Uisce Éireann

Chemical Treatment for Corrosion Control: General Specification

Revision History

Revision Number	Description of Change	Author(s)	Approved By	Date of Approval
V0	Review and restructure of existing TEC-900-11 and TEC-900-12 specifications			
v0.1	Issue for Discussion	J Goggin		
v0.2	Document Update	J Goggin		
v0.3	Update to various specification reference numbers	J Goggin		
v0.4	Minor corrections and alterations	J Goggin		
V0.51	Review	J G / S Matlák		
1.0	First Approval	J Goggin	Des Joyce	29/11/2023

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

Under the current European Union (Drinking Water) Regulation 2023 (S.I. No. 99 of 2023), Uisce Éireann has the responsibility to provide drinking water to all users on public supplies in Ireland. These Regulations prescribe the water quality standards to be achieved, the supervision required to ensure water quality is maintained, and the enforcement procedures necessary to ensure the safe and secure supply of drinking water to all public support users.

Uisce Éireann is committed to meeting this obligation by ensuring that potable drinking water is free from any micro-organisms, parasites or any substances which in numbers or concentrations, constitute a potential danger to human health. The implementation of control measures to minimise the risk of metallic corrosion by-products (particularly lead) being released from distribution network infrastructure (public water mains and domestic plumbing systems) and entering the drinking water supply is a key barrier to ensuring this commitment is met.

1.1 DRINKING WATER SAFETY PLAN APPROACH

Uisce Éireann has adopted the World Health Organisation (WHO) risk-based approach to ensure the provision of safe and secure drinking water to all public supply users. This approach is based on Drinking Water Safety Plans (DWSP) which provide an integrated framework for the operation and management of water supply systems.

A key part of a DWSP is the identification of hazards across the whole process of water supply from source to tap, and an assessment of how to manage the risks associated with those hazards. The DWSP hazards directly associated with the implementation of corrosion control systems to minimise the release of metallic corrosion by-products from distribution network infrastructure are outlined in Table 1 below.

As well as describing the minimum standards for corrosion control systems implemented on Uisce Éireann sites, this Specification also aims to address the specific DWSP hazards as shown in Table 1.

Hazard Code	Hazard Description
TO010	Unapproved treatment chemicals/materials (other than those in coagulation/disinfection process) causing contamination
TO020	Ineffective chemicals (other than those in coagulation/disinfection process) causing inadequate final water
TO040	Malfunction/failure of chemical dosing point (other than those in coagulation/disinfection process) causing inadequate final water
TO180	Poor process control causing chemical overdose
DN150	Presence of lead mains in the ownership of the Water Supplier causing contamination
DN160	Presence of lead communication pipes in the ownership of the Water Supplier causing contamination
DN170	Leaching and pipework corrosion causing entry of corrosion by-products into water supply
OP010	Presence of lead pipework in the ownership of the consumer causing contamination

Table 1: Drinking Water Safety Plan (DWSP) hazards associated with Corrosion Control Systems

1.2 UISCE ÉIREANN TREATMENT BARRIER APPROACH

Management of physical, chemical and microbiological risks on all water supply schemes should include measures to protect water sources and minimise the risk of re-contamination in the distribution network.

However, the implementation of control measures prior to treated water distribution is one of the most effective means of minimising the corrosive properties of treated water. Such control measures can be utilised to great effect to prolong the life of distribution network infrastructure, as well as preventing the formation of metallic corrosion by-products (lead, copper or iron residuals) in drinking water supplied to consumers.

In order to implement effective control measures to mitigate against the DWSP hazards identified on a particular asset, Uisce Éireann has developed a set of water treatment barriers, as presented in Table 2 overleaf

- the categorisation and standardisation of control measures, each of which has been specifically developed to mitigate against potential hazards associated with water quality (safety) and reliability of supply (security)
- the assignment of key performance indicators (KPIs) for each control measure, as a means of verifying the quality of water entering distribution
- the adoption of a 'building block' approach to the development of water treatment specifications and standards, and consequently, the implementation of standardised control measures / water treatment processes
- targeted investment at each treatment asset to specifically address the hazards which are deemed to have the highest risk.
- the adoption of a national 'programme' approach to asset investment, targeting the barriers which will result in the greatest improvement to water quality and reliability of supply, on a nationwide basis
- potential for significant CAPEX and OPEX savings by adoption of the 'programme' approach which will ultimately result in the implementation of standardised and consistent infrastructural solutions, as far as reasonably practicable.

The control measures necessary to implement Barriers 1 – 8 are described in detail within the **TEC-900** suite of design specifications.

Uisce Éireann Treatment Barriers		
Barrier 1	Bacteria & Virus (4-log)	Primary Chlorination (achieve Effective Ct)
Barrier 2	Maintain Barrier 1 (Network)	Chlorine Residual at Tap (> 0.1mg/L)
Barrier 3	Protozoa (3-log) [UV]	UVI / UV RED > Validation Limit
Barrier 4	Protozoa (≥ 3-log) [CFC + Filtration, SSF]	Turbidity < Limit
Barrier 5	Interruption to Supply	Supply > Demand
Barrier 5.1	Raw Water Yield	Supply > Demand
Barrier 5.2	24 Hour Production Capacity	Supply > Demand
Barrier 5.3	Treated Water Storage	> 24 Hours or > 36 Hours
Barrier 5.4	Low Pressure	≥ 15m at tap

Barrier 5.5	Distribution Capacity	-
Barrier 6	Disinfection By-Products (THMs)	≤ 100µg/L at Tap
Barrier 7	Pollution of Environment	≤ Discharge Limit
Barrier 8	Other Physical/Chemical Contamination	≤ Limit at Tap (as per Drinking Water Regs)
Barrier 8.1	Lead	≤ 5µg/L at Tap
Barrier 8.2	Pesticides	≤ 0.5µg/L at Tap
Barrier 8.3	Nitrates	≤ 50µg/L at Tap
Barrier 8.4	Aluminium	≤ 200µg/L at Tap
Barrier 8.5	Iron	≤ 200µg/L at Tap
Barrier 8.6	Manganese	≤ 30µg/L at Tap
Barrier 8.7	Taste & Odour	Acceptable at Tap
Barrier 8.8	Other	≤ Limit at Tap
Barrier 9	Leakage	≤ Distribution Target

Table 2: Uisce Éireann Treatment Barriers

2 PURPOSE AND STRUCTURE

The **TEC-900-11** suite of specifications outlines a standard to describe Uisce Éireann's minimum requirements for all chemical treatment systems necessary to control the corrosivity of treated water entering the distribution network, and to minimise the concentration of metallic corrosion by-products released from distribution infrastructure to the water supply during storage and conveyance. This suite of documents forms part of a series of standard 'building block' specifications (**TEC-900**) which are to be used when compiling project designs.

The documents are intended to guide project stakeholders in establishing engineered solutions that deliver robust, reliable and repeatable performance that meet Uisce Éireann's Health, Safety, Quality and Environmental (HSQE) objectives for corrosion control systems on water treatment assets. This specification should be read in conjunction with each project's Employer's Requirements which shall set out Uisce Éireann's site-specific requirements for each particular installation. The document user shall note that the application of this, and

every other specification within the 'building block' structure must also give due consideration to the health & safety, operability, CAPEX and OPEX of each installation.

2.1 ASSET DATA HIERARCHY

The **TEC-900** suite of specifications are aligned to Uisce Éireann's Asset Data Hierarchy (ADH) which provides a consistent structure for water treatment assets and their associated data. The ADH is outlined in Table 3 below and as well as allowing the structured development of suites of 'building block' design specifications, also facilitates the creation of a standardised asset register which can be used as a base for a range of business activities, which includes;

- the planning of efficient operation and maintenance practices;
- more effective capital investment;
- accurate and reliable regulatory reporting.

ADH Level	Name	Description
Level 1 Asset	**Root Node**	Identifies the location in relation to the Uisce Éireann business
Level 2 Asset	**Business Level**	Identifies the location in relation to the Uisce Éireann business
Level 3 Asset	**Regional Level**	Identifies the location in relation to the Uisce Éireann business
Level 4 Asset	**Chart of Accounts Level**	Identifies the location in relation to the Uisce Éireann business
Level 5 Asset	**Site**	Identifies an operational site which is defined by as "an enclosed area of land owned or utilised by UÉ"
Level 6 Asset	**Process**	A grouping of assets which combined, form a distinct stage of a treatment process *e.g. Coagulation, Flocculation, Clarification (CFC)*
Level 7 Asset	**Process Stage**	is a physical entity which forms part of the process *e.g. Sedimentation, Dissolved Air Flotation, etc. as a subset of CFC*
Level 8 Asset	**Asset**	An item or piece of equipment owned by UÉ; it is the building blocks of a site which largely define its maintenance

Table 3: Uisce Éireann Asset Data Hierarchy (ADH)

2.2 SPECIFICATION STRUCTURE – LEVEL 6 (PROCESS)

In accordance with the Asset Data Hierarchy, the **TEC-900** suite of specifications are divided into a suite of Level 6 (Process) documents which ultimately aim to specify the minimum requirements for each of the water treatment barriers described in Table 2. The content of the Level 6 document will outline general high-level information and requirements relating to the selection and design of the Level 6 (Process) Asset as a whole, without going into the specifics of the Level 7 (Process Stage) document. The structure of the **TEC-900** suite of Level 6 (Process) specifications is illustrated in Figure 1 below.

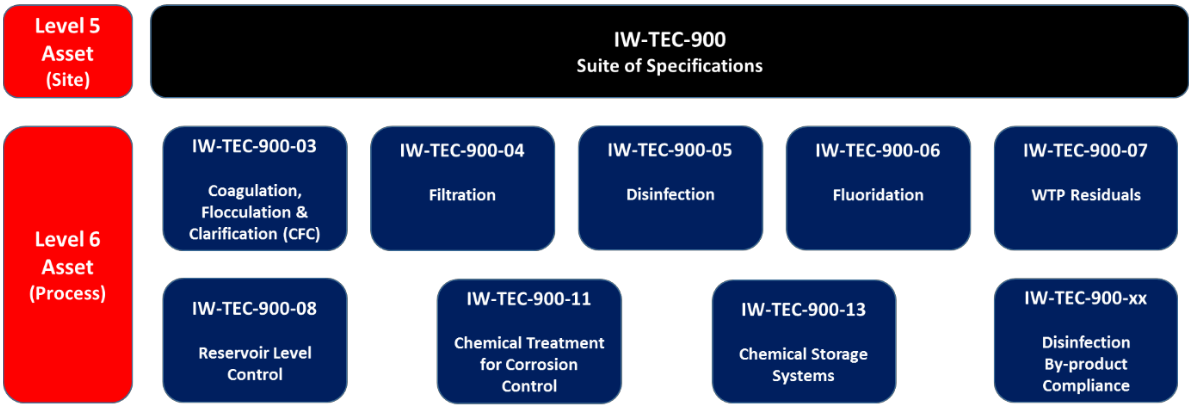


Figure 1: Structure of TEC-900 suite of specifications.

