American Water Works Association
Dedicated to the World's Most Important Resource

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Association of State Drinking Water Administrators

COURSE 2
ASSESSING NEED FOR A CORROSION CONTROL EVALUATION

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Purpose

Protecting Public Health is the purpose of drinking water treatment. To support this purpose this course presents information on the following:

- Why corrosion occurs and how to control it
- How to determine if a corrosion control evaluation is needed
- How to perform a corrosion control evaluation
- How to use a corrosion control evaluation to help meet LCRR

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LEARNING OBJECTIVES

As a result of this course, you will be able to:

Explain	The importance of applying CCT
Identify	What data to collect to support decisions
Interpret	How to analyze data to support CCT decisions
Determine	When it is appropriate to initiate or revisit CCT
Analyze	Which corrosion control studies are appropriate

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MODULE 1

Importance of Applying Corrosion Co… Treatment

4

LEARNING OBJECTIVES

Explain	Context for applying CCT Historical perspective on CCT Performance evaluation Basic concepts

5

What is Optimal Corrosion Control Treatment (OCCT)?

- Legal definition (40 CFR § 141.2)

> *"…treatment that minimizes the lead and copper concentrations at users' taps while ensuring that the treatment does not cause the water system to violate any national primary drinking water regulations"*

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What is Corrosion Control Treatment (CCT)?

- Practical definition for this training
  - Actions taken to meet primary drinking water standards, i.e., minimize lead and copper concentrations at user taps
  - By creating and maintaining water quality conditions near and at the user's tap which minimize the release of lead and copper.

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What is Corrosion Control Treatment (CCT)?

- Typically achieved by adjusting pH, DIC and/ or addition of corrosion inhibitors
- Some utilities have utilized silica addition
- While simultaneously maintaining appropriate distribution system conditions to successfully manage water quality.

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KNOWLEDGE CHECK

Which of the following statements about OCCT is **NOT** true?

A. It is a treatment that minimizes lead and copper at users' tap
B. One method of CCT is issuing "boil water" notices
C. Typical methods include adjusting pH, DIC and/ or addition of corrosion inhibitors
D. CCT must not cause the water system to violate any national primary drinking water regulations

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Historical Corrosion Control Practice

- Corrosion control practice developed to protect infrastructure assets
  - Reports in the literature from the early 20th century reflect
    - pH and alkalinity control
    - Installation of linings
    - Prevention of galvanic corrosion
    - Role of disinfection and microbially induced corrosion
    - An initial understanding of scale formation

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Historical Corrosion Control Practice

- By mid-20th century corrosion control was recognized as a tool to protect public health
  - By 1974, considering the corrosivity of finished water on distribution systems was accepted practice
  - Following 1974 SDWA, EPA set a secondary standard that water be **noncorrosive**

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Historical Corrosion Control Practice

- In 1982 an EPA report "Corrosion in Potable Water System" reflects how corrosion control practice was taken into account:
  - Water quality characteristics (e.g., pH, alkalinity)
  - Treatment effects (e.g., disinfectant residual)
  - Flow (e.g., water age)
  - Scale formation
  - Distribution system materials (e.g., iron, concrete, plastic, copper, lead)

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Historical Corrosion Control Practice

- A classic manual by AWWARF (2nd Edition 1996 Internal Corrosion) introduces:
  - Concepts of scale analysis
  - Lead and copper corrosion and their control
- With promulgation of the Lead and Copper Rule the sector turned to a regulatory focus on using corrosion control to manage:
  - Lead
  - Copper

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Systems Can Treat their Distributed Water to Reduce Metals Release by Using CCT

- Optimized corrosion control treatment was required for systems in the LCR of 1991
  - Large water systems (>50,000 persons served) had to determine OCCT
  - Smaller water systems exceeding Action Level were to determine OCCT
- Data show that LCR was effective in lowering lead release at consumer taps

It is important to recognize how effective corrosion control treatment has been in lowering lead and copper levels

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Active Management of Distribution System Water Quality

Calcium carbonate ← Controlling excessive deposition

High free chlorine residual ← Managing iron, manganese and lead release

Optimize pH and alkalinity
Orthophosphate inhibitor
Silicates
← Limiting occurrence of soluble lead and copper

RELIABLE LCR COMPLIANCE

Polyphosphate ← Used to mitigate iron , manganese, calcium deposition

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Exam Question

True or False?

Corrosion Control Treatment (CCT) is creating and maintaining water quality conditions near and at the user's tap which minimize the release of lead and copper

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Effectiveness of CCT Method is Determined by Water Chemistry and Specific to Each System

- Key factors in selecting CCT
  - Water quality
  - Existing treatment
  - Distribution system materials and design
  - Type and prevalence of premise plumbing materials present
  - Distribution system operation

There is no universally effective corrosion control treatment for all water systems

Evaluating CCT prior to a treatment or source change is very important

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Effectiveness of CCT Method is Determined by Water Chemistry and Specific to Each System

- Some systems may be limited by:
  - How much of certain chemicals can be added or
  - Treatment options that can be tolerated

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Slide 15

CW6 Any suggestions for animation can go in the Notes Section.
Chad Weikel, 7/16/2021

When is Evaluating CCT Critical?

- Responding to or preparing for key events
  - Planning a change in treatment
  - Planning a change in source of supply
  - Responding to a regulatory trigger (e.g., LCR)
- Making a change in CCT strategy
- Ongoing practice

All utilities should inform themselves about the corrosivity of their treated water, even if CCT is not required in their system per the LCR.

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CCT Evaluation Should Not Proceed Until System is Ready

- Stable finished water quality
- Maintaining a reliable secondary disinfectant residual
- Minimized sediment accumulation in distribution system and finished water storage
- Sound monitoring and analysis protocols, practices, and locations
- When possible, a workable distribution system hydraulic model in place

Effective corrosion control requires stable conditions. If such conditions are not present create them.

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KNOWLEDGE CHECK

Which of the following statements about CCT is **NOT** true?

A. Effectiveness of CCT method is determined by water chemistry
B. CCT is specific to each system
C. There is one method of CCT that is effective in all systems
D. Some systems are limited by the type of chemical that can be used

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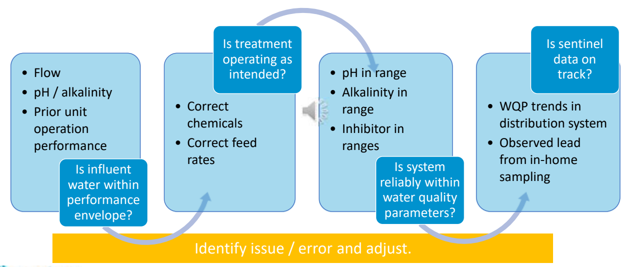
Elements of Monitoring Ongoing Performance



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Addressing a Key Event

1. What does ongoing evaluation show?
   - Is there a recognized issue / error in practice?
   - Has or can the issue be corrected?
2. Assess current conditions influencing corrosion control performance
   - Characterize current sources of supply
   - Characterize current finished and distributed water quality
   - Assess current facilities

If not evaluating routinely then review performance retrospectively

Address issues / errors and monitor for impact

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Addressing a Key Event

- Understand distribution system pipe materials

3. What CCT is appropriate?
   - Determine if current CCT remains valid
   - Assess if change is likely to effect current CCT strategy
4. Determine how to adjust CCT?
   - Collect data to inform CCT change
   - Develop a CCT strategy based on weight of evidence approach

Maintain ongoing dialogue with primacy agency

Identify need for collecting additional data / Collect data to support decision making

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Addressing a Key Event

5. Adjust CCT
   - Prepare distribution system
   - Establish monitoring strategy
   - Change CCT
   - Monitor and adjust
   - Establish WQPs
6. Implement control charting and QA/QC

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KNOWLEDGE CHECK

True or False?

Addressing a key event requires the following:

A. Assessing current CCT
B. Determining impact of change on CCT
C. Evaluating alternate CCTs
D. Monitoring water quality after change

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A Review of Some Important Basics

- Why is dissolved inorganic carbon (DIC) measured?
- What does a solubility curve tell us –and what doesn't it?
- How should orthophosphate, polyphosphate, or a blended phosphate concentration be reported?
- How should phosphate concentration be measured?
- What are important considerations in measuring pH?

