pH, alkalinity, etc.) at your entry points and distribution system.
- Submit a corrosion control study/plan for review/approval and implement it.
- Collect PBCU samples every 6 months until results are below the action level for two consecutive 6-month periods.

There is a purpose behind each requirement but I want to focus on the fourth. If you have perfect sample collection at perfect monitoring sites and metal results are not source related (rare that they are), your water has uniform corrosion and you will be able to identify an effective treatment chemical to use for corrosion control. Even though the rule assumes all this, chances are reasonably good that adding chemical will not lower your metal levels because you do not have a perfect monitoring program, a perfect O&M program, and there may be little if any uniform corrosion taking place.

While uniform corrosion is very real, as we discussed previously, there are other issues that need to be uncovered and addressed if you are going to get to the root cause of high PBCU. So how do we do the best we can, with the rule we have, and lower PBCU levels?

**Strategies**

Systems that exceed the action level for the first time will want to complete a comprehensive evaluation of monitoring, sampling, and O&M practices. The last thing you want to do is go through the motions of developing a corrosion control plan and select a chemical that will not work or be antagonistic to other important goals ~ water disinfection, eliminating nutrient pollution, or even controlling corrosion.

Dig into your historic PBCU monitoring/sampling practices and spend time evaluating historic PBCU sample results, water quality data, and O&M practices. With an understanding of the physical and chemical properties involved, you may inductively solve the puzzle or at least narrow the focus for further investigation. This typically requires a major investment of time, expertise, and resources few utilities have.
Another difficulty, you were likely not even around when your utility exceeded the action level in the first place. You will need outside help and it may come from multiple sources. Consider the following points:

• While you can compare your situation with a nearby community, do not automatically assume you have the same problem and need to use the same treatment chemicals.
• Don’t rely on the help from a one-trick Joe unless you want a long, costly ride and no long term solution. Uniform corrosion may not be a factor and their chemical may not work as advertised.
• Even specialized experts struggle through difficult cases. Complex processes and relationships are involved that require time, energy, and resources to uncover, understand, and control.
• Keep your WDNR engineer informed on where you are going with your study and even pick our brains. While we do not have the time, resources, and in some cases, the expertise required to complete a thorough review and solve your problem, we can provide guidance and direction that may prove beneficial.

Several systems around the state found out the hard way that their corrosion control strategy did not work as planned. After installing treatment, some failed to meet the standard and others dropped PBCU levels just enough to provide perfect moments of anxiety through subsequent monitoring rounds. Eventually they exceeded the action level and were funneled into the full program.

Sometimes the chemical control strategy appears to be working fine but improvements in monitoring, sampling, or O&M practices were responsible for the drop in metal content. This may surface years later after being lulled into a false sense of comfort in chemical treatment land.

You are making important decisions for your utility that have long term consequences. Do not roll out ineffective treatment strategies that have mediocre or counter-productive results. Get to the root cause or causes and tackle them. Also, be sure you are vigilant during every monitoring round lest you introduce another reason for high metal levels.

Since I cannot provide answers on each situation that might be encountered, I plan to discuss a few cases I have been involved with over the years. As the title of the article suggests, I am also bringing to light the fact that phosphate has not been the common cure as many had thought it would be. In fact, in some cases, it may be antagonistic to program goals and not in the best interest of the water utility.

**Case Studiest**

Five case studies are presented. The first deals with problems on many fronts that took years and considerable resources to investigate or study. The remaining cases involve communities lacking resources but who have found ways to lower lead and copper levels.

Utility “A” exceeded the copper action level from the get-go (early 90’s), spent considerable resources over the years trying to figure out the cause, and have implemented several strategies in an attempt to reduce metal levels.

Prior to exceeding the standard, a phosphate blend (25% ortho / 75% poly) was used at two wells for iron sequestering and continuous disinfection was not practiced. The chemical supplier did coupon tests, a common test used in the chemical process industry which is unsuitable for these types of drinking water evaluations, and recommended they continue with the blend and begin injecting it at the other wells. The utility implemented the recommendation with a requirement of continuous chlorination disinfection.

Copper dropped under the action level but then incrementally increased toward the action level during subsequent monitoring rounds. An outside consultant was hired to evaluate the PBCU monitoring program, examine water quality relationships, and use a pilot plumbing system to test variables that could be involved in contributing to high PBCU levels.
Initial study results pointed towards microbial induced corrosion. The following O&M recommendations were made to lower metal levels: shut off the high iron well, complete unidirectional flushing, and increase disinfection levels.