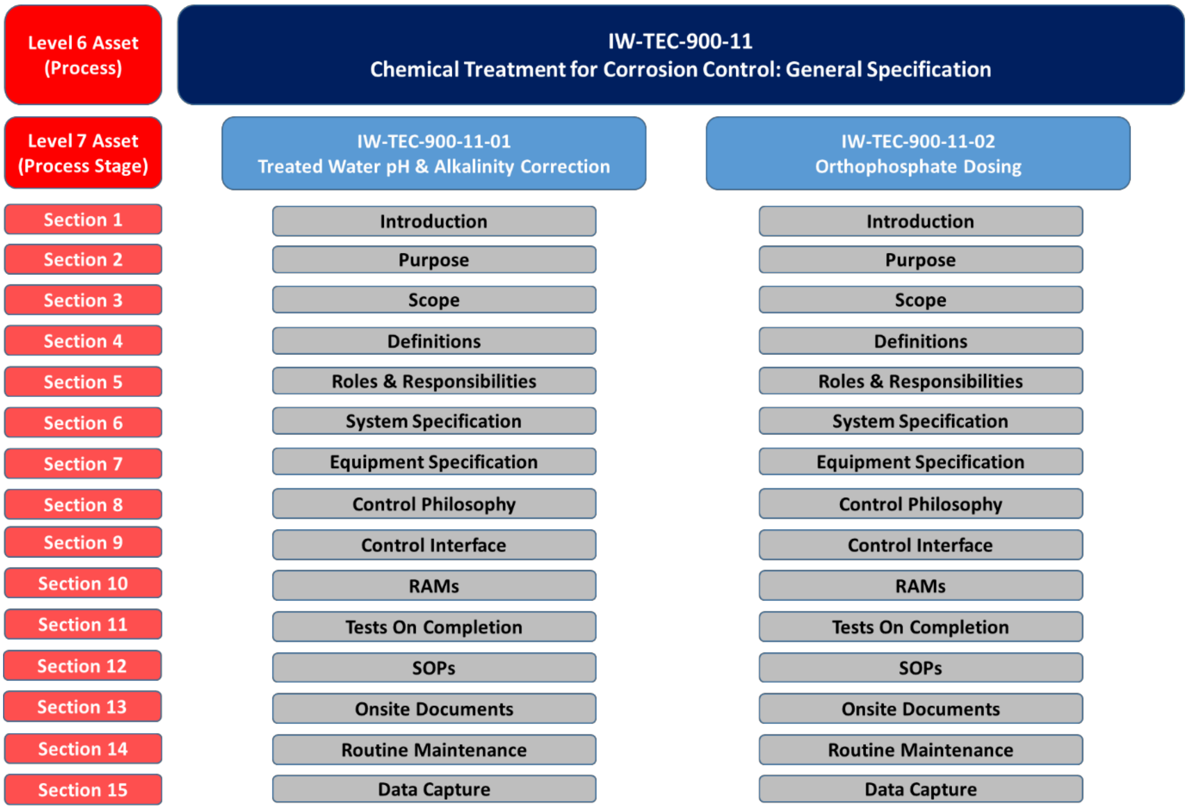
2.3 SPECIFICATION STRUCTURE – LEVEL 7 (PROCESS STAGE)

Where required due to the complexity of a Level 6 (Process) Asset, or where a number of alternative process options exist (i.e. clarification by sedimentation or dissolved air flotation), Level 6 (Process) specifications are further divided into sub-specifications, which align to the ADH Level 7 (Process Stage) Assets. The content of the Level 7 specifications will outline in detail the requirements deemed necessary for each process stage to achieve the general requirements outlined in the Level 6 specification.

For Corrosion Control systems, the structure of the **TEC-900-11** suite of specifications is illustrated in Figure 2 overleaf, with separate documents developed for each of the following approved Level 7 (Process Stage) Assets:

TEC-900-11-01	Treated Water pH / Alkalinity Adjustment	**Barriers 8.1, 8.5 & 8.8**
TEC-900-11-02	Orthophosphate Dosing	**Barriers 8.1 & 8.8**

Each of the Level 7 (Process Stage) documents is linked by the overarching Level 6 (Process) document **TEC- 900-11 Chemical Treatment for Corrosion Control: General Specification** (this document).



Level 6 Asset (Process)	IW-TEC-900-11 Chemical Treatment for Corrosion Control: General Specification	
Level 7 Asset (Process Stage)	IW-TEC-900-11-01 Treated Water pH & Alkalinity Correction	IW-TEC-900-11-02 Orthophosphate Dosing
Section 1	Introduction	Introduction
Section 2	Purpose	Purpose
Section 3	Scope	Scope
Section 4	Definitions	Definitions
Section 5	Roles & Responsibilities	Roles & Responsibilities
Section 6	System Specification	System Specification
Section 7	Equipment Specification	Equipment Specification
Section 8	Control Philosophy	Control Philosophy
Section 9	Control Interface	Control Interface
Section 10	RAMs	RAMs
Section 11	Tests On Completion	Tests On Completion
Section 12	SOPs	SOPs
Section 13	Onsite Documents	Onsite Documents
Section 14	Routine Maintenance	Routine Maintenance
Section 15	Data Capture	Data Capture

Figure 2: Structure of TEC-900-11 suite of specifications.

3 SCOPE

The scope of the **TEC-900-11** suite of specifications covers all methods of post-treatment corrective dosing approved for use on Uisce Éireann treatment assets for the minimisation of metallic corrosion by-products, and in doing so describes how the relevant Barriers (Barrier 8.1, 8.5 and 8.8) are to be implemented at each installation. The documents outlined in Table 4 below make up the full suite of **TEC-900-11** Chemical Treatment for Corrosion Control specifications.

Scope of TEC-900-11 Specifications			
Document No	**ADH Level**	**Title**	**Barrier**
TEC-900-11	**Level 6** (Process)	Chemical Treatment for Corrosion Control – General Specification	Barriers 8.1, 8.5 & 8.8
TEC-900-11-01	**Level 7** (Process Stage)	Treated Water pH / Alkalinity Adjustment	Barriers 8.1, 8.5 & 8.8
TEC-900-11-02	**Level 7** (Process Stage)	Orthophosphate Dosing	Barriers 8.1 & 8.8

Table 4: Full suite of TEC-900-05 (Disinfection) Specifications

3.1 TERMINATION POINTS AND EXCLUSIONS

The **TEC-900-11** suite of specifications encompasses all elements of chemical treatment systems for corrosion control, from the chemical dosing pump to the point of compliance at the consumers tap. It is possible

that other non-corrosion control processes may be installed within these termination points (i.e. fluoridation systems, secondary chlorination, etc.) however such processes are excluded from the **TEC-900-11** suite of specifications. Similarly, all aspects of chemical storage systems pertinent to the storage of pH/alkalinity adjustment chemicals, orthophosphate, etc. have been excluded from the **TEC-900-11** suite of specifications and compartmentalised in a dedicated suite of documents (see **TEC-600-06**).

3.2 APPLICATION OF THE SPECIFICATION

This suite of specifications shall be applied to all future upgrade works which require chemical correction of treated water for the purposes of corrosion control, across all Uisce Éireann assets. These works will generally be categorised under the Employer’s Requirements as:

- **Replacement** of individual corrosion control system components; (i.e. Level 8 assets)
- **Upgrades** (partial to full) of existing corrosion control systems
- **New Development** of corrosion control systems (on existing or greenfield sites)

In each of the above cases the Contractor shall retain the role of detailed system designer for the specified works, and each design shall be carried out on a site-specific basis, accounting for all constraints and restrictions therein. It should be noted that the application of this, and every other Uisce Éireann specification must also give due consideration to Health and Safety, operability and TOTEX of each proposed design and installation.

The user shall note however that the full magnitude of the specification may not require implementation in every case. For example, for the development of a new build corrosion control system, this specification sets out the minimum baseline requirements, and all systems as described herein shall be implemented.

However, where the Employer’s Requirements (or an approved Corrosion Control Implementation Plan in lieu of a formal ER) identifies that only the replacement of an individual component is required, then only this individual component shall require compliance with the specification. Similarly, if a partial upgrade is specified, or identified under a Corrosion Control Treatment Implementation Plan, then only the elements that are replaced shall be required to be compliant.

All Contractors shall therefore study the site-specific Employer’s Requirements, and where appended, the approved Corrosion Control Implementation Plan in order to fully appreciate the scope of works required at each site and shall then ensure that the specified works are carried out in full compliance with this specification and associated documents.

3.3 DEROGATIONS FROM THE SPECIFICATION

Whilst the minimum requirements of this standard / specification shall be met (where applicable) this document is not intended to stifle innovation by the Contractor, or delay progress. Should the Contractor wish to apply for a derogation from any aspect of the document, they shall submit a derogation application to the Employer’s Representative, in accordance with AD-EDS-SOP-005, in advance of any proposed departure from the requirements of the specification (the required form for the derogation application will be provided to the Contractor by the Employer’s Representative). Submission of the derogation application does not confer permission to proceed, and the application should be submitted allowing sufficient time for the Employer and the Employer’s Representative to evaluate. Works can only proceed on the basis of the derogation, after the Contractor has received written confirmation from the Employer’s Representative. The written confirmation of the derogation shall be treated as a change order/variation under the contract and its consequences shall be decided pursuant to the change/order variation mechanism of the contract.

The submission of a derogation application shall not impact on the programme of works for the specified project and shall be made at the risk and expense of the Contractor. Uisce Éireann or the Employer’s Representative shall retain the right to reject the derogation application in favour of compliance with this document.

For the avoidance of doubt, the derogation, where approved, shall only pertain to the specific circumstance for which the derogation is approved. An approved derogation shall not carry any precedent to another project/contract and shall not be used or applied on other similar projects/contracts or circumstances thereafter. The subject of a derogation can only be applied on another contract/project if it has been directly incorporated into the standards/specifications for the relevant contract/project.

3.4 ASSOCIATED DOCUMENTS

All **TEC-900-11** specifications will also, where appropriate, make reference to other relevant Uisce Éireann specifications, including, but not limited to:

TEC-100-006	Piping and Instrumentation Diagram Standards
TEC-100-011	Asset Hierarchy Rules and Definitions
TEC-100-013	Asset Tagging Standard
TEC-xxx-xxx	Asset Information Requirements (AIR) – Building Information Modelling (BIM)
TEC-200	General Mechanical and Electrical Specification
TEC-400	Instrumentation, Control and Automation Specification
TEC-600-05	Commissioning, Testing and Handover – General Specification

- **TEC-600-06** Chemical Storage Systems

If situations arise where compliance with the specifications listed above, the Employer’s Requirements, or UÉ Water Treatment Strategy documents is not possible and an alternative solution is proposed, then the Contractor shall obtain prior approval from the Employer’s Representative by submitting a Derogation Application as described in Section 3.3.

4 DEFINITIONS

The terminology and associated definitions used in this specification for various contractual roles and activities is aligned to the FIDIC® Conditions of Contract for DBO Projects (Gold Book), 1st Edition, 2008. Should an Uisce Éireann project be carried out under alternative Conditions of Contract, the interchangeability of terminology as outlined in the below equivalence table shall apply.