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pH, Alkalinity, DIC

- One common CCT option is pH and alkalinity control
- So how does DIC fit in (see Course 1 for more detailed discussion)
  - Alkalinity is $HCO_3^- + 2CO_3^{-2} - H^+ + OH^-$
  - Alkalinity is expressed as $CaCO_3$ with a molecular weight of 100

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pH, Alkalinity, DIC

- DIC is only the carbon portion of alkalinity plus the carbon portion of H_2CO_3
  - And is expressed as carbon with a molecular weight of 12
  - As a quick mental estimate, in a typical pH range of 7.5-9, DIC is about 25% of the alkalinity
  - For example, at pH 8 and alkalinity =170, DIC=40
- Carbon (DIC) is important because we want to form lead carbonate
  - $PbCO_3$ called cerussite, or
  - $Pb_3(CO_3)_2(OH)_6$ called hydrocerussite

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Solubility Curves

- Traditional curve using EPA published constants (called Leadsol)
- The following curve shows the solubility of lead when the two lead carbonate species form
- One can get an idea of which way to adjust their pH or DIC to move into a less soluble range

Solubility curves are specific to a particular water quality and should be created for each situation

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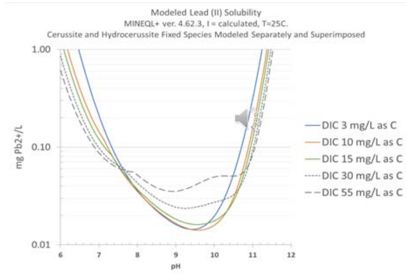
Lead-Carbonate Solubility Curve



Based on constants EPA uses in Leadsol model These are not predictors of values in the system---only trends

asdwa Source: Cornwell Engineering Group

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Basis for Solubility Curves

- A basic assumption underpinning solubility curves is which solubility constants are used
- **So**, these curves are useful to see trends
- **But** they don't tell us absolute numbers or clearly predict what minerals will form in pipe scales
- Use solubility curves as a guide—but couple with solubility tests (Course 3)
- Don't use a single value for lead concentration and compare it to another single value under different conditions

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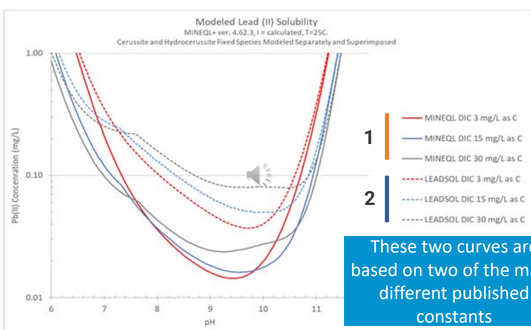

These two curves are based on two of the many different published constants

asdwa Source: Cornwell Engineering Group

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CCT Using pH and Alkalinity

- Tries to maximize formation of the two lead carbonate compounds
- pH and DIC influence that formation
- Solubility curve gives us insights into how to adjust pH and DIC
  - Scale analysis can provide insights as to how the actual scale on the pipes relates the curves

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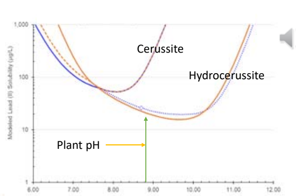
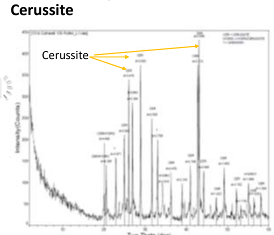
An Example: Curve Doesn't Match Scales

Curve Predicts Hydrocerussite



But scale analysis showed more Cerussite



asdwa Source: Cornwell Engineering Group

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KNOWLEDGE CHECK

Why is Carbon (DIC) important in corrosion control?

A. Because we want to form lead carbonate
B. Because we want to form lead phosphate
C. Because it's blue
D. Because it affects water temperature

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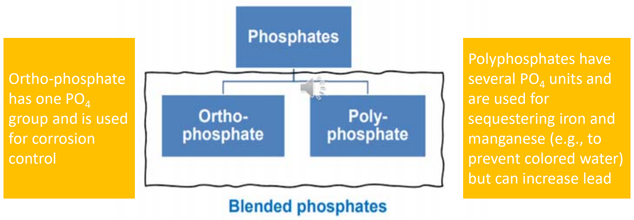
Classes of Phosphates Used in Water Treatment



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Polyphosphate, Orthophosphate and Blends

- Uniform reporting is critical to understanding and sharing data especially between a utility and regulators
- Phosphates are often reported as product or as chemical
- What does "as product" mean?
  - Often this is determined by the utility measuring how many gallons of product that was fed
  - The vendor will provide weight of the product
  - "as product" is typically *gallons x weight*

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Reporting Product

- Gallons *X* weight of product = pounds of product fed
  - Say 10 gallons fed x 10.2 pounds/gallon = 102 pounds product fed
  - Say this volume was fed into 10 mgd = 102 /10 = 10.2 pounds/MG (MG=million gallons)
  - A convenient conversion is (pounds/MG)/8.34= mg/L
  - 10.2/8.34 converts to 1.2 mg/L as product

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Reporting Product

- So, what's wrong with reporting "product" dose?
  - Often all that is reported is the feed concentration in milligram per liter (e.g., 1.2 mg/L)
  - How does one know if the value is for product or as chemical in the product
  - The liquid product is not 100% phosphorous
  - The product could be 3% P, 20% P, …

Do not report concentration "as product"

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Clearly Report What is Fed as Either P or PO_4

- Take the last example
  - 1.2 mg/l of product was fed
  - Let's say the utility purchases 36% orthophosphate reported as PO_4
- Therefore, this utility should report a feed rate of
  - 1.2 mg/L product X 0.36 orthophosphate concentration in the product
  - Or they feed 0.44 mg/L as PO_4
  - That would be the same as ~0.15 mg/L as P
  - Note that is 3 times P to equal PO_4 (it's actually 3.06= MW PO_4/MW P= 95/31)

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Polyphosphate and Blended Phosphates are More Complicated

- Say a blend is used and the utility reports feeding 0.3 mg/L as P
- What does that mean? total P? or only the ortho-P portion of the blend?
- Often it is reported as PO_4, in this case 0.9 mg/L as PO_4
- This now even more confusing as this could imply 0.9 mg/L of the ortho-P portion of the blend is being fed, or that this is the total P being fed expressed as PO_4
- Sometimes polyphosphates are expressed as PO_4 when in the product itself there actually isn't any PO_4

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KNOWLEDGE CHECK

Which of the following phosphates are not used in water treatment?

A. Orthophosphate
B. Blended phosphate
C. Liquid phosphate
D. Rock phosphate

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Let's Introduce Some Terms to Help Clarify

- The orthophosphate portion of what is fed = o-PO_4
- The polyphosphate portion of what is fed = p-PO_4
- The total phosphate fed = t-PO_4
- So, let's say in our last example the feed was 0.9 mg/L t-PO_4 and the blend is 60 % polyphosphate and 40% orthophosphate
- p-PO_4= 0.54 mg/L p-PO_4
- o-PO_4= 0.36 mg/L o-PO_4

If we report the o-PO_4 and p-PO_4 portions as chemical fed it is now clear to all

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Finally, How Do We Measure These in the Lab?

- Testing for only the orthophosphate portion
  - Often this is referred to as *reactive phosphate*
  - The sample is analyzed directly without digestion
- To test for *total phosphate* which includes p-PO_4 and o-PO_4 the sample must be digested

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Finally, How Do We Measure These in the Lab?

- So, if you have a blend and don't digest you are only measuring o-PO_4
- If you have a blend and digest it, then analyze it, it's t-PO_4
- If you test once without digestion and once with digestion you can get all three, o-PO_4, p-PO_4 and t-PO_4

Caution

What we often see is that the sample is digested and reported as mg/L PO_4. The implication is that it is ortho-P, but it isn't if the product is a blend or a p-PO_4

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Polyphosphates

- p-PO4 can degrade to o-PO_4
  - In storage if stored too long
  - In the distribution system
- So, measured reactive phosphate might increase with time and utilities using a p-PO_4 or blend may want to measure both the p-PO_4 and o-PO_4 portions of the phosphate in the distribution system.

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KNOWLEDGE CHECK

What is reactive phosphate

a. Polyphosphate
b. Any phosphate
c. One that reacts with lead
d. Orthophosphate

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Knowledge Check

Example Generic Corrosion Inhibitor Product Label

GCI is a combination product based on sodium polyphosphates.

Phosphate content: 90.0 ± 2.0 % t-PO_4

Conversion factors: PO_4-content x 0.7473 equates P_2O_5-content

PO_4-content x 0.3261 equates P-content

If system is feeding 1.5 mg/L of GCI product, what is orthophosphate feed rate?