After making improvements, pilot testing resumed but correlations were weak. The study did show that the phosphate blend had little influence on corrosion either way. Due to expense, they discontinued the formal study and use of the pilot plumbing system.

Since copper levels were increasing and phosphates were not effective, the Department asked that phosphate use be discontinued. Two other factors went into this decision. The two communities bordering the water system in opposite directions used the same sand & gravel aquifer, have similar water quality, neither used phosphates, and neither had corrosive water as evidenced by PBCU test results. Also, polyphosphates in general are used in the water industry to prevent scaling, to clean metal pipes, and it is a nutrient for biological communities.

Being cautious, the utility asked for an opinion from another chemical supplier. Water quality parameters were analyzed so that the Langelier Saturation Index and Ryznar Saturation Index could be calculated. These parameters estimate calcium carbonate precipitation which, based on outdated theory, is supposed to provide a barrier for preventing uniform pipe corrosion. Most researchers now agree that the matrix structure of the film is not dense enough to prevent corrosion. Regardless, the test results or indexes showed little corrosion potential.

A meeting was scheduled with the chemical supplier, utility, and DNR to discuss findings. The supplier was reluctant to recommend discontinuing phosphate use and warned about massive descaling if stopped abruptly. While this seemed contrary to the use of polyphosphate, in that it is being actively promoted as a de-scaling or pipe cleaning agent, the utility decided to discontinue it several months before collecting a full set of investigation samples.

The investigation samples were collected, the 90th percentile was calculated, and the utility was over the copper action level (1300ug/l). Eight of the thirty samples were above 1300ug/l and they had an average concentration of 1528ug/l.

At this point, the utility took a step back and re-evaluated their monitoring program. What they found was disturbing.

Some homeowners did not refresh their water (flush their plumbing) at the start of stagnation with some having stagnation time in the days (one being three weeks). Furthermore, some samples came from unapproved taps and several plumbing systems had electrical current. When monitoring and sampling problems were thought to have been resolved, they resurface.

Having gross monitoring problems, the utility developed a sampling form so homeowners could record critical sample collection information. They met with the homeowners to evaluate their plumbing systems and explain sampling procedures. After sampling was controlled (flushed plumbing, stagnate 6 to 10 hours, collect 1st draw sample from cold water drinking faucet), follow-up results at the same eight residents averaged 1106 ug/l. This was a 421ug/l difference or a net reduction of almost 30% copper. As for homes with electrical current, preliminary test results show copper dropped when current was eliminated. The utility is currently collecting additional samples at these sites to determine if the trend continues. The utility hopes to have improvements in place before the official lead and copper monitoring event this summer.

While this utility’s experience may seem to be an outlier, I can point to several other utilities that had similar implementation missteps that have been costly, misleading, and sometimes difficult to address.

Utility “B” began use of the same phosphate blend for sequestering iron after a new well was placed into service. The primary well had iron filtration so the operator was comforted by phosphate use at the new well even though iron levels were negligible. When copper levels increased in the wastewater facility’s effluent, the utility began looking for sources. Closer examination of drinking water quality showed that copper levels began increasing when the utility started sequestering. Since iron was well below the secondary, aesthetic standard, the Department recommended discontinuing phosphate. The utility metered down phosphates and copper began dropping in both the water system as well as the wastewater effluent. An additional advantage is phosphorus levels are lower at the wastewater treatment plant.

Utility “C” began using orthophosphate in the early 90’s to address lead corrosion. They began chlorine disinfection at the same time to maintain biostability. While lead levels fell abruptly and remained low, studies were not carried out to determine whether lead dropped because of the phosphates or the disinfectant to prevent biofilm.

Looking back at the historical record shows that prior to the first PBCU test, the utility had dozens of bacteriological contamination incidents as measured by total coliform test results. This is a key indicator of biofilm problems. In fact, historically, many water systems had severe biofilm problems before the practice of continuous chlorination disinfection.
Corrosion continued from page 32

was promoted in the state (see previous pictures of biofilm).

The utility gradually metered off the phosphates while maintaining good disinfection residuals throughout the water system. Lead concentration remains low. This has proven to be a successful move and timely given the utility’s new phosphorus effluent limit in their WPDES discharge permit.

Like the previous case, it’s difficult to make an accurate inference of cause and effect when there are so many factors that can contribute to high metal levels. In the meantime, this utility is doing its part in reducing nutrient pollution while meeting tough drinking water standards.