Term No.	FIDIC Gold	Minor MEICA Conditions of Contract	Public Works Contracts	Other Common Terms	UÉ Compliance
001	Contractor	Contractor	Contractor	Designer	-
002	Employer	Employer	-	-	-
003	Employer's Representative	Employer's Representative	Employer's Representative	-	-
004	Employer's Requirements	Work Order Requirements	-	Work Requirements	-
005	Performance Testing	Process Proving	-	Process Proving	-
006	Commissioning Certificate	Certificate of Completion	-	-	Projected Date of Completion (PDOC)
007					
008					

Table 5: Definitions used for various contractual roles and activities

5 ROLES AND RESPONSIBILITIES

This section of the document outlines the responsibilities of key personnel involved in key processes, the document owner and who is responsible for ensuring the Specification:

- aligns with UÉ documents
- aligns with relevant legislation and other requirements.
- is implemented and monitored and
- reviewed to evaluate its continuing effectiveness

Role	Responsibility	Summary Activity
Uisce Éireann - Asset Planning	*Document Owner*	- *Periodic document review* - *Ensure alignment to UÉ document framework* - *Ensure alignment with other UÉ documents* - *Ensure alignment with relevant legislation and other requirements* - *Monitor and review*
Uisce Éireann Technical Services	*Advise*	- *Document Management System* - *Implement and Monitor*
Contractor	*Execute the Specification*	- *Complete the design and build in accordance with the specification* - *Carry out all contractual duties as outlined in the Employer's Requirements*
Employers Representative	*Co-ordinate and monitor the execution of the Specifications*	- *Ensure design build works are completed in accordance with this specification* - *Monitor implementation and report updates and changes to Technical Services and Asset planning*
Uisce Éireann HSQE and Operations	*Site Walk Over*	- *UÉ HSQE, accompanied by UÉ Operations Lead and Engineer to complete a site walk over* - *Ensure site and plant are safe, secure and designed, built and installed in accordance with the Contract*

Table 6: Roles and responsibilities for the development and execution of this specification

6 SPECIFICATION

While modern water distribution infrastructure predominantly consists of polymer-based pipework (typically HDPE), prior to the 1970s iron and lead pipes were commonly used for the conveyance of treated water in public distribution networks. As a significant proportion of Ireland's network still relies on infrastructure laid in the late 19th or early 20th century, there remains a legacy of metallic pipework in public water supply schemes.

Domestic plumbing systems have also moved towards polymer-based piping systems, but the use of lead pipework in private premises was widespread until the 1970s, following which, copper became the mainstay of domestic plumbing up to and beyond the turn of the century. As such, copper and lead domestic plumbing systems remain widespread in buildings throughout Ireland today.

6.1 CORROSION IN WATER DISTRIBUTION NETWORKS

Many natural source waters with low to moderate background pH and alkalinity levels can be aggressive to lead, copper or iron piping systems still commonly found within water distribution networks, in both public infrastructure and private domestic plumbing systems. Over time, persistent contact with an aggressive water may result in the corrosion of these metal components within the network and/or household plumbing systems, and the consequent release of metal residuals (corrosion by-products) into the drinking water supply.

In addition to naturally occurring pH and alkalinity levels, chemical treatment (coagulation, oxidation, etc.) of source waters is often employed during water purification processes for the removal of organic and inorganic contaminants. These processes can often result in the alteration of natural pH and alkalinity levels, thereby exacerbating the aggressiveness of treated water, and increasing the risk of metal residual release.

To minimise the implications of aggressive water entering the distribution network, the general strategy is to implement treated water pH and alkalinity adjustment systems in order to;

- Produce water that is less aggressive to materials within distribution infrastructure (public and private);
- Encourage the formation of a protective layer on inner walls of distribution pipework (passivation);
- Prepare the water for the addition of a further post treatment corrosion inhibitor (orthophosphate);

6.2 IMPLICATIONS OF CORROSION IN DISTRIBUTION NETWORKS

Failure to appropriately correct treated water chemistry prior to entering distribution can significantly increase the corrosion rate of metallic elements of network infrastructure, which may ultimately result in:

- **Compromised infrastructure:** deterioration of drinking water distribution infrastructure and an increased potential for subsequent failure of both public watermains and domestic plumbing systems.
- **Public health issues:** leaching of corrosion by-products into drinking water at a rate which increases the concentration of metal residuals to levels which exceed safe limits for human consumption

6.3 PARAMETRIC LIMITS FOR METAL RESIDUALS

Exceedances of parametric limits of certain metals in drinking water supplies constitutes a hazard to public health. In the case of lead and copper, the risk associated with these hazards is increased, given the prevalence of these materials in public distribution networks and private plumbing systems from a certain era.

Both elements are toxic to humans if ingested in excessive quantities, with children and pregnant women being especially vulnerable to lead and/or copper poisoning. Current Irish Drinking Water Regulations, sets parametric limits of **5µg/L in respect of lead** and **2000µg/L in respect of copper**. Limits for other metals are outlined in Table 7 below. At a minimum, all proposed installations of chemical dosing systems for corrosion control shall consider these limit values and incorporate provisions in the design to meet these standards.

Parameter	Limit	Parameter	Limit
Aluminium	200 µg/L	**Iron**	200 µg/L
Arsenic	10.00 µg/L	**Lead**	5.00 µg/L
Cadmium	5.00 µg/L	**Manganese**	30.00 µg/L
Chromium	25.00 µg/L	**Mercury**	1.00 µg/L
Copper	2000 µg/L	**Nickel**	20.00 µg/L

Table 7: Limits of metal residual concentrations in drinking water supplies.

6.4 FACTORS INFLUENCING CORROSION (GENERAL)

Corrosion is the physicochemical reaction between a metal and its environment and may be caused or accelerated by the complex interaction of a combination of differing factors which may be chemical, physical, or microbiological in nature. An overview of the most prominent influencing corrosion factors is given below:

Chemical Factors

- Chemical properties of treated water, particularly:
  - *For lead and copper*: pH; alkalinity; hardness; buffer capacity; dissolved inorganic carbonate (DIC) concentration; dissolved organic carbon (DOC) concentration; orthophosphate concentration;
  - *For copper only:* dissolved oxygen concentrations; nature and concentrations of chlorine residuals;
- The oxidation potential of the distribution pipework when in contact with water of varying ionic strengths;
- Pipework and valve materials throughout the distribution network and their oxidation potentials with respect to each other (minimisation of galvanic current);
- *Concentration Cell Corrosion* by the creation of an *Oxygen Differential Cell* resulting from the deposition of debris on the inner surface of pipes;

Physical Factors (resulting in pitting & tuberculation)

- Excessively low flow rates in the carrier pipe, particularly in dead ended pipes (tuberculation)
- Excessively high flow rates and velocities in the carrier pipe (erosion, pitting)
- High liquid temperatures or high ambient temperatures in the operating environment

Microbiological Factors (bacterial corrosion)

- Anaerobic Bacterial Growth (iron related/sulphate reducing bacteria), following Concentration Cell Corrosion resulting from debris deposits on the inner surface of pipes.

6.5 FACTORS INFLUENCING PLUMBOSOLVENCY & CUPROSOLVENCY

Lead and copper concentrations at the consumer tap are strongly influenced by the chemistry of the water conveyed within the distribution system, and are affected by combinations of the complex chemical and physical reactions as described in Section 6.4 above. Such reactions may occur in both public watermains and privately-owned plumbing systems, where lead/copper may be released directly from pipe itself; from lead/copper-containing corrosion scales formed on the inside of the pipe; or from brass and solder that may contain lead.

The following sections outline the major chemical and physical factors which influence the plumbosolvency and cuprosolvency of treated water, and as such, the propensity for that water to corrode lead/copper pipework and result in the degradation of network infrastructure and elevated levels of lead/copper concentrations at the point of compliance (i.e. the consumer's tap).

6.5.1 pH

The pH of a water is a measure of acidity, or more specifically, its hydrogen ion concentration (H^+ or H_3O^+);

- **Low pH**: high concentration of hydrogen ions in the water, and consequently, high corrosivity water.
- **High pH**: low concentration of hydrogen ions in the water. Corrosivity of the water is significantly reduced, less tendency for lead or copper to be stripped from pipe walls and dissolve in water supplies.

6.5.2 Alkalinity

Alkalinity is the capacity of water to neutralise acid. It is the sum of carbonate, bicarbonate and hydroxide anions and is typically measured in mg/L “as calcium carbonate” ($CaCO_3$).

- **Low alkalinity**: water will not neutralise acids well, the formation of protective carbonate coatings is limited, and the water will tend to have a low buffering capacity (i.e. poor resistance to changes in pH);
- **High alkalinity**: water is very effective at neutralising acids, promotes the formation of protective carbonate coatings, and will tend to have a high buffering capacity (i.e. strong to resistance to changes in pH);

For the majority of surface waters, alkalinity can vary seasonally as a result of run-off from the surrounding catchment, algal growth or drought. Ground water alkalinity tends to be more stable due to the reduced influence of variable surface conditions.

6.5.3 Buffering Capacity

Buffering capacity is an attribute of alkalinity and is a measure of the resistance of water to changes in pH value. Carbonate and bicarbonate anions are the most important buffering species in the majority of drinking waters, but at higher pH values (over 9), silicate anions also supply buffering capacity. Phosphate contributions are normally insignificant as long as DIC is approximately ≥ 5.00mg C/L. Even in water of a stable alkalinity, buffering capacity varies with pH value:

pH Value = 6.3:	Maximum buffering capacity
pH Value = 8.0 – 8.5:	Minimum buffering capacity
pH Value ≥ 9.0:	Buffering capacity begins to get increasingly higher

Treated water in the very low buffer pH range (8.0 – 8.5) tends to have increasingly variable pH in the distribution network, which is aggravated further by waters with very low DIC concentrations (< 10.00 mg C/L). Waters with low buffer capacity are prone to rapid pH decreases from sources such as uncovered storage, nitrification, secondary chlorination, and rapid pH increases following contact with concrete / concrete lined pipe surfaces.

Maintaining sufficient buffering capacity is extremely important consideration when proposing pH adjustment or orthophosphate addition as control measures for lead or copper corrosion, as such control measures are only effective within particular pH ranges. Even if the pH of the water leaving the treatment plant is correct, pH changes in the distribution system may nullify the intended corrosion control measures.

6.5.4 Dissolved Inorganic Carbonate (DIC)

DIC is an estimate of the total carbonates in the form of carbonate ions (CO_3^{2-}); bicarbonate ions (HC0$_3^-$); andcarbon dioxide gas (CO_2 or H_2CO_3) in a particular water, and is measured in milligrams of carbon per litre (mg C/L). DIC is related to pH and alkalinity in that if these parameters are known, the DIC concentration can be accurately predicted. A comprehensive illustration of how DIC levels correspond to alkalinity at different pH readings is presented in Table 13 (Section 6.9.2 – extracted from the US EPA publication '*Revised Guidance for Selecting Lead and Copper Control Strategies*'), but the relationship between DIC, pH and alkalinity can be concisely summarised as follows:

- DIC concentration increases with increasing alkalinity;
- DIC concentration decreases with increasing pH;

DIC concentrations can be used to determine the saturation pH of water for particular carbonate compounds, i.e. the pH at which that carbonate compound will begin to precipitate from solution. This is an important parameter in corrosion control systems, as it gives an indication of the pH and alkalinity levels necessary to promote the formation of a passivation layer, without resulting in excessive scaling on the inner pipe walls.