_____ mg/L o-PO_4

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Properly Measuring pH

- Some waters cannot be exposed to the atmosphere when measuring pH
- Any water **with low buffering capacity** can experience these effects

Implication

pH cannot be measured if these waters are exposed to air or even measured from a beaker that is filled slowly

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Properly Measuring pH

- A water oversaturated with CO_2 will release CO_2 when exposed to atmosphere and the pH will rise
  - This tends to happen with groundwaters
  - Can also happen with CO_2 oversaturated lakes and reservoirs
- A water undersaturated with CO_2 will gain CO_2 and the pH will decrease
  - Softening plants will often experience this situation

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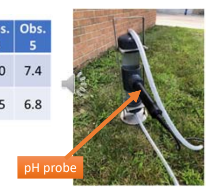
When CO_2 is Out of Balance Need Headspace Free Measurement

Sample Protocol	Obs. 1	Obs. 2	Obs. 3	Obs. 4	Obs. 5
Exposed to air	6.9	7.1	7.2	7.0	7.4
Headspace free	6.6	6.9	6.5	6.5	6.8



Source: Cornwell Engineering Group, 2020
Sampler courtesy of Joliet, IL

Headspace Free Sampler

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Not All Waters Require Headspace Free pH Measurement

- Some waters are **well buffered or already in equilibrium** with the atmosphere
- Some waters may be **stable or only slightly over- or under-saturated** with CO_2
  - In this case gently filling a beaker while minimizing air contact and measuring pH can be sufficient
  - Another alternative is to fill a pocket pH cap with water (again gently filling) and place the meter in the cap

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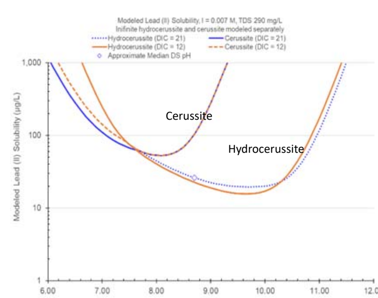
AA3

Learning Activity

Which lead scales (species) dominate at each of the following pH values?

1. 7.0
2. 10.0
3. 9.5
4. 6.5.



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Slide 49

CW2 Feels like a trick question.
Chad Weikel, 7/16/2021

Slide 54

AA3 Kris: Make a Cerussite and Hydrocerussite box option next to each pH value to set this up?
Andrew Appell, 11/3/2021

Learning Activity

For each of the following changes, theoretically, drag the statement into the appropriate box:

1. At a DIC of 30, the pH goes from 9 to 9.5
2. At a DIC of 10, pH goes from 8 to 9
3. At DIC of 30, pH goes from 7.0 to 7.5
4. At pH 7, DIC goes from 15 to 55
5. Using leadsol, at DIC of 30, pH goes from 7.0 to 7.5

Lead increases

Lead decreases

No or slight change in lead

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Learning Activity

A system is using a blended product that is 25% p-PO4 and 75 % o-PO4. The utility is feeding 2 mg/L as product with a specific gravity of 1.2 and 30% t-PO4.

How many mg/L of p-PO4 are being fed?

A. 0.10
B. 0.15
C. 0.20
D. 0.25

How many mg/L of o-PO4 are being fed?

A. 0.35
B. 0.40
C. 0.45
D. 0.50

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Summary

- Corrosion control approaches serve specific end goals
- The history of corrosion control demonstrates the effectiveness of well-selected and implemented corrosion control practice
- Corrosion control practice should be monitored and evaluated on a continuous basis
- Several factors are important in selecting and effectiveness of CCT

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Summary

- Evaluating unexpected corrosion changes has four possible steps
  1. Begins with confirming current practice is being implemented as intended
  2. Goes on to evaluate if change (occurred / will occur) will interfere with intended practice
  3. Considers if corrosion control practice should change
  4. Monitors and evaluates the success of any change in practice

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Summary

- Having a clear understanding of DIC underpins corrosion control evaluation
- Solubility curves are a valuable tool---but must be used with caution
- Clear and correct use of nomenclature is essential to proper application of phosphate-based corrosion inhibitors
- Collecting field data that represents actual "in-pipe" conditions can be very important to understanding pH and corrosion for certain waters

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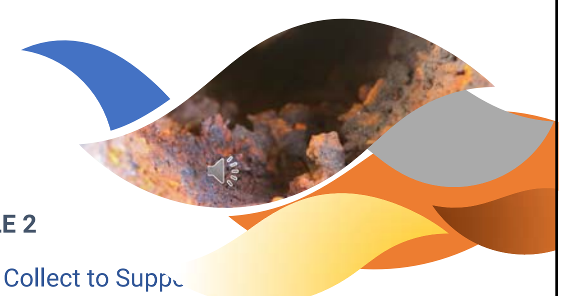

MODULE 2

Data to Collect to Supp
Decisions

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LEARNING OBJECTIVES

Describe

- Key data for all systems
- System-specific data needs
- Considerations for evaluating available data and identifying data gaps

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Various Data Sources May Be Available

- Water Quality Data
- Physical & Hydraulic Information
- Customer Complaints
- Operations and Maintenance Data
- Public Health Data

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Pertinent Data Sets for All Systems – Historical Water Quality Data

- Raw, point-of-entry (POE) and distribution system data - *system specific*
- Lead and Copper Rule (LCR) tap and water quality parameter (WQP) data
- Revised Total Coliform Rule (RTCR) data, *paired with WQP samples, if possible*
- Complaint data (i.e., colored water issues)
- Special sample results (total vs. dissolved, profile sampling, etc.), *if available*

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Pertinent Data Sets for All Systems – Additional Information

- Treatment and operations data including established water quality targets and daily chemical doses
- Inventory of water mains, service lines and premise plumbing materials
- Understanding of distribution system water flow paths and influence zones for systems with multiple sources
- Water age
- Distribution system practices (e.g., flushing and cleaning)

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KNOWLEDGE CHECK

High priority data needs include:

a. Lead and Copper Rule tap and WQP data
b. Revised Total Coliform Rule data
c. Materials inventory
d. (a) and (c) only
e. All of above

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Specific WQPs are Essential Based on Scales Present

Example Scales *(Mineral Form)*	System Characteristics	Key Water Quality Parameters (WQPs)
Lead(II) carbonate(s) *Cerussite* *Hydrocerussite*	Systems adjusting pH/alkalinity or without CCT / sequestration	pH Alkalinity DIC
Lead(II) phosphate(s) *Hydroxpyromorphite*	Systems adding phosphate-based inhibitor or sequestrant	Orthophosphate DIC pH
Lead(IV) *Plattnerite*	Chlorinated distribution systems	Free Chlorine Residual pH

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Slide 61

CW12 Modfied.
Chad Weikel, 7/16/2021

SR5 i tweaked these based on what are in the actual slides for this module
Slabaugh, Rebecca, 8/27/2021

Slide 65

CW14 Answer?
Chad Weikel, 7/16/2021

Key Water Quality Data Needs – All Systems

Level 1[¥] (Priority)	Level 2 (Supplemental)	Level 3 (Diagnostic)
pH	Temperature	Bacterial speciation
Total alkalinity	Dissolved oxygen	Sulfide
DIC (calculated)	Lead (total and dissolved)	Nitrite/nitrate
Disinfectant residual	Copper (total and dissolved)	DBPs
Lead (total)	Iron (total and dissolved)	
Copper (total)	HPC	
Hardness (total and calcium)	ATP	
Conductivity or TDS	Color (apparent)	
Chloride[#]	TOC	
Sulfate[#]	Turbidity	
Iron (total)[#]	CCPP (calculated)	
Manganese (total)[#]	LSI (calculated)	

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[#] Could reduce monitoring frequency pending baseline / event.
[¥] Raw, finished and distribution data if available.

Source: Adapted from AWWA M58: Internal Corrosion Control in Water Distribution Systems, 2nd ed. , 2017

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Key Water Quality Data Needs – System Specific

Level 1[¥] (Priority)	Level 2 (Supplemental)	Level 3 (Diagnostic)
Phosphate (total and ortho), *systems using phosphate-based inhibitor or sequestrant*		
Silica, *systems using silica-based inhibitor*		
Ammonia (total and free), *chloraminated systems or where present in source*[#]		
Oxidation reduction potential (ORP), *chlorinated systems*[#]		
Aluminum, *systems using Al-based coagulant or with high source water aluminum*[#]		

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[#] Could reduce monitoring frequency pending baseline / event.
[¥] Raw, finished and distribution data if available.

Source: Adapted from AWWA M58: Internal Corrosion Control in Water Distribution Systems, 2nd ed. , 2017

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KNOWLEDGE CHECK

All systems need to monitor the same set of water quality parameters.

a. True
b. False

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Developing Useful Data

- Collect data at appropriate locations at a useful frequency
- Collect data for an appropriate period of record
- Utilize appropriate sampling and analytical techniques
  - pH: headspace free, analyzed in field
  - Orthophosphate: reactive portion only

Collect / organize data with key questions for decision-making in mind.

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Developing Useful Data

- Use consistent units, for example:
  - Phosphate: mg/L o-P vs mg/L as o-PO_4
  - DIC: mg C/L vs mg/L as $CaCO_3$
  - Calcium: mg Ca/L vs mg/L as $CaCO_3$
- Use paired data, where available
- Understand the sources of variability in your analysis (e.g., analytical, process control)

Data quality and quantity should be appropriate to the key questions being posed.

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Determining Additional Monitoring Needs

What data are available?

- Across the entire distribution system?
- In all supply zones?
- In areas where key materials are located?
- From the same sites over time?