Utility “D” practices continuous chlorine disinfection and began adding a phosphate blend in 1995 to address iron related problems. In 2000, they had a lead action level violation. Some of the high lead results came from seasonal buildings. Regardless, they replaced the plumbing with new copper pipe, began caustic treatment, monitored again, and this time they had a copper action level violation. Fortunately, they were able to get below the standard the next monitoring round and stayed below the standard for the next several rounds.

Years later, the Department recommended they discontinue phosphates since source water had very little iron, the original action level exceedance occurred when feeding phosphates, and high results came from unused buildings. They implemented the recommendation, passed the next few monitoring rounds, but exceeded the copper action level last year.

Further investigation revealed they were once again using poor monitoring sites and sampling technique. They sampled from buildings that were not used, used unapproved sample taps, did not refresh the water before stagnation, and did not control maximum stagnation times. Once these were corrected, copper levels fell well below the action level.

Again, many factors may be involved in elevated metal levels. Several additional monitoring rounds will be needed to help authenticate the approach used in lowering metal levels.

Utility “E” is another twist on corrosion that involves chemical treatment. This utility was adding a phosphate blend for years as an iron sequesterant and had relatively low PBCU levels. In 2011, their 90th percentile exceeded the lead action level. Fortunately, the utility sampled early enough so they could collect another 10 samples, at previously approved sites, before the monitoring period ended. The larger sample size brought their 90th percentile level down considerably and prevented an action level exceedance.

The utility revaluated their monitoring sites to verify plumbing material and sampling locations. With this information, they revised their monitoring plan. The utility also increased disinfection levels to address possible microbial induced corrosion. Finally, they discontinued phosphates altogether since iron levels were well below the secondary standard and manageable with a good flushing program (see my previous Wisconsin Water Association article entitled “Sequestering of Iron and Manganese: Minimize Phosphates and Improve Treatment”).

Results have been positive during the last two monitoring rounds. In fact, ninetieth percentile lead results were less than half the action level.

As you can see, water systems still struggle with proper implementation of the PBCU rule. From poor monitoring and sampling practices to ineffective or unproven corrosion control treatment strategies, the game goes on. The other lesson is that poly and poly-ortho phosphate blends do not appear to be reducing corrosion and may be a factor behind higher PBCU levels.

Summary

There are many reasons for elevated PBCU levels. Exceeding an action level will put you on the Federal treatment bus whether you deserve it or not. Treatment may be unnecessary or counter-productive, but you are going for the ride. Fortunately, you have some control over this whether you are a large or small utility. You can avoid getting picked up but it takes time, effort, and downright vigilance on your part. Here are the “take-aways”:

- Review previous PBCU results. Are they increasing or decreasing and is there any correlation with monitoring sites, water use, plumbing material, sampling methods, water quality changes, chemical use, or O&M practices. Your water is being tested for a lot of parameters so use this information.

- Examine your monitoring locations before sample collection not afterwards. Contact the homeowner to find out if there were any changes to plumbing. Better yet, visit them to examine the plumbing material and configuration, sample tap, and determine water use. You will likely have to make some changes to your monitoring site list. Just be sure to notify the DNR when changing sites so your monitoring plan can be updated.

- Develop written instructions on how to collect the first-draw sample and give the homeowner a monitoring form so you can document relevant information. If stagnation
time does not meet the minimum requirement of 6 hours or is unreasonably high (8 to 10 hours is reasonable) or the proper tap was not used, throw the sample out and ask them to collect another. Collect samples early in the monitoring period so you have time to react if things sour.

- Review your O&M practices so you can reduce both corrosion potential and metal levels in your water system. Use low nutrient and low iron/manganese water, flush solids/scales/films out regularly, maintain good disinfection residuals, and optimize treatment.

If you are unfortunate and exceed the lead or copper action level, elicit the help of various experts in the water community that are well versed in various mechanisms of corrosion and the lead and copper rule in general. You are in it for the long haul so be sure you identify the problem and resolve it.

Treatment is costly; ensure it’s necessary.

If you are already treating your water chemically for corrosion, are you sure your treatment chemical is the principle agent behind lowering your lead and copper levels? How do you know your chemicals are not exacerbating corrosion? Are you certain other factors are not responsible for causing lead or copper results to exceed the action level?

No one water system is the same but you can eliminate glaring errors in your PBCU testing program, lower your metal levels, and prevent being funneled into unnecessary treatment. While some water systems definitely have corrosive water and need to treat, others need to peel back layers and years of missteps before discovering root causes for high metals. ☀

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