- DIC concentrations that are either too low or too high may encourage / increase the rate of corrosion;
- DIC concentrations in the mid-range may have the effect of minimising metal release by decreasing the solubility of carbonate compounds in the treated water and promote formation of a passivation layer;

6.5.5 Lead Compounds

The nature of a protective carbonate coating may be influenced by the pipework material. In the case of lead piping, the inside surface of the pipe initially oxidizes to a divalent lead oxide (II) (PbO). In waters with sufficient DIC concentrations (i.e. carbon dioxide gas, bicarbonate ions, carbonate ions), this lead oxide converts to lead carbonates [Cerrusite ($PbCO_3$) and Hydrocerrusite ($Pb_3(CO_3)_2(OH)_2$], which over time, form a protective coating on the inner wall of the pipe.

In the absence of phosphates, the efficacy of this passivation layer depends on the solubility of these lead carbonate coatings, which in turn is dependent on the pH, alkalinity and DIC of the treated water:

- ***High-alkalinity, high-pH water:*** the formation of Cerrusite [$PbCO_3$] is predominant, and because of its lower solubility, results in an increased deposition of a protective lead carbonate barrier on the inner pipe wall, and consequently, a reduced concentration of lead in conveyed water;
- ***Low-alkalinity, low pH waters:*** the formation of Hydrocerrusite [$Pb_3(CO_3)_2(OH)_2$] is predominant, and because of its higher solubility, limits the formation of a protective lead carbonate barrier on the inner pipe wall and consequently, results in an increased concentration of lead in conveyed water;

6.5.6 Copper Compounds

Following commencement of flows through new copper piping systems, solubility decreases with passing time, primarily due to the transformation of copper minerals into a passivation layer. This layer initially comprises of a thin film of soluble cupric hydroxide $Cu(OH)_2$. As further time elapses, a more thermodynamically stable and less soluble layer, consisting of Malachite [$Cu_2CO_3(OH)_2$], or Tenorite [CuO], develops on top of the cupric hydroxide layer, thereby offering enhanced protection from corrosion and the leaching of copper residuals to the water supply.

When exposed to corrosive low pH water, the more soluble cupric hydroxide layer is unable to adequately form, and consequently the less soluble top layers do not form, resulting in the continued dissolution of copper into the conveyed water, and an increased risk of pitting after prolonged exposure to such corrosive waters. The formation of malachite or tenorite compounds as an inner passivation layer also depends on DIC levels, dissolved oxygen levels and free chlorine concentrations in the water.

- **Low – Moderate Alkalinity water:** pH and alkalinity adjustment is recommended as a precursor to orthophosphate dosing in a dual aspect solution to realise the most appropriate cuprosolvency control measure should copper exceedances persist over time.
- **High Alkalinity water:** In the case of corrosive high alkalinity water, where the DIC is elevated and a high buffering capacity limits the effectiveness of treated water pH adjustment, orthophosphate as a standalone solution may be the most appropriate cuprosolvency control measure.

6.5.7 Hardness

Hardness is a measure of the combined calcium and magnesium in water and is usually reported “as $CaCO_3$”, i.e. as calcium carbonate. Calcium and magnesium compounds can interfere with corrosion control efforts because they are less soluble at higher pH values than at lower pH values:

- **Low pH Water**: the formation of protective carbonate coatings is limited, risk of increased corrosion
- **High pH Water**: the formation of protective carbonate coatings is excessive, risk of excessive scaling

Calcium concentrations can be estimated from hardness “as CaCO3” data by dividing the hardness number by 2.5, and then used, in conjunction with DIC values, to determine the pH saturation point in order to minimise unintended side effects of corrosion control efforts (i.e. increased scaling of pipework).

6.5.8 Orthophosphate

Orthophosphate can combine with lead and copper to form several different compounds, which have very low solubility within particular pH ranges. As with carbonates, these low solubility compounds form a passivation layer on the inner wall of the pipework, thereby protecting the pipe from further corrosion. The addition of orthophosphate as a corrosion control treatment chemical is therefore a highly effective means of reducing lead and copper concentrations in water supplies where these materials form part of the distribution infrastructure.

Key issues to ensure that orthophosphate will reduce lead and copper concentrations are as follows:

- Maintenance of the pH value within the proper range throughout the network.
  - If the pH value is too low, even high doses of orthophosphate will be ineffective.
  - If the pH value is too high, the orthophosphate passivation layer will be unstable and offer little protection against corrosion.
- Maintenance of the orthophosphate residual (i.e. the free amount of orthophosphate measured in the distribution system) at a level sufficient to ensure the stability of the passivation layer.

6.5.9 Total Organic Carbon (TOC)

Elevated levels of organic carbon in water supplies can act as a chelating agent, and when in contact with lead pipework, may bind to lead ions and thereby increase their solubility. Organic carbon, in both its dissolved and particulate fractions can therefore result in increased plumbosolvency by several orders of magnitude.

6.5.10 Dissolved Oxygen

Elevated levels of dissolved oxygen can have a significant effect on water quality as it oxidises dissolved iron and/or manganese and forms more soluble copper compounds (in the presence of copper piping) than waters with low levels of dissolved oxygen. This is something which must be considered when developing Corrosion Control Implementation Plans or implementing corrosion control measures for processes which may employ upstream aeration systems for the purposes of iron and/or manganese removal.

6.5.11 Chlorine Residual

The addition of chlorine to a groundwater source that has low levels of dissolved oxygen has the same effect on water chemistry as the addition of dissolved oxygen. As such, many water treatment processes in Ireland are at risk of elevated levels of copper corrosion, which must be considered when developing the Corrosion Control Implementation Plan.

6.5.12 Temperature

The temperature of the water in the lead piping also has a significant bearing on lead and copper concentrations, with residuals found to be twice as high in the summer than in the winter.

6.5.13 Contact Time

Lead concentrations at the consumer tap have also been found to vary considerably at different times of the day. This is primarily governed by contact time between the water and the lead service pipe, which in turn is dependent on the length and internal diameter of the lead service and the water usage within the property.

6.6 CORROSION CONTROL STRATEGY

The ultimate solution to exceedances of parametric metal limits caused by the corrosion of distribution network infrastructure is the replacement of all pipework services which are vulnerable to corrosion. However, given the scale of Ireland’s distribution infrastructure, and the prevalence of metallic pipework, full replacement of all lead, copper and iron services is an unrealistic goal. Instead, targeted replacement of pipework and services will be focussed on the material which poses the biggest risk to public health – lead.

6.6.1 Permanent Solution for Plumbosolvency Issues

The permanent solution to achieve a concentration of 0 µg/L of lead in Ireland’s public water supplies is:

- The targeted replacement of all 180,000 PUBLIC side lead services, and;
- The targeted replacement of up to 250,000 PRIVATE side lead services

However, replacement of all public side lead services is estimated to take until 2026, with the replacement of private side services not being in Uisce Éireann's control. In the intervening period, Uisce Éireann has an obligation to mitigate against the associated DWSP hazards, and to maintain lead residual concentrations, as well as residual concentrations of other metals, below the parametric limits as set out in the Drinking Water

Regulations. This obligation will be met by the implementation of interim corrosion control measures.

6.6.2 Interim Solution for Plumbosolvency Issues

Control measures based around chemical treatment shall be implemented to mitigate against plumbosolvency issues until such time as the replacement of all lead services is completed. Incidentally, the interim control measures proposed to address plumbosolvency issues, will also be effective in addressing copper / iron exceedances, which may be a parallel issue in corresponding WSZs.

As copper and iron residuals do not present as great a risk to public health as lead, it is unlikely that there will be a targeted replacement of such pipework services. In order to mitigate against copper and iron exceedances resulting from corrosive water, the interim control measures proposed for plumbosolvency may well form the permanent solution for water supply zones experiencing copper and iron exceedances.

6.6.3 Corrosion Control Measures

Due to the multiple parameters which determine the corrosivity of treated water, control measures to limit metal exceedances at consumer properties served by lead, copper or iron pipework (either public side, private side, or both) requires a multi-faceted approach to water treatment involving some, or combinations of, the following process elements:

- **Treated Water pH & Alkalinity Adjustment**: addition of an approved pH and alkalinity adjustment chemical, ideally administered following achievement of Effective Ct, and which will serve to;
    - Elevate treated water pH in order to reduce the concentration of hydrogen ions, and thereby reduce the water's potential for lead, copper or iron corrosivity;
    - Optimise the buffering capacity of water throughout the distribution network to maximise resistance to pH change;
    - Manipulate the solubility of various carbonate species to promote the formation of protective passivation layers, but limit their formation to prevent excessive scaling to public and private network infrastructure;
    - Create optimal pH conditions for the potential addition of orthophosphate dosing as a supplementary control measure.
- **Post Treatment Corrosion Inhibitor:** addition of an approved chemical (orthophosphate) to promote the formation of a protective passivation layer. Effective formation of the passivation layer requires treated water to be within an appropriate pH range, therefore this control measure may often require implementation in tandem with an optimised Treated Water pH & Alkalinity Adjustment system upstream.

Note: as referenced in Section 6.6.2 above, in the case of lead services, the use of orthophosphate dosing is proposed as an interim measure only whilst existing lead pipework remains in use. A permanent solution can only be achieved through the replacement of existing lead services and pipework.

- **Natural Organic Matter Removal:** for sources with elevated levels of total organic carbon (TOC), the implementation or optimisation of effective natural organic matter removal systems (enhanced coagulation, flocculation and clarification, etc.) may be necessary to minimise the chelation capability of treated water. See Section 6.5.9 for further details on the effects of elevated TOC on the corrosivity of treated water.

6.6.4 Corrosion Control Strategy Targets

Table 8 below sets out the targets for compliance which Uisce Éireann have set following implementation of corrosion control measures. All concentrations are based on the results of Random Daytime (RDT) testing methodology carried out on premises within the water supply zone.

Parameter	Compliance Date	Compliance Target
Lead	By 2021	98% of RDT samples are beneath the parametric limit of 10µg/L
	By 2027	99% of RDT samples are beneath the parametric limit of 10µg/L
	By 2040	99.5% of RDT samples are beneath the parametric limit of 10µg/L

Table 8: Corrosion control strategy targets

6.7 IMPLEMENTATION OF CORROSION CONTROL STRATEGY

Uisce Éireann will establish a longlist of water supply zones (WSZ) which are experiencing metal exceedances, and assess each WSZ on the longlist to determine if the chemical properties of treated water are contributing to elevated concentrations of metal residuals in treated water supplies.

For WSZs where treated water corrosivity is identified as a contributory factor in elevated metal concentrations, the implementation of control measures will be prioritised on the basis of risk to public health (see Section 6.8 for prioritisation methodology).