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Slide 69

CW13 Revise answer.
Chad Weikel, 7/16/2021

SR6 moved this down since it wasn't covered yet
Slabaugh, Rebecca, 8/27/2021

Determining Additional Monitoring Needs

- What data are available?
- Reflect use of all relevant water supplies and/or treatment?
- Include potentially challenging seasonal conditions?
- Are data paired? Align with LCR monitoring periods?

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Suggested Monitoring Program Components

- Monitor for Level 1 Parameters weekly at each POE
  - Frequency for select parameters may be reduced once a baseline has been established
- Monitor for key water quality parameters at all or a subset of RTCR locations
  - Ensure sites are geographically distributed and capture all supplies or blend zones
  - WQPs typically include pH, alkalinity, orthophosphate or silicate
- Determine if additional tap sampling data are necessary

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Learning Activity

Drag & Drop the following utility data used for assessing historic CCT performance

Alkalinity | Disinfectant Residual | Nitrate | pH | Hardness | Lead sequential sampling data | Lead & Copper Compliance Data | Phosphate | ATP

Level 1 (Priority) | Level 2 (Supplemental) | Level 3 (Diagnostic)

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Summary

- The necessary data for a proper corrosion control study depends on system-specific water quality, treatment, and scales.
- At a minimum, all systems should be actively reviewing LCR tap data, WQP data, and disinfectant residual.
- Collect and organize data with key questions for decision-making in mind.

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MODULE 3

How to Analyze Data to CCT Decisions

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LEARNING OBJECTIVES

Describe

- Key considerations and presentation approaches when analyzing data
- Key questions to pose in analysis
- Which data help answer key questions

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Data Visualization and Analysis

	Level 1 (Routine)	Level 2 (Supplemental)
Per POE	Plot on a time series chart (pH, alkalinity, disinfectant residual, orthophosphate, CSMR) Calculate ranges and percentiles / create box and whisker plot	Create control charts for each POE
Distribution	Create box and whisker plots of WQP/ tap data by monitoring round	Create box and whisker plots and/or control charts of key WQPs by site Map WQP / tap data (*integrate with materials inventory*)

Sample size (n) and time period over which data are available may influence the type of visualization or analysis performed.

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Key Considerations – pH and Alkalinity

Are conditions consistent with the corrosion control strategy?

- Is there significant variability as determined by your CCT method
- Is variability
  - Site-specific or systemwide
  - Short-term, intermittent, or long-term

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CW17 CW18

Key Considerations – pH and Alkalinity

- Are changes in the raw water source, treatment, or operations leading to deviations from target conditions?
- Are there differences between the quality of water leaving the plants versus what is observed in the distribution system?

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Key Considerations – pH and Alkalinity

- What are the resulting DIC and buffer intensity in the water at each point of entry?
  - Are they consistent with historical data?
  - Does the supply have adequate buffer intensity?

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KNOWLEDGE CHECK

1. Trending and evaluation are only necessary following an upset or ahead of change.
   a. True
   b. False
2. Creating time series plots for each POE is a good first step for analyzing water quality data.
   a. True
   b. False

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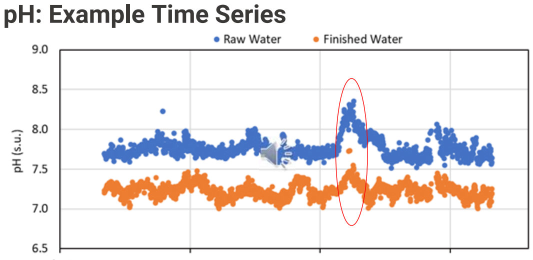
pH: Example Time Series



Source: Arcadis

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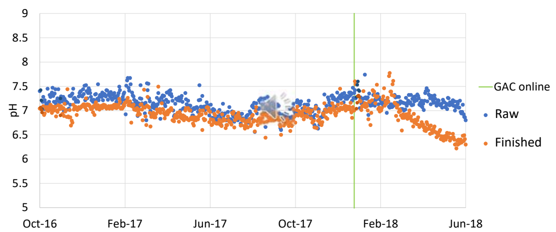
Slide 81

CW17 A lot of content for one slide. This will be more effective broken up into 3 slides.
Chad Weikel, 7/16/2021

CW18 Guideline: one minute/slide.
Chad Weikel, 7/16/2021

pH: Example Time Series



Source: Arcadis

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pH: Example Box and Whisker Plots

Source: Arcadis

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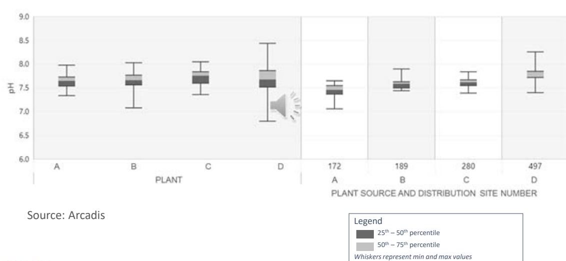
pH: Example Box and Whisker Plots



Source: Arcadis

Legend

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Estimating DIC

- DIC can be estimated from published figures or tables, such as those in EPA's "Optimal Corrosion Control Treatment Technical Recommendations" USEPA (2019)
- Also see Module 1 for a quick estimation

Estimated DIC (mg C/L) for water temperature of 25 degrees C and TDS of 200

Total Alkalinity	pH 8.0	8.2	8.4	8.6	8.8	9.0	9.2	9.4	9.6	9.8	10.0
0											
2	0	0	0	0	0	0	0	0			
4	1	1	1	1	1	1	1	1	0	0	
6	1	1	1	1	1	1	1	1	1	0	0
8	2	2	2	2	2	2	2	1	1	1	0
10	2	2	2	2	2	2	2	2	2	1	1
12	3	3	3	3	3	3	2	2	2	2	1
14	3	3	3	3	3	3	3	3	2	2	1
16	4	4	4	4	4	4	3	3	3	2	2
18	4	4	4	4	4	4	4	4	3	3	2
20	5	5	5	5	5	4	4	4	4	3	3
22	5	5	5	5	5	5	5	4	4	4	3
24	6	6	6	6	5	5	5	5	4	4	3
26	6	6	6	6	6	6	6	5	5	4	4
28	7	7	7	7	6	6	6	6	5	5	4
30	7	7	7	7	7	7	6	6	6	5	4
35	9	8	8	8	8	8	8	7	7	6	5
40	10	10	10	9	9	9	9	8	8	7	6
45	11	11	11	11	10	10	10	9	9	8	7
50	12	12	12	12	12	11	11	10	10	9	8
55	13	13	13	13	13	12	12	11	11	10	9
60	15	14	14	14	14	14	13	12	12	11	10

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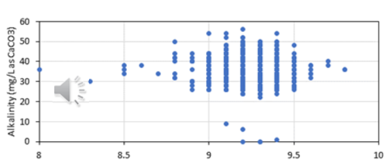
Estimating DIC

- Using average finished water pH and alkalinity for each POE is a good start
- However, if possible, used paired data to understand changes to DIC as pH and/or alkalinity change



Source: Arcadis

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Estimating DIC

- Table is modified from EPA's "Optimal Corrosion Control Treatment Technical Recommendations" USEPA (2019)

Estimated DIC (mg C/L) for water temperature of 25 degrees C and TDS of 200

Total Alkalinity	pH 8.0	8.2	8.4	8.6	8.8	9.0	9.2	9.4	9.6	9.8	10.0
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18	4	4	4	4	4	4	4	4	3	3	2
20	5	5	5	5	5	4	4	4	4	3	3
22	5	5	5	5	5	5	5	4	4	4	3
24	6	6	6	6	5	5	5	5	4	4	3
26	6	6	6	6	6	6	6	5	5	4	4
28	7	7	7	7	6	6	6	6	5	5	4
30	7	7	7	7	7	7	6	6	6	5	4
35	9	8	8	8	8	8	8	7	7	6	5
40	10	10	10	9	9	9	9	8	8	7	6
45	11	11	11	11	10	10	10	9	9	8	7
50	12	12	12	12	12	11	11	10	10	9	8
55	13	13	13	13	13	12	12	11	11	10	9
60	15	14	14	14	14	14	13	12	12	11	10

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Slide 86

CW19 Please include any animation suggestions in Notes.
Chad Weikel, 7/16/2021

SR5 Point to a box
Point to the whiskers
Add in line across figure at pH of 7
Slabaugh, Rebecca, 9/17/2021

Slide 87

SR6 could circle plant at and site 172 at the same time
Slabaugh, Rebecca, 9/17/2021

Slide 89

CA3 did you mean to next show how DIC cnahes as alk/pH changes
Cornwell,David Alan, 5/24/2021

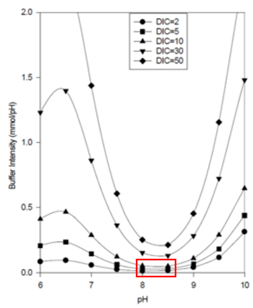
SR4 flipped the order on these and renamed slides. slide 12 adn 13 really go together, but i realize they want tne figure and table split. this could maybe be an animation.
Slabaugh, Rebecca, 6/15/2021

CW20 Include any animation suggestions in Notes.
Chad Weikel, 7/16/2021

AA2

Assess Buffer Intensity

- Buffer intensity measures how resistant water is to change in pH (refer to Course 1 for more information)
  - Minimum at pH 8 – 8.5
  - Maximum pH 6.3 and 10.3
  - Buffer intensity increases with DIC



Source: Clement & Schock 1998

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CW21
CW22

KNOWLEDGE CHECK

Waters without adequate buffer intensity may experience which of the following:

a. pH swings in the distribution system
b. Increased chloride concentrations
c. Increased particulate release

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Key Questions for Corrosion Inhibitor

- Are **dose and residual at points-of-entry** reliably within target range consistent with corrosion control strategy?
- Are changes in the **raw water source, treatment, or operations** leading to deviations from the target?
- Are target residuals maintained **throughout distribution system**? Is there a demand in the distribution system?