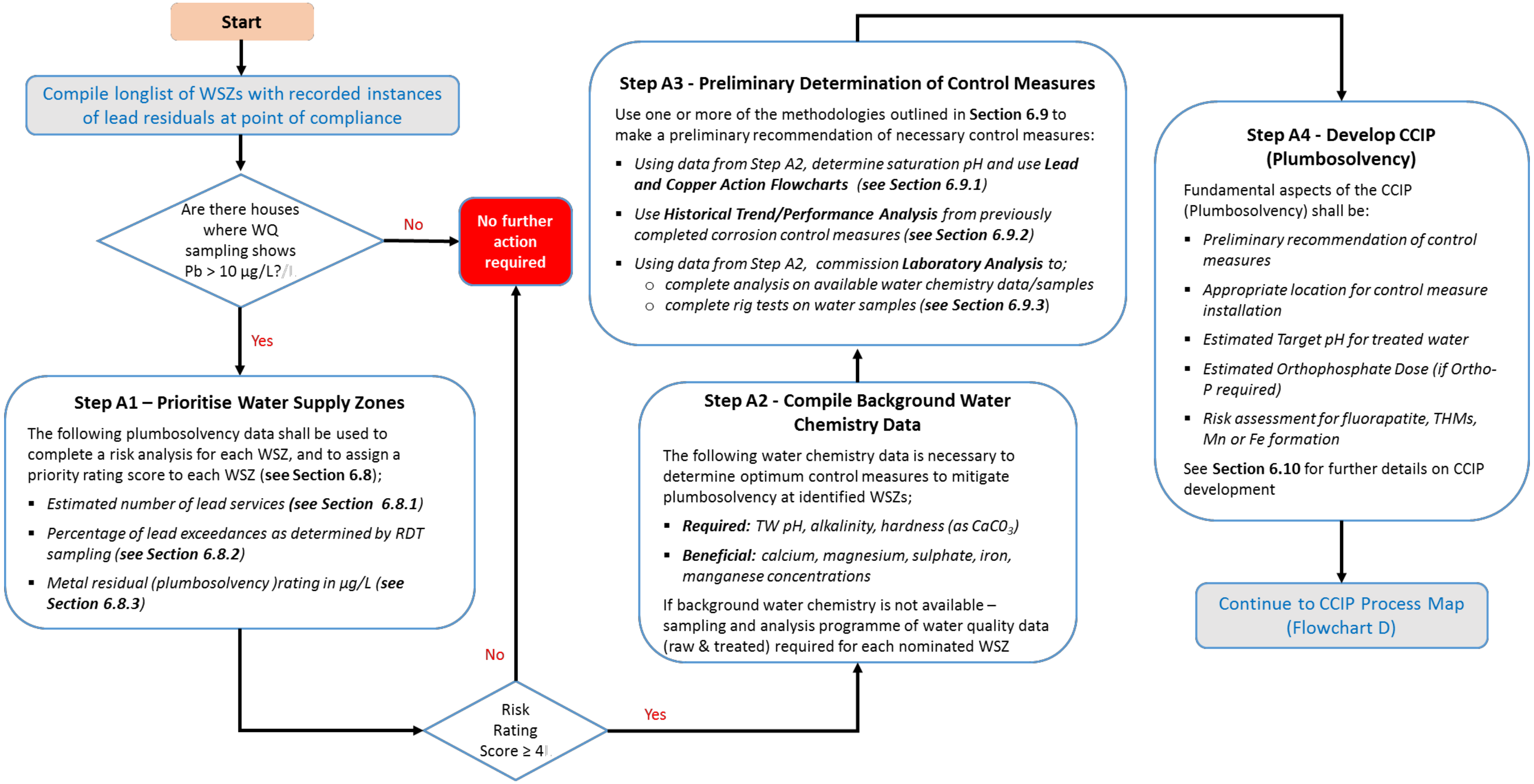
For each supply on the prioritised list, Uisce Éireann will commission the preparation of a Corrosion Control Implementation Plan (CCIP), specific to that WSZ, to outline the control measures required to mitigate against the leaching of metals from distribution network infrastructure.

The steps involved in development and execution of the CCIP are outlined in the flowcharts presented in the following sections of this document:

- Section 6.7.1: Flowchart A – CCIP Development (Plumbosolvency)
- Section 6.7.2: Flowchart B – CCIP Development (Cuprosolvency)
- Section 6.7.3: Flowchart C – CCIP Development (Iron Residuals)
- Section 6.7.4: Flowchart D – CCIP Process Map (Execution of CCIP)

6.7.1 Flowchart A – CCIP Development (Plumbosolvency)

The below flowchart outlines the general steps to be taken when establishing a hierarchy of WSZs at which plumbosolvency control measures should be implemented. The flowchart also outlines a general approach to deciding the most appropriate control measure(s) to be implemented to address plumbosolvency issues.



Step A1 – Prioritise Water Supply Zones

The following plumbosolvency data shall be used to complete a risk analysis for each WSZ, and to assign a priority rating score to each WSZ (**see Section 6.8**);

- *Estimated number of lead services **(see Section 6.8.1)***
- *Percentage of lead exceedances as determined by RDT sampling **(see Section 6.8.2)***
- *Metal residual (plumbosolvency)rating in µg/L **(see Section 6.8.3)***

Step A2 - Compile Background Water Chemistry Data

The following water chemistry data is necessary to determine optimum control measures to mitigate plumbosolvency at identified WSZs;

- ***Required:** TW pH, alkalinity, hardness (as $CaCO_3$)*
- ***Beneficial:** calcium, magnesium, sulphate, iron, manganese concentrations*

If background water chemistry is not available – sampling and analysis programme of water quality data (raw & treated) required for each nominated WSZ

Step A3 - Preliminary Determination of Control Measures

Use one or more of the methodologies outlined in **Section 6.9** to make a preliminary recommendation of necessary control measures:

- *Using data from Step A2, determine saturation pH and use **Lead and Copper Action Flowcharts** (**see Section 6.9.1**)*
- *Use **Historical Trend/Performance Analysis** from previously completed corrosion control measures (**see Section 6.9.2**)*
- *Using data from Step A2, commission **Laboratory Analysis** to;*
  - *complete analysis on available water chemistry data/samples*
  - *complete rig tests on water samples (**see Section 6.9.3**)*

Step A4 - Develop CCIP (Plumbosolvency)

Fundamental aspects of the CCIP (Plumbosolvency) shall be:

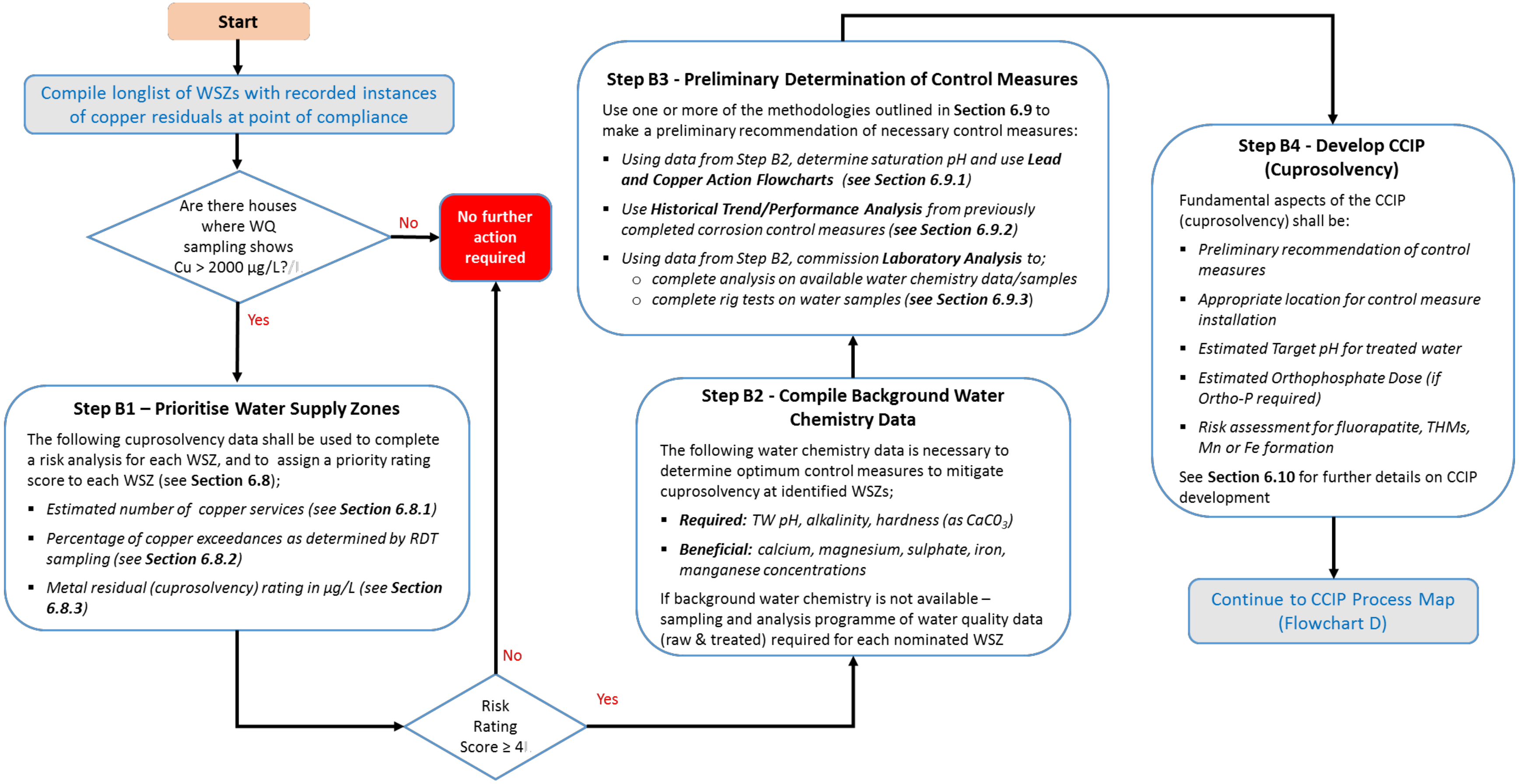
- *Preliminary recommendation of control measures*
- *Appropriate location for control measure installation*
- *Estimated Target pH for treated water*
- *Estimated Orthophosphate Dose (if Ortho-P required)*
- *Risk assessment for fluorapatite, THMs, Mn or Fe formation*

See **Section 6.10** for further details on CCIP development

Figure 3: Flowchart A – WSZ Prioritization and CCIP Development (Plumbosolvency)

6.7.2 Flowchart B – CCIP Development (Cuprosolvency)

The below flowchart outlines the general steps to be taken when establishing a hierarchy of WSZs at which cuprosolvency control measures should be implemented. The flowchart also outlines a general approach to deciding the most appropriate control measure(s) to be implemented to address cuprosolvency issues.