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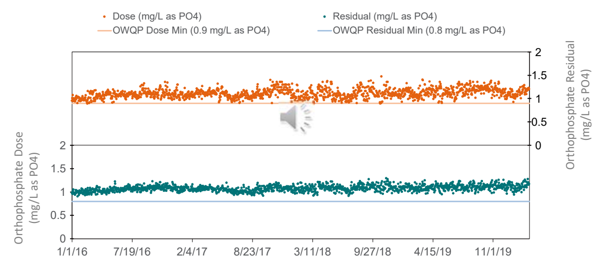
Orthophosphate: Example Plots



asdwa Source: Arcadis

94

Key Questions for Disinfectant Residual Data

- Are target levels being achieved at the points-of-entry?
- Are there geographic trends in observed occurrence?
- Do observed levels or trends in residual data suggest underlying conditions that may affect corrosion control practice?
- Is there evidence of biological activity (i.e., nitrification in chloraminated systems)?

Similar analytical approaches to those previously described can be applied to disinfectant residual.

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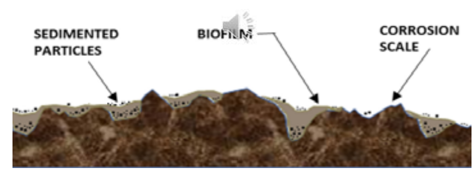
Assessing Impacts from Legacy Deposits

- Over time, all water mains accumulate a deposit/biofilm complex – ***legacy deposits***



asdwa Source: Hill et al., WRF 4653, 2018

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Slide 91

AA2 Please put your instructions for animations here.
Andrew Appell, 10/13/2021

Slide 92

CW21 Where is this explicitly covered?
Chad Weikel, 7/16/2021

CW22 Please check answer.
Chad Weikel, 7/16/2021

Assessing Impacts from Legacy Deposits

- Review and track pertinent data
  - Discolored water complaints
  - Iron and manganese
  - Adenosine triphosphate (ATP), heterotrophic plate count (HPC)
  - Nutrients (C, N, P)
- Proper distribution system management is needed to remove hydraulically mobile deposits (refer to Course 3)

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Key Questions for Operations

- Were there any deviations from routine treatment practice?
- Were there any deviations from typical source water(s)?
- Were there distribution system activities that would have affected observed values?
  - Main breaks
  - Scheduled pipe replacement
  - Non-water activities, sewer, gas, road construction etc.

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CW9

KNOWLEDGE CHECK

Which of the following changes to operations could impact lead or copper concentrations at customer taps?

A. Main breaks
B. Change in treatment
C. Change in source
D. All of the above

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Control Charts Provide Utility Feedback on Process Optimization and Control

Benefits

- Separate WQP trends from statistical noise
- Tighter data bands: less variability
- Outliers excluded if median is used

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Control Charts

- Based on Shewhart control charts for process control
- Use statistical subsets (or "bins") of WQP data
- Establish control limits:
  - Target goal based on mean or median
  - Upper limits (UCL) and lower limits (LCL) are based on a ±3 sigma range

Control charts are an optimization tool, not a regulatory compliance requirement

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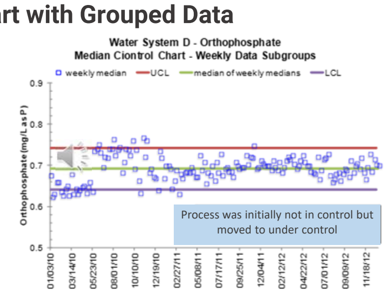
Example Control Chart with Grouped Data

Performance	
Goal	= 0.7 mg/L as P
Requirement	= 0.33-1.3 mg/L as P



Source: Cornwell et al. 2015. Controlling Lead and Copper Rule Water Quality Parameters. Journal AWWA, 107, 2.

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Slide 99

CW9 Good spot for a knowledge check on key operations questions.
Chad Weikel, 7/16/2021

Control Charts Allows Operators to Make Informed Decisions

- Operators can react to first low data trends seen in the plot and then high data trends seen
- Changes can be made slowly without over-reacting
- Operations will get better at reducing variability and the upper and lower control limits will come closer together over time

Operator now can easily see trends in the plants control of phosphate dose over time

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Key Questions for Lead and Copper

- Are lead and copper levels reliably within community's target performance range?
  - How do they compare to the action levels, trigger level (lead only), and practical quantitation limits?
- Are there any trends in observed levels over time?
  - By season?

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Key Questions for Lead and Copper

- How variable is observed occurrence?
- Are observed levels consistent throughout distribution system?
- Is there a correlation between higher levels and:
  - Materials (or home age)
  - Sources
  - Water quality (pH, free chlorine, inhibitor)
  - Water use/stagnation
  - Events (changes in source, treatment, operations, construction)

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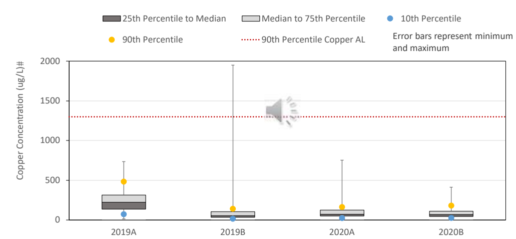
Example Plot -- Copper



Source: Arcadis

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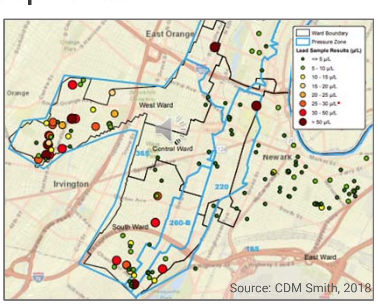
Example Map -- Lead



Source: CDM Smith, 2018

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KNOWLEDGE CHECK

1. How are Control Charts useful?
   a. They focus on trends, allowing for corrections
   b. They focus on the outliers

2. If elevated lead is observed, which is the more appropriate reaction:
   a. Immediately change the chemical dose
   b. Investigate possible reasons for the change

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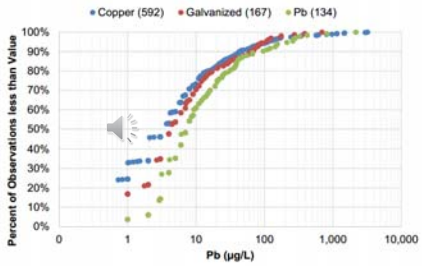
Understanding Sources of Lead

Graph reflects maximum lead concentrations at locations by service line type. All data are from a single year, 2016. Plotted percentile is based on the number of sample locations.



Source: Arcadis, Cornwell Engineering Group, and Confluence Engineering, 2017

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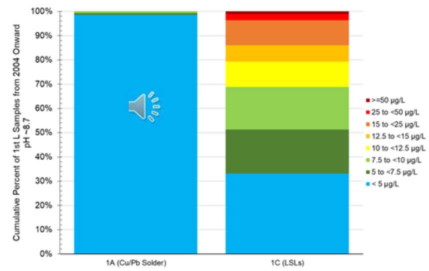
Understanding Sources of Lead

Graph reflects binned lead levels for lead pipe homes and lead solder homes

Note, for this utility, samples are primarily collected from homes with lead service lines

Refer to Course 1 for additional detail on potential sources of lead.



Source: Cornwell Engineering Group

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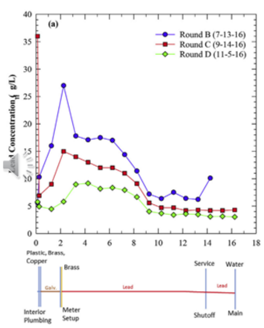
Sequential Samples – "Profiling"

One-liter samples are collected consecutively up to a specified maximum



Source: D.A. Lytle et al. Water Research 157 (2019) 40-54

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Sequential Sampling Can Inform

- Understanding of contributions from each source (faucet, premise plumbing, service lines)
- Whether or not iron and/or manganese are playing a role in lead release
- The relative contribution of particulate lead

Refer to Course 3 for additional information.

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Dissolved vs Particulate Lead Analysis

- Corrosion control theory and practice focuses on managing soluble lead
- Particulate lead can be an indicator of
  - Lack of scale stability
  - Galvanic corrosion
- Managing particulate release is difficult

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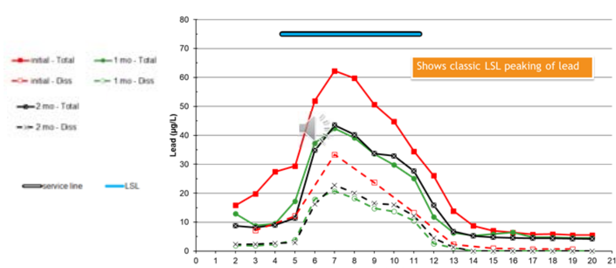
Example Profile: Total and Dissolved Lead



Source: Cornwell and Brown. (2015). WRF 4569: Evaluation of Lead Sampling Strategies

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Slide 111

AA1 Please put your instructions for an
Andrew Appell, 10/13/2021

Dissolved vs Particulate Lead Analysis

Corrosion Control Status		Scale	
		Durable	Non-Durable
Corrosion Control	Optimized	Low soluble Pb / Low Particulate Pb	Low soluble Pb / High Particulate Pb
	Not-Optimized	High soluble Pb / Low Particulate Pb	High soluble Pb / High Particulate Pb

Modified from: Clark et al., 2014; Environmental Science and Technology. 2014, 48, 12, 6836–6843

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Pipe Scale Analysis

- Provides insight into
  - Mineralogical and elemental composition of scale
  - Physical morphology of scale
- Powerful tool for understanding type and composition of pipe scales
- Limitations to be aware of
  - Representativeness of sample
  - Cost of analysis

Pipe scale analysis methods require careful sample collection, handling and preservation. Results should be interpreted by experts.

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KNOWLEDGE CHECK

Which of the following can contribute lead to water at customer taps?

A. Lead service lines
B. Lead solder on copper pipes
C. Galvanized pipes
D. All of the above

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Considering Chloride-to-Sulfate Mass Ratio (CSMR)

- Adverse impacts to lead more commonly observed for:
  - Low alkalinity / mineral waters
  - Systems with galvanic connections (i.e., copper pipe with lead solder, lead pipe connected directly to copper pipe)
  - Order of magnitude changes in CSMR (i.e., 0.2 >> 2.0)

Acceptable ratio is system-specific

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Considering Chloride-to-Sulfate Mass Ratio (CSMR)

- Assess trends over time and as compared to lead levels
  - Is CSMR different for each source?
  - Is CSMR stable?
  - Is chloride increasing in my source(s)?
  - Is sulfate decreasing in my source?
  - Are chemical doses changing (coagulant, chlorine)?
- Understand data limitations
  - Paired data preferred and frequency of collection

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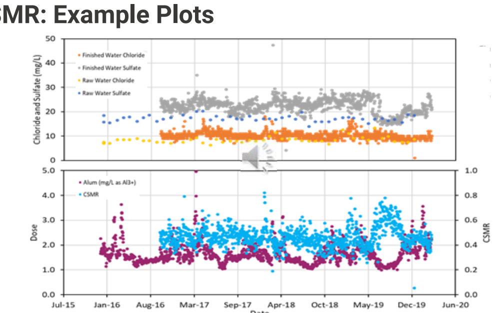
CSMR: Example Plots



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Source: Arcadis

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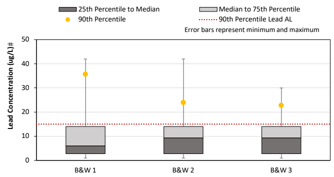
LEARNING ACTIVITY

Which Box & Whisker plot represents the data set?

Lead Concentration (µg/L)
1
42
2
15
9.7
9
11
5
22
2



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Summary

- Evaluating available data streams can identify
  - Additional data needs
  - Changes in process control
  - Unexpected impacts from operational changes or inadvertent changes in treatment
  - Areas of distribution system where water quality may be influencing corrosion control practice

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Summary

- Evaluating existing data may not point directly to a needed action but it can identify areas for
  - Further investigation
  - Preventative action

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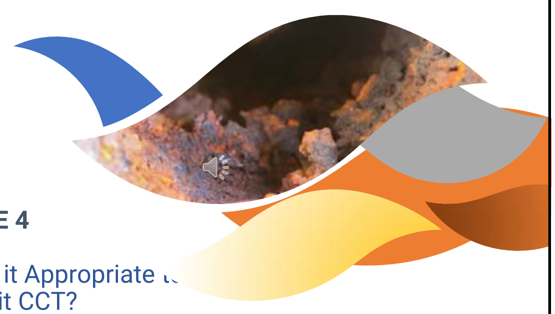

MODULE 4

When is it Appropriate to or Revisit CCT?

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LEARNING OBJECTIVES

Recall: Decision framework for determining if CCT needs to be established or re-visited?

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LEARNING OBJECTIVES

Interpret:
- What key events trigger an evaluation of CCT?
- When to evaluate CCT if making a source water or treatment change
- How extensive an analysis might be needed?

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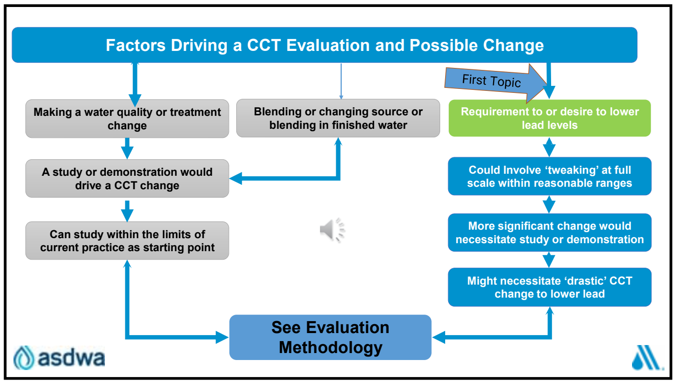
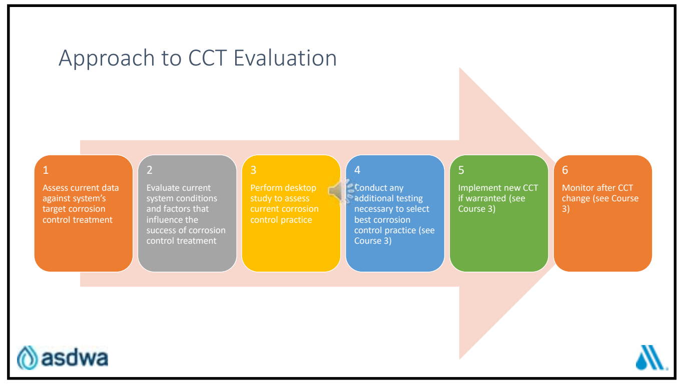
Slide 126