Step B1 – Prioritise Water Supply Zones

The following cuprosolvency data shall be used to complete a risk analysis for each WSZ, and to assign a priority rating score to each WSZ (see **Section 6.8**);

- *Estimated number of copper services (see **Section 6.8.1**)*
- *Percentage of copper exceedances as determined by RDT sampling (see **Section 6.8.2**)*
- *Metal residual (cuprosolvency) rating in µg/L (see **Section 6.8.3**)*

Step B2 - Compile Background Water Chemistry Data

The following water chemistry data is necessary to determine optimum control measures to mitigate cuprosolvency at identified WSZs;

- ***Required:** TW pH, alkalinity, hardness (as $CaCO_3$)*
- ***Beneficial:** calcium, magnesium, sulphate, iron, manganese concentrations*

If background water chemistry is not available – sampling and analysis programme of water quality data (raw & treated) required for each nominated WSZ

Step B3 - Preliminary Determination of Control Measures

Use one or more of the methodologies outlined in **Section 6.9** to make a preliminary recommendation of necessary control measures:

- *Using data from Step B2, determine saturation pH and use **Lead and Copper Action Flowcharts** (**see Section 6.9.1**)*
- *Use **Historical Trend/Performance Analysis** from previously completed corrosion control measures (**see Section 6.9.2**)*
- *Using data from Step B2, commission **Laboratory Analysis** to;*
  - *complete analysis on available water chemistry data/samples*
  - *complete rig tests on water samples (**see Section 6.9.3**)*

Step B4 - Develop CCIP (Cuprosolvency)

Fundamental aspects of the CCIP (cuprosolvency) shall be:

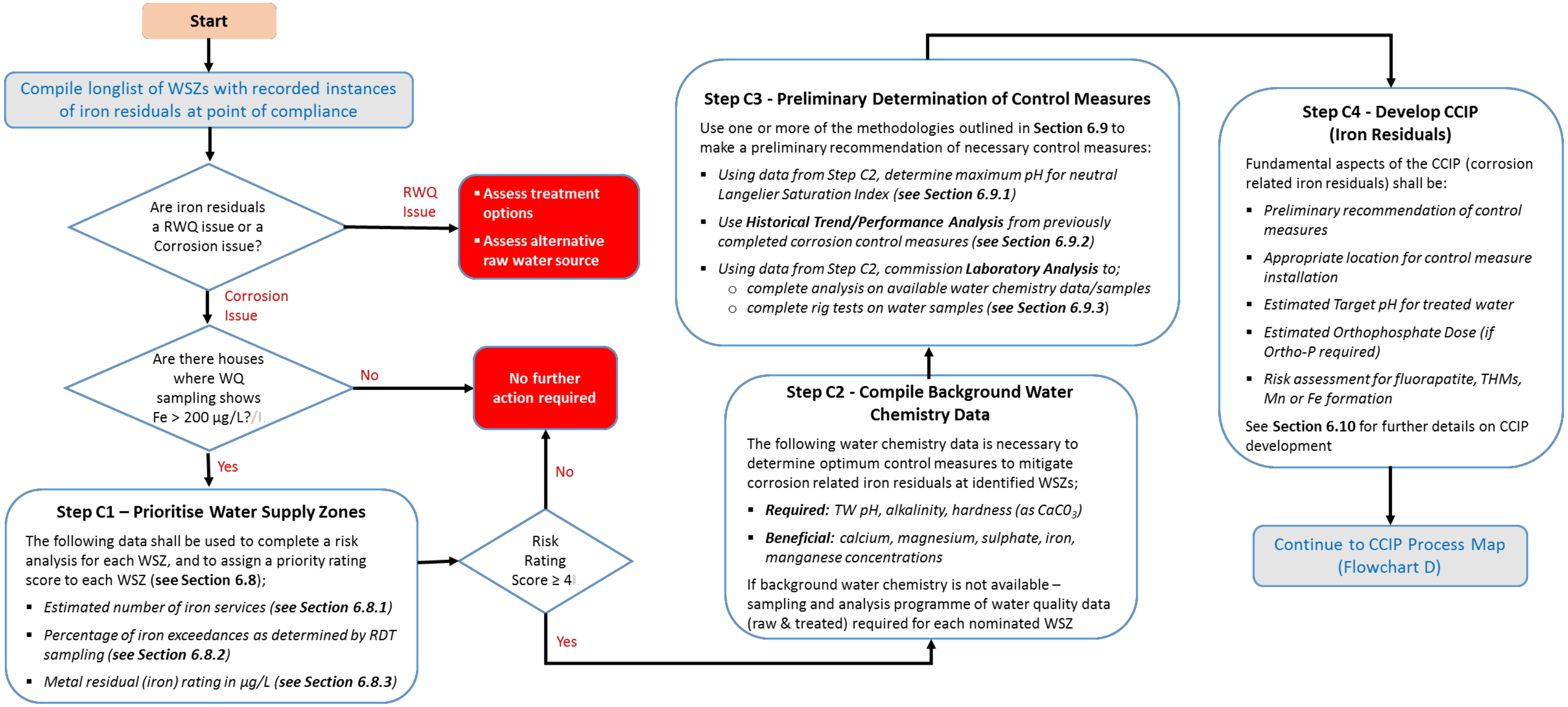
- *Preliminary recommendation of control measures*
- *Appropriate location for control measure installation*
- *Estimated Target pH for treated water*
- *Estimated Orthophosphate Dose (if Ortho-P required)*
- *Risk assessment for fluorapatite, THMs, Mn or Fe formation*

See **Section 6.10** for further details on CCIP development

Figure 4: Flowchart B – WSZ Prioritization and CCIP Development (Cuprosolvency)

6.7.3 Flowchart C – CCIP Development (Iron Residuals)

The below flowchart outlines the general steps to be taken when establishing a hierarchy of WSZs at which corrosion control measures should be implemented to address iron redisual exceedances. The flowchart also outlines a general approach to deciding the most appropriate control measure(s) to be implemented. Note that if iron residuals in treated water are a result of a raw water quality (RWQ) issue, the below flow chart is not applicable.



Step C1 – Prioritise Water Supply Zones

The following data shall be used to complete a risk analysis for each WSZ, and to assign a priority rating score to each WSZ (**see Section 6.8**);

- *Estimated number of iron services (**see Section 6.8.1**)*
- *Percentage of iron exceedances as determined by RDT sampling (**see Section 6.8.2**)*
- *Metal residual (iron) rating in µg/L (**see Section 6.8.3**)*

Step C2 - Compile Background Water Chemistry Data

The following water chemistry data is necessary to determine optimum control measures to mitigate corrosion related iron residuals at identified WSZs;

- ***Required:** TW pH, alkalinity, hardness (as $CaCO_3$)*
- ***Beneficial:** calcium, magnesium, sulphate, iron, manganese concentrations*

If background water chemistry is not available – sampling and analysis programme of water quality data (raw & treated) required for each nominated WSZ

Step C3 - Preliminary Determination of Control Measures

Use one or more of the methodologies outlined in **Section 6.9** to make a preliminary recommendation of necessary control measures:

- *Using data from Step C2, determine maximum pH for neutral Langelier Saturation Index (**see Section 6.9.1**)*
- *Use **Historical Trend/Performance Analysis** from previously completed corrosion control measures (**see Section 6.9.2**)*
- *Using data from Step C2, commission **Laboratory Analysis** to;*
  - *complete analysis on available water chemistry data/samples*
  - *complete rig tests on water samples (**see Section 6.9.3**)*

Step C4 - Develop CCIP (Iron Residuals)

Fundamental aspects of the CCIP (corrosion related iron residuals) shall be:

- *Preliminary recommendation of control measures*
- *Appropriate location for control measure installation*
- *Estimated Target pH for treated water*
- *Estimated Orthophosphate Dose (if Ortho-P required)*
- *Risk assessment for fluorapatite, THMs, Mn or Fe formation*

See **Section 6.10** for further details on CCIP development

Figure 5: Flowchart C – WSZ Prioritization and CCIP Development (Iron Residuals)

6.7.4 Flowchart D – CCIP Process Map (Execution of CCIP)

The below flowchart outlines the general steps to be taken when executing a Corrosion Control Implementation Plan, particularly when orthophosphate dosing forms part of the recommended control measures.

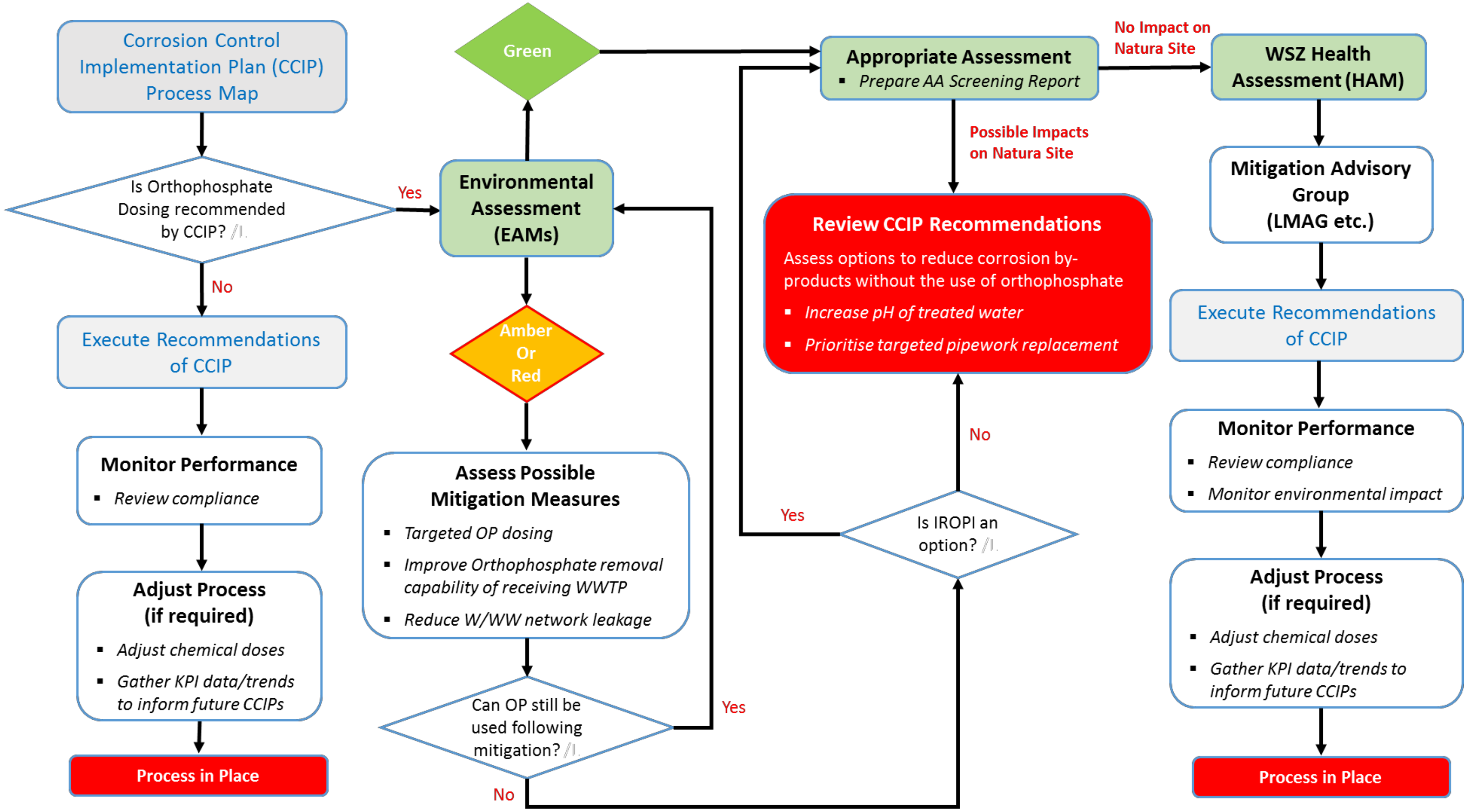


Figure 6: Flowchart D – CCIP Process Map (Execution of CCIP)

6.8 PRIORITISATION OF WATER SUPPLY ZONES

Prioritisation of water supply zones for the implementation of corrosion control measures shall be based on the following criteria:

- Estimated number of services (lead, copper or iron) within the WSZ
- Percentage of metal residual exceedances as determined by Random Day Time (RDT) testing in the WSZ
- Plumbosolvency / Cuprosolvency / Iron Residual rating of treated water sample taken from each WSZ

Should any <u>one</u> of the parameters listed above exceed its corresponding threshold in the below tables, that WSZ shall be given the corresponding Risk Rating Score.