CW1 modified

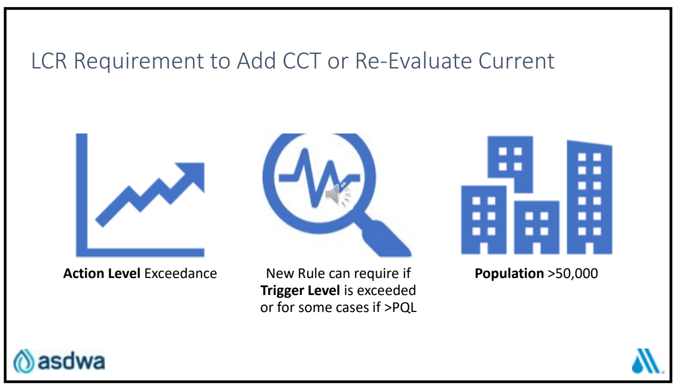
Chad Weikel, 7/16/2021



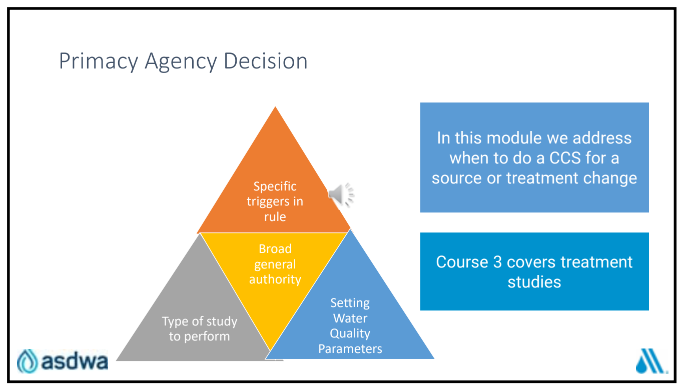
127



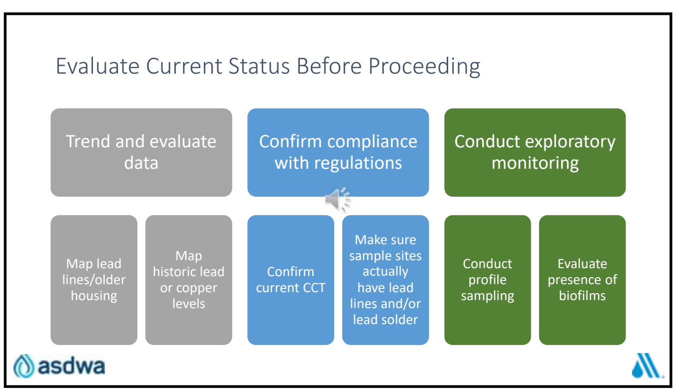
128



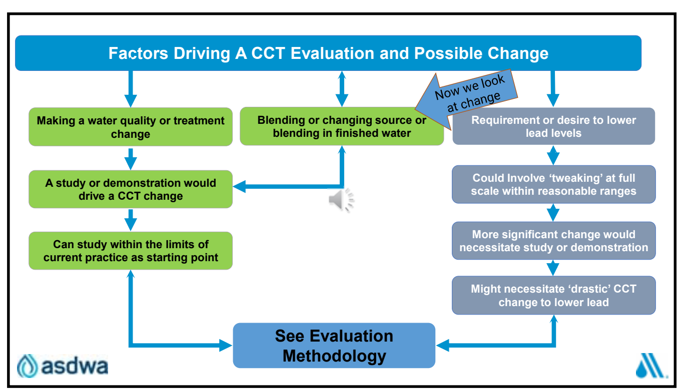
129



130



131



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Key Question

Will the proposed change result in a significant water quality change influencing corrosion?

- If change is **enough to have a possible impact on corrosion, then further evaluation is needed**
- **A simple desktop study may be sufficient to rule out an issue**
- Desktop could be sufficient if **it's determined that impact is not significant enough to impact corrosion**
- **On the other hand,** initial evaluation may determine a **test program may be warranted**

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Always Start with a Desktop Study

Desktop Study → Pb, Cu Solubility Studies → Flow-through Material Study → Full-Scale Demon-stration

Adjusting corrosion control practice starts with a desktop study to assess if more data are needed and which data are needed to support a decision.

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First Evaluation Step

- A desktop study is always a first step
- By desktop study we refer to evaluating on paper and through models or comparison to similar systems if the change is significant enough to require testing
- The desktop study might be simple, and the change quickly dismissed as insignificant

Level of Effort Can Vary Significantly

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KNOWLEDGE CHECK

What are reasons for doing a desktop?

a. Exceed AL
b. Changing water source
c. Adding a well into distribution system
d. All of the above
e. a and b
f. a and c

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Likely to Require More than Desktop Study

Source		Treatment		Water Quality
Change with significantly different water quality as determined in the desktop study	Blending source or finished water seasonally or regularly	Changes which modify water quality and affect corrosion parameters	Disinfection practice change especially if changing from free to combined chlorine	Water quality parameters directly affecting corrosion control treatment are changing

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Raw Water Source Change

- Change in raw source from groundwater wells to surface water
- Change from one groundwater to another or one surface water to another
- Adding another source water (blending) to the treatment plant(s)

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Source Change in Distribution System

- Bringing a new groundwater well into a distribution system with existing wells
- Blending a groundwater into a distribution system that uses surface water
- Interconnecting with a neighboring water system
- Purchasing surface water from one system to blend into a groundwater system or surface water system

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Seasonal Blending of Source or Finished Water

- Blending of different source waters
- Blending of different finished waters
- There could be a different consideration for regular or planned blending versus a water emergency

Warning
Short-term emergency may require evaluation based on primacy agency requirements.

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KNOWLEDGE CHECK

What are lead or copper concerns about blending in a finished water

a. Scales could change
b. Inhibitor might be different
c. Taste could be different
d. All of the above
e. a and b
f. a and c

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Disinfection

- Change in disinfectant type
  - Free chlorine to chloramines or the other way
  - Adding chlorine dioxide or ozone
- Change in disinfection strategy
  - Change in residual level goal

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Free Chlorine Residual

- High free chlorine residual has been associated with the formation of Pb(IV) scale in lead service lines
- Pb(IV) has very low lead release
  - **But** Pb(IV) scales are unstable if residual is lost or too low
- Pb(IV) scales may be present and destabilized following chloramine conversion
- If converting to free chlorine oxidation state of scales can change

asdwa Source: EPA, 2020

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Change in WQPs Directly Affecting CCT

- Change in ORP
  - Affects Pb(IV), Mn, and Fe in the scales and therefore affect Pb release
- Change in pH or alkalinity (DIC)
  - Affects pH/alkalinity corrosion control treatment
  - Can affect orthophosphate effectiveness
- Change in source or treated water dissolved oxygen levels

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Change in WQPs Directly Affecting CCT

- Change in inhibitor type (e.g., changing any combination of polyphosphate, blended phosphate, or orthophosphate)
  - Moving from one type, such as a polyphosphate, to blended or pure orthophosphate
  - Changing polyphosphate ratio in a blended product
- Adding any P-containing product when no ortho- or poly-phosphate was previously added

Why

These kinds of changes can alter pipe scales

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KNOWLEDGE CHECK

What Should I do if changing polyphosphate?

a. Testing to see if it performs the same
b. Consult the vendor
c. Discuss with purchasing
d. None of the above

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Change in WQPs Directly Affecting CCT

- Change of blended or polyphosphate inhibitor product or supplier
  - All products are not the same
  - Polyphosphates are of many different types
    - Long chained compounds with P interwoven
    - Dehydrated polyphosphates
    - Sodium tripolyphosphate $Na_5P_3O_{10}$
    - Hexameta phosphate—mixture $(NaPO_3)_6$
    - Lots of combos available depending on the manufacturer heating and crystalizing process
    - Often no crystal structure –glassy phosphates

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Change in WQPs Directly Affecting CCT

- Changing to or from a Zn-ortho to straight ortho
  - Depends on the amorphous nature of the scales
  - Zn could try to replace iron for example in the scale if changing to a zinc product
  - Zn could leave the scales if eliminating the zinc

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Treatment Changes

- Change in coagulant type

1. Fe-based to/from Al-based
2. Cl-based to/from SO4-based

1. Is the pH changing?
2. Will the scale Fe or Al balance be changed?
3. Will the CSMR change?

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Treatment Changes

- Change in treatment process that increases natural organic matter in finished water
- Increasing NOM can have an impact on scales

Likely a rare treatment event when a utility would increase NOM/TOC Could be a source change event

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Treatment Changes

- Change or addition of new oxidant
- Addition of ion exchange (IX)
  - Used to remove Fe, Mn, TOC, PFOS, As, etc
  - Can affect ionic balance
  - Can affect CSMR
- Granular activated carbon addition if effluent pH is changed

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Treatment Changes

- pH adjustment chemicals
  - Primarily if changing to or from a chemical that has carbonate, such as changing from sodium bicarbonate to caustic soda can change DIC
- Addition of reverse osmosis
  - Can affect ionic balance and pH

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Treatment Changes Unlikely to Require Corrosion Control Treatment Evaluation

- Change in orthophosphate **dose**
  - Increasing dose
- Change in orthophosphate **vendor**
  - Limited to orthophosphate (does not apply to blends or polyphosphate)

Corrosion control adjustments

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Treatment Changes Unlikely to Require Corrosion Control Treatment Evaluation

- Addition of granular activated carbon (GAC)
  - Except pH issues if not controlled
- Low Pressure Membrane filtration **(filter media replacement)**
  - As long as distributed water quality is not anticipated to change
- Addition of iron and manganese removal
  - Except for ion exchange
- Addition of UV

New unit processes

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Treatment Changes Unlikely to Require Corrosion Control Treatment Evaluation

- Adding or removing fluoride
  - As long as distribution pH is similar to previous
- Changing from gas chlorine to liquid
  - As long as distribution pH is similar to before
- Adding permanganate, PAC ,polymer, as long as WQP the same

Changes in chemical feeds

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Treatment Changes Unlikely to Require Corrosion Control Treatment Evaluation

- Adding or changing a polymer to aid coagulation or filtration
- Changing coagulant dose
  - As long as distribution pH and DIC is similar to before
- Change in softening agent
  - As long as distribution pH and DIC are similar to previous

Changes in coagulation / filtration practice

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KNOWLEDGE CHECK

Which treatment change will likely require CCT re-evaluation?

A. Adding PAC
B. Adding low pressure membranes
C. Change from free chlorine to chloramines
D. Change in orthophosphate vendor

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Does the New Source or Treatment Change Require Evaluation Beyond a Desktop Study?