For example, consider a WSZ with 80 lead services, a plumbosolvency rating of 200 and an RDT of 12%. In accordance with Table 9 below, this WSZ shall automatically be given a Risk Rating Score of 5, and be prioritised for corrosion control measures. WSZs which receive a risk rating score ≥ 4, will be prioritised for preparation of a Corrosion Control Implementation Plan, and implementation of corrosion control measures.

WSZ Prioritisation - Plumbosolvency					
	Colour	**Rating**	**No. of Lead Services (≥)**	**RDT% (≥)**	**Plumbosolvency Ra**
⚫	**5. Black**	**5**	200	10.0%	500
🔴	**4. Red**	**4**	100	5.0%	100
🟠	**3. Amber**	**3**	75	2.0%	50
🟡	**2. Yellow**	**2**	50	1.0%	25
🟢	**1. Green**	**1**	0	0.0%	0

Table 9: Prioritization criteria for plumbosolvency control measures

6.8.1 Estimated Number of Services

One or more of the following datasets shall be used for each county to estimate the number of relevant (i.e. lead, copper or iron) services in each water supply zone:

- 2016 Census occupancy data for each county to estimate the numbers of persons supplied by each WSZ
- Uisce Éireann data regarding the total number of connections in each WSZ
- Pre-Metering Programme survey reports completed by Local Authorities to identify domestic properties with shared services
- Uisce Éireann data gathered during boundary box installation (as part of the Metering Programme) to determine the number of lead / copper / iron services encountered

A reasonable estimate of the number of services can also be determined by multiplying the total number of connections within a WSZ by the RDT non-compliance rate for a particular metal in that WSZ (see Section 6.8.2 below). This is also a useful means of verifying the results obtained from analysis of the above datasets

6.8.2 Percentage of RDT Exceedances

Uisce Éireann have implemented a water sampling programme using the Random Day Time (RDT) methodology for lead, copper, manganese, zinc, nickel, pH and temperature at locations across a wide range of WSZs. The sampling locations were chosen using a random generation of addresses within the supply zones, and were allocated to achieve an even spread of sampling points for each sampling round. Exceedances of any of the parameters tested were notified to the owner/occupier in accordance with a procedure agrees with the HSE/EPA.

RDT sampling was undertaken by Uisce Éireann in advance of the implementation of corrosion control measures involving pH correction and/or orthophosphate dosing, so as to establish an initial baseline of regulatory metal compliance levels at properties within the WSZ. The sampling programme was completed over a 12-month period so as to capture any seasonal variations. The number of samples taken during the programme was based on the sampling bands outlined in Table 10 below.

WSZ Sampling Band	A	B	C	D	E
Properties (No/WSZ)	< 250	< 1000	< 5000	< 10000	> 10000
People (No/WSZ)	< 675	< 2700	< 13500	< 27000	> 27000
Estimated Demand (m3/day/WSZ)	< 170	< 675	< 3375	< 6750	> 6750
Number of Samples (No/WSZ)	0	30	60	180	300
Number of Samples (No/WSZ/month)	0	5	10	30	50

Table 10: Sampling Bands for UÉ's RDT methodology

6.8.3 Metal Residual Rating

A Plumbosolvency, Cuprosolvency or Iron Residual Rating may be determined by issuing treated water samples, preferably accompanied by background water chemistry data, from a particular WSZ to an external laboratory and completing a series of pipe rig tests, the results of which shall determine the rating score used to prioritise WSZs.

The precise requirements for such tests may vary depending on the metal residual being analysed, but for plumbosolvency testing (which Uisce Éireann has already been completed in partnership with a UK based laboratory), the methodology consisted of a series of 30-minute contact and 16-hour stagnation tests within lead pipes at a test temperature of 25°C:

- **30-minute contact (30MC):** provides an indication for average lead concentrations at the tap, but is a simplistic figure as stagnation within the distribution network or domestic plumbing is not accounted for

- **16-hour stagnation (16HS):** provides a 'worst-case' lead concentration at the tap, accounting for stagnation within the distribution network or domestic plumbing

The plumbosolvency rating is the concentration of lead, as measured in µg/L, after the 30-minute contact, and the associated Plumbosolvency Risk may be classified in accordance with Table 11 below. Note that for rig testing of copper and iron pipework, all methodologies and risk categorisation bands shall be approved in writing by Uisce Éireann before any samples are issued to external laboratories for analysis.

Metal Residual (Plumbosolvency) Rating (µg/L) 30MC Concentration of Lead @ 25°C	Plumbosolvency Risk
< 60	Low
60 to < 100	Moderate
100 to < 200	High
> 200	Very High

Table 11: Plumbosolvency Rating and associated Plumbosolvency Risk Categorisation

6.9 PRELIMINARY DETERMINATION OF CONTROL MEASURES

A major element of the CCIP is the preliminary determination of the control measures to be implemented. As the CCIP shall be a high-level desk-top review of a high number of WSZs, it is not possible to be definitive as to the most appropriate control measure, the most suitable installation location, or the target pH and/or orthophosphate levels to be maintained to ensure compliance with parametric limits for metal residuals.

The CCIP should however give all stakeholders a good early indication of the appropriate control measures necessary to achieve compliance with the parametric limits for metal residuals. Refinements to the CCIP, if required, can be made for each WSZ during value engineering workshops once more detailed site inspections have been completed.

When completing the preliminary determination of control measures for inclusion in the CCIP, the following methodologies shall be utilised:

- **Method 1:** Lead and Copper Action Flowcharts
- **Method 2:** Historical Trend/Performance Analysis
- **Method 3:** Laboratory Analysis Method

6.9.1 Target pH and Alkalinity for Treated Water

Following upstream treatment processes, particularly coagulation, the pH of water at the end of a water treatment process can typically be in the range of 6.0 to 6.5. To minimise corrosivity, Uisce Éireann shall require the pH of treated water entering all distribution networks to be within a pH range of 7.0 – 8.5. Table 12 below presents general ranges of pH & alkalinity values for various treated water scenarios.

Parameter	Minimum	Maximum
General pH Range for Treated Water	7.0	8.5
General pH Range for Treated Water (Ground Water)	7.2	8.0
General pH Range for Treated Water (Surface Water, Alkalinity > 50mg/L $CaCO_3$)	7.5	8.0
General pH Range for Treated Water (Surface Water, Alkalinity < 50mg/L $CaCO_3$)	8.0	8.5
General pH Range in advance of OP Dosing	7.2	7.8
General pH Range in advance of OP Dosing (Alkalinity > 50mg/L $CaCO_3$)	7.2	7.8
General pH Range in advance of OP Dosing (Alkalinity < 50mg/L $CaCO_3$)	7.5	7.8
Final Water Alkalinity as mg/L $CaCO_3$	30.0	150

Table 12: General pH ranges for various treated water scenarios

The precise pH target will be dependent on a number of other factors however, and may need to be increased to the levels outlined in the Lead and Copper Action Flowcharts below. An initial estimation of the target pH shall be made in the Corrosion Control Implementation Plan (CCIP), shall be confirmed during detailed design stages (by jar testing), and optimised during system commissioning. Factors which will influence the precise pH target, and must therefore be considered when selecting the target, include;

- the concentrations of lead and/or copper at the point of compliance;
- the concentration of dissolved inorganic carbonate (DIC) in the treated water;
- proposals to use orthophosphate as a supplementary corrosion inhibitor;
- the raw water source, and its background alkalinity (groundwater likely to have a stable alkalinity);

While the figures listed in Table 12 may be used for indicative purposes when preparing the CCIP, the treated water pH target for each site shall be determined on a case by case basis during detailed design, taking all the influencing factors as described above into account.

6.9.2 Lead and Copper Action Flowcharts

In order to recommend the most appropriate control measures to realise the Corrosion Control Implementation Plan, the developer of the plan shall adhere to the procedures laid out in this section of the document. The recommended pH and alkalinity adjustment control measures proposed in the Corrosion Control Implementation Plan shall be based on the solubility of lead (and copper if necessary), which is mainly a function of pH and the Dissolved Inorganic Carbonate (DIC) concentrations in the treated water, as described in Section 6.5.

The steps outlined overleaf are extracted from the US EPA '*Revised Guidance Manual for Selecting Lead and*

Copper Control Strategies', and shall be followed when determining the most appropriate pH and alkalinity adjustment option for proposal within the Corrosion Control Implementation Plan, and to assess if further chemical treatment is necessary by the implementation of an Orthophosphate dosing system.

Step 1: **Examine the available lead and copper data**. It is important to ensure that a copper/lead concentration exceedance is due to corrosive water, rather than some other cause. Treated water with a pH > 7.8 and with a residual alkalinity of between 30 and 100 mg $CaCO_3$/L would generally not be considered corrosive, whereas water with a neutral pH and an alkalinity greater than 150 mg CaCO3/L is frequently highly corrosive toward copper. If the pH and alkalinity concentrations are in the non-corrosive range, yet there are some excessive lead or copper concentrations detected in the treated water, then the possibility of re-sampling or materials replacement (either in the distribution network or in a private domestic dwelling) should be considered, as the exceedances are most likely not as a result of metal stripping due to the production of corrosive water.

Step 2: **Examine the available background chemistry of the treated water.** Accurate pH, alkalinity and hardness (as $CaCO_3$) data is critical to establish which of the approved pH / alkalinity adjustment systems is the most appropriate in each instance. In addition, having comprehensive calcium, magnesium, sulphate, iron, manganese, and other water quality data may help in defining constraints to pH / alkalinity adjustment when attempting to minimise risks of scaling.

Step 3: **Establish the DIC concentration of the treated water**. Using Table 13 overleaf determine the dissolved inorganic carbonate concentration (DIC mg C/L) based on treated water pH and alkalinity results.

Step 4: **Determine the saturation pH that can be targeted without creating scaling conditions**. Using the graph in Figure 7 of the determine the highest permissible pH (saturation pH) for calcium carbonate precipitation by locating the point of intersection of DIC (mg C/L) and calcium (mg Ca/L). The resulting value is the maximum allowable pH that can be targeted in the treated water without scaling becoming an issue. Note the following:

- the calcium concentration can be approximated by dividing the hardness concentration by 2.5
- the calcium concentration must be expressed as calcium (Ca) and not calcium carbonate ($CaCO_3$)
- maintaining the pH below the level estimated on the chart should minimize, not eliminate, the potential for precipitating calcium carbonate. In many cases, it will be possible to exceed the estimated pH levels without having a calcium precipitation problem as the precipitation of calcium is affected by many other factors, such as temperature and the presence of other dissolved metals.