- The desktop study could quickly dismiss the need for demonstration testing
- During the desktop study the change being made must be linked to the water quality parameter that is changing
- For example, will the new source have an alkalinity change that is considered significant enough to test?
- Are there existing pipe scales that could be impacted by the change?

Existing data should already have been gathered and analyzed—see Module 2 and 3 of this Course.

This is also where solubility diagrams could help a lot

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So, Now We Have a Change Requiring a Review …

- Next step is to define what is changing
  - For example, if a new source is blending in, what important parameter changes?
  - If pH is different, can it be adjusted before entering distribution?
    - If so , no impact
  - If alkalinity (DIC) is different, probably need to evaluate it
  - If TOC higher, will it be removed in treatment to match existing?
- Following two tables illustrate parameter changes
- The hardest to define factor --- "Are existing scales likely to be upset?"

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Possible Impacts on Water Quality of Change

	Enhanced coagulation for NOM removal	Change coagulant type or dose	Change in finished water pH	Change in finished water DIC	Addition of a corrosion inhibitor	Change in inhibitor type or dose
Change in finished water pH	•	•	•		•	•
Change in finished water dissolved inorganic carbon/alkalinity	•	•		•		
Change in chloride to sulfate mass ratio ($Cl:SO_4$)	•	•				
Change in oxidation reduction potential	•					
Change in natural organic matter	•	•				
Change in biofilm	•				•	•
Change in water temperature						
Change in aluminum, iron, or manganese concentration in distributed water	•	•				
Any finished water change that could disrupt scales-inhibitor, pH, hardness, iron etc.	•	•	•	•	•	•

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	Addition of a new source of supply	Blending of different source waters	Blending of different finished waters	Change in free chlorine dose	Change from chlorine gas to hypochlorite	Addition of other oxidants / disinfectants	Conversion to chloramine
Change in finished water pH	•	•	•	•	•		•
Change in finished water dissolved inorganic carbon/alkalinity	•	•	•				
Change in chloride to sulfate mass ratio ($Cl:SO_4$)	•	•	•				
Change in oxidation reduction potential e.g Adding a chloraminated water to a free chlorine system.	•	•		•		•	•
Change in natural organic matter	•	•	•			•	
Change in biofilm			•	•		•	•
Change in water temperature	•	•	•				
Change in aluminum, iron, or manganese concentration in distributed water	•	•	•			•	
Any finished water change that could disrupt scales-inhibitor, pH, hardness, iron etc.	•	•	•	•	•		•

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What Changes in Water Quality Might We Look for - Raw Water Source Change?

- Alkalinity/DIC
  - Could change lead solubility
  - Could impact scales
  - Could change lead species
- pH
  - Probably can be adjusted at water treatment plant and not a factor
- TOC
  - Higher TOC might affect scales or solubility
  - Might affect biological growth
  - Perhaps can be reduced to match existing and not be a factor

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What Changes in Water Quality Might We Look for - Raw Water Source Change?

- Iron or manganese change
- Chloride to sulfide mass ratio change
- Dissolved oxygen change
- TDS change

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What Changes in Water Quality Might We Look for - Finished Water Addition?

- Alkalinity/DIC
  - Could change lead solubility
  - Could impact scales
  - Could change lead species
- pH
- TOC
- Iron or manganese change
- CSMR change
- Different inhibitor or residual
- Free chlorine versus chloramine
- TDS

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If Testing Is Needed …

- Must decide what type of test
- There are some common features specific to when a source or treatment change is being made
- We must answer the question as to the purpose of the test in order to determine what test method to use and how to do the test

See Course 3

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When is a Change Justified After the CCS?

- Analysis and testing provide **relative** comparisons **not** quantitative answers
- Decision-making must balance:
  - Achieving corrosion control objectives (e.g., degree of improvement sought)
  - Unintended consequences
  - Complexity of implementing and sustaining new strategy

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AA6
AA10

LEARNING ACTIVITY

A utility is adding a new raw water source. They have determined that they will likely need a different coagulant, and that the pH will change, and therefore they may need a corrosion inhibitor when they do not currently use one.

On the following table fill in with dots the key corrosion control factors that could be changing

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CA [2]1

Possible Impacts on Water Quality of Change Learning Activity

		Change coagulant type or dose	Change in finished water pH		Addition of a corrosion inhibitor	
Change in finished water pH		•	•		•	
Change in finished water dissolved inorganic carbon/alkalinity		•				
Change in chloride to sulfate mass ratio (Cl:SO_4)		•				
Change in oxidation reduction potential						
Change in natural organic matter		•				
Change in biofilm					•	
Change in water temperature						
Change in aluminum, iron, or manganese concentration in distributed water		•				
Any finished water change that could disrupt scales-inhibitor, pH, hardness, iron etc.		•	•		•	

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Slide 167

AA6 Andrew Appell, 11/4/2021

AA10 Kris: Dave rewrote the instructions, and I'm sorry to say he didn't want just the first 3 columns
Andrew Appell, 11/5/2021

Slide 168

CA [2]1 remove these dots and have them fill them back in
Cornwell,David Alan, 11/5/2021

Introduction to Which Corrosion Control Studies are Appropriate – Detail in Course 3

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System Size – Does it Matter?

Current EPA guidance advises states that smaller systems can more easily rely on desktop or analogous systems analysis without further testing of corrosion control options

But in reality, …
Understanding water chemistry is the same for systems of all sizes.

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Progression of CCT Study Methods

Desktop Study → Pb, Cu Solubility Studies → Flow-through Material Study → Full-Scale Demon-stration

Adjusting corrosion control practice starts with a desktop study to assess if more data are needed and which data are needed to support a decision.

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Test Methods

Benchtop testing
- Batch lead or copper solubility
- Batch harvested pipe
- Batch galvanic tests new or harvested
- Flow through harvested pipe

Pilot-scale testing
- Flow through harvested pipes
- Corrosion rigs new pipes
- Corrosion rigs coupons

Combination of field and specialized lab analysis
- Scale analysis
- Field studies

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Source: Cornwell, EPA Small System Workshop, 2020

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Lead or Copper Solubility Studies

- Developed specifically for evaluating lead, copper other metal solubility in water
- Key differences from traditional coupon test practice in
  - Water preparation
  - Testing protocol

Source: Cornwell and Wagner, Journal AWWA, Volume: 111, Issue: 10, Pages: 12-24, First published: 04 October 2019, DOI: (10.1002/awwa.1377)


Source: Cornwell Engineering Group, Inc


Source: Confluence Engineering Group, LLC

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When is harvested pipe study appropriate?

LCRR has specific rules on when harvested pipe study must be employed. See Course 4

- No → Is there a concern that pipe scales could be upset?
  - Might need scale analysis to clarify
  - Yes → Harvested pipe study likely.
  - No → Consider alternatives to harvested pipe study.
- Yes → Harvested pipe study likely.

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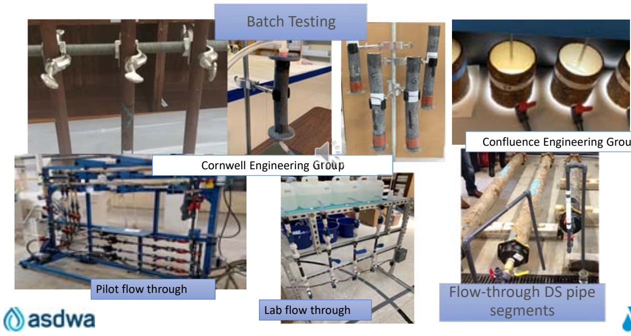
Demonstration Tests – Harvested Materials



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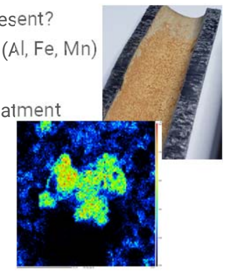
When You Might Consider Pipe Scale Analysis

- Free chlorine systems – is lead(IV) present?
- Systems with potential legacy metals (Al, Fe, Mn)
- Systems with multiple sources
- Before making a change in source/treatment
- Systems changing from a p-PO_4
- Confirming compounds present



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KNOWLEDGE CHECK

True of False?

Are the following all Corrosion Control Studies:

a. Desktop study

b. Solubility study

c. Laboratory harvested pipe study

d. Pilot harvested pipe study

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Summary

- If the Primacy Agency requires a new CCS they may determine the type of study needed
  - If not, the decision on the type is similar to below
- If a source or treatment change is being made:
  - Define what variables are changing
  - Do a desktop to see if more study is needed
  - That will help determine the type of study needed
- Not all changes need more than a simple desktop

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Summary

- Evaluating unexpected corrosion, changes in treatment, or changes in water supply has four possible steps
  1. Begins with confirming current practice is being implemented as intended
  2. Goes on to evaluate if change (occurred / will occur) will interfere with intended practice
  3. Considers if corrosion control practice should change
  4. Monitors and evaluates the success of any change in practice

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