Step 5: **Select appropriate pH/alkalinity adjustment system**. Using one of the five sets of treatment recommendation flow chart sheets outlined below, determine the most appropriate pH / alkalinity adjustment system using the results obtained from completing the previous steps. The treatment recommendation flow charts suggest appropriate water quality modifications based on the limited amount of water quality information available.

Dissolved Inorganic Carbonate Determination (DIC mg/L)
for Systems with pH of 4.6 to 7.4 and Alkalinities of 0 to 100
For a Purely Carbonate +H_2O Closed System at 10°C; Ionic Strength = 0.005 (TDS @ 200 or Cond. @ 312)

Alpha H_2CO_3*	0.98	0.97	0.96	0.94	0.91	0.86	0.79	0.71	0.60	0.49	0.38	0.28	0.20	0.13	0.09
Alpha HCO_3-	0.02	0.03	0.04	0.06	0.09	0.14	0.21	0.29	0.40	0.51	0.62	0.72	0.80	0.87	0.91
Alpha CO_3=	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

pH	***4.6***	***4.8***	***5.0***	***5.2***	***5.4***	***5.6***	***5.8***	***6.0***	***6.2***	***6.4***	***6.6***	***6.8***	***7.0***	***7.2***	***7.4***
Alkalinity (as $CaCO_3$)															
0	19	8	3	1	1	0	0	0	0	0	0	0	0	0	0
5	93	55	33	21	13	9	6	4	3	2	2	2	1	1	1
10	167	102	64	40	26	17	12	8	6	5	4	3	3	3	3
15	241	149	94	60	39	26	18	12	9	7	6	5	4	4	4
20	316	197	124	79	52	34	23	16	12	9	8	7	6	6	5
25	390	244	154	99	64	43	29	21	15	12	10	8	7	7	7
30	464	291	185	119	77	51	35	25	18	14	12	10	9	8	8
35	539	339	215	138	90	60	41	29	21	17	14	12	10	10	9
40	613	386	245	158	103	68	47	33	24	19	15	13	12	11	11
45	687	433	276	177	116	77	52	37	27	21	17	15	13	12	12
50	761	480	306	197	128	85	58	41	30	24	19	17	15	14	13
55	836	428	336	216	141	94	64	45	33	26	21	18	16	15	14
60	910	575	366	236	154	102	70	49	36	28	23	20	18	17	16
65	984	622	397	255	167	111	76	53	39	31	25	22	19	18	17
70	1058	670	427	275	179	119	81	58	43	33	27	23	21	19	18
75	1133	717	457	295	192	128	87	62	46	35	29	25	22	21	20
80	1207	764	488	314	205	136	93	66	49	38	31	27	24	22	21
85	1281	812	518	334	218	145	99	70	52	40	33	28	25	24	22
90	1355	859	548	353	231	153	105	74	55	42	35	30	27	25	24
95	1430	906	578	373	243	162	110	78	58	45	37	32	28	26	25
100	1504	953	609	392	256	170	116	82	61	47	39	33	30	28	26

Table 13: Tables for the Determination of DIC
For systems with treated water pH of 4.6 to 7.4 and alkalinities between 0 – 100 mg $CaCO_3$/L (Step 3)

Dissolved Inorganic Carbonate Determination (DIC mg/L)
for Systems with pH of 4.6 to 7.4 and Alkalinities of 110 to 400
For a Purely Carbonate +H_2O Closed System at 10°C; Ionic Strength = 0.005 (TDS @ 200 or Cond. @ 312)

Alpha H_2CO_3*	0.98	0.97	0.96	0.94	0.91	0.86	0.79	0.71	0.60	0.49	0.38	0.28	0.20	0.13	0.09
Alpha HCO_3-	0.02	0.03	0.04	0.06	0.09	0.14	0.21	0.29	0.40	0.51	0.62	0.72	0.80	0.87	0.91
Alpha CO_3=	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pH	***4.6***	***4.8***	***5.0***	***5.2***	***5.4***	***5.6***	***5.8***	***6.0***	***6.2***	***6.4***	***6.6***	***6.8***	***7.0***	***7.2***	***7.4***
Alkalinity (as $CaCO_3$)															
110	1652	1048	669	431	282	187	128	90	67	52	42	37	33	30	29
120	1801	1143	730	470	307	204	140	99	73	57	46	40	36	33	32
130	1949	1237	790	510	333	221	151	107	79	61	50	43	39	36	34
140	2098	1332	851	549	358	238	163	115	85	66	54	46	42	39	37
150	2247	1426	912	588	384	255	174	123	91	71	58	50	45	41	39
160	2395	1521	972	627	409	272	186	132	97	75	62	53	48	44	42
170	2544	1616	1033	666	435	289	198	140	103	80	66	56	51	47	45
180	2692	1710	1093	705	461	306	209	148	109	85	69	60	54	50	47
190	2841	1805	1154	744	486	323	221	156	115	90	73	63	57	53	50
200	2989	1899	1214	783	512	340	232	164	121	94	77	66	60	55	53
220	3319	2130	1323	881	587	377	264	185	135	108	85	73	66	61	58
240	3619	2312	1443	961	641	412	288	202	148	118	93	80	72	67	63
260	3919	2504	1563	1041	694	446	312	219	160	127	101	87	78	73	68
280	4219	2696	1683	1121	747	480	336	236	172	137	108	93	84	78	74
300	4519	2888	1803	1201	801	515	360	253	185	147	116	100	90	84	79
320	4819	3080	1923	1281	854	549	384	270	197	157	124	107	96	89	84
340	5119	3272	2043	1361	907	583	408	286	209	167	132	113	102	95	90
360	5419	3464	2163	1441	961	617	432	303	222	176	139	120	108	100	95
380	5719	3656	2283	1521	1014	652	456	320	234	186	147	127	114	106	100
400	6019	3848	2403	1601	1067	686	480	337	246	196	155	133	120	112	105

Table 14 (continued): Tables for the Determination of DIC
For systems with treated water pH of 4.6 to 7.4 and alkalinities between 110 – 400 mg $CaCO_3$/L (Step 3)

Dissolved Inorganic Carbonate Determination (DIC mg/L)
for Systems with pH of 7.6 to 10.4 and Alkalinities of 0 to 100
For a Purely Carbonate +H_2O Closed System at 10°C; Ionic Strength = 0.005 (TDS @ 200 or Cond. @ 312)

Alpha H_2CO_3*	0.06	0.04	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alpha HCO_3-	0.94	0.96	0.97	0.98	0.98	0.98	0.97	0.95	0.93	0.90	0.84	0.77	0.68	0.58	0.46
Alpha CO_3=	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.07	0.10	0.16	0.23	0.32	0.42	0.54
pH	***7.6***	***7.8***	***8.0***	***8.2***	***8.4***	***8.6***	***8.8***	***9.0***	***9.2***	***9.4***	***9.6***	***9.8***	***10.0***	***10.2***	***10.4***
Alkalinity (as $CaCO_3$)															
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
10	3	2	2	2	2	2	2	2	2	2	2	2	2	1	1
15	4	4	4	4	4	4	3	3	3	3	3	3	2	2	2
20	5	5	5	5	5	5	5	5	4	4	4	4	3	3	2
25	6	6	6	6	6	6	6	6	6	5	5	5	4	4	3
30	8	7	7	7	7	7	7	7	7	6	6	6	5	5	4
35	9	9	9	8	8	8	8	8	8	8	7	7	6	5	5
40	10	10	10	10	10	9	9	9	9	9	8	8	7	6	6
45	11	11	11	11	11	11	11	10	10	10	9	9	8	7	6
50	13	12	12	12	12	12	12	11	11	11	10	10	9	8	7
55	14	14	13	13	13	13	13	13	12	12	11	11	10	9	8
60	15	15	15	15	14	14	14	14	13	13	12	12	11	10	9
65	17	16	16	16	16	15	15	15	15	14	13	13	12	11	9
70	18	17	17	17	17	17	16	16	16	15	14	14	12	11	10
75	19	19	18	18	18	18	18	17	17	16	15	14	13	12	11
80	20	20	20	19	19	19	19	18	18	17	16	15	14	13	12
85	22	21	21	21	20	20	20	20	19	18	18	16	15	14	13
90	23	22	22	22	22	21	21	21	20	19	19	17	16	15	13
95	24	24	23	23	23	23	22	22	21	21	20	18	17	16	14
100	25	25	24	24	24	24	23	23	22	22	21	19	18	16	15

Table 14 (continued): Tables for the Determination of DIC
For systems with treated water pH of 7.6 to 10.4 and alkalinities between 0 – 100 mg $CaCO_3$/L (Step 3).

Dissolved Inorganic Carbonate Determination (DIC mg/L)
for Systems with pH of 7.6 to 10.4 and Alkalinities of 110 to 400
For a Purely Carbonate +H_2O Closed System at 10°C; Ionic Strength = 0.005 (TDS @ 200 or Cond. @ 312)

Alpha H_2CO_3*	0.06	0.04	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alpha HCO_3-	0.94	0.96	0.97	0.98	0.98	0.98	0.97	0.95	0.93	0.90	0.84	0.77	0.68	0.58	0.46
Alpha CO_3=	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.07	0.10	0.16	0.23	0.32	0.42	0.54

pH	***7.6***	***7.8***	***8.0***	***8.2***	***8.4***	***8.6***	***8.8***	***9.0***	***9.2***	***9.4***	***9.6***	***9.8***	***10.0***	***10.2***	***10.4***
Alkalinity (as $CaCO_3$)															
110	28	27	27	27	26	26	26	25	25	24	23	21	20	18	16
120	30	30	29	29	29	28	28	28	27	26	25	23	22	20	18
130	33	32	32	31	31	31	30	30	29	28	27	25	23	21	20
140	36	35	34	34	34	33	33	32	31	30	29	27	25	23	21
150	38	37	37	36	36	36	35	35	34	33	31	29	27	25	23
160	41	40	39	39	38	38	37	37	36	35	33	31	29	27	24
170	43	42	42	41	41	40	40	39	38	37	35	33	31	28	26
180	46	45	44	44	43	43	42	41	40	39	37	35	33	30	27
190	48	47	46	46	46	45	44	44	43	41	39	37	34	32	29
200	51	50	49	48	48	47	47	46	45	43	41	39	36	33	31
220	55	54	54	53	53	52	51	51	49	48	45	43	40	37	34
240	60	59	59	58	58	56	56	56	54	52	50	47	43	40	37
260	65	64	63	63	62	61	61	61	58	57	54	51	47	43	40
280	70	69	68	68	67	66	65	65	63	61	58	54	51	47	43
300	75	74	73	73	72	71	70	70	57	65	62	58	54	50	46
320	81	79	78	77	77	75	75	75	72	70	66	62	58	54	49
340	86	84	83	82	82	80	79	79	76	74	70	66	62	57	52
360	91	89	88	87	86	85	84	84	81	78	74	70	65	60	55
380	96	93	93	92	91	89	89	89	85	83	78	74	69	64	59
400	101	98	98	97	96	94	93	93	90	87	83	78	72	67	62

Table 14 (continued): Tables for the Determination of DIC
For systems with treated water pH of 7.6 to 10.4 and alkalinities between 110 – 400 mg $CaCO_3$/L (Step 3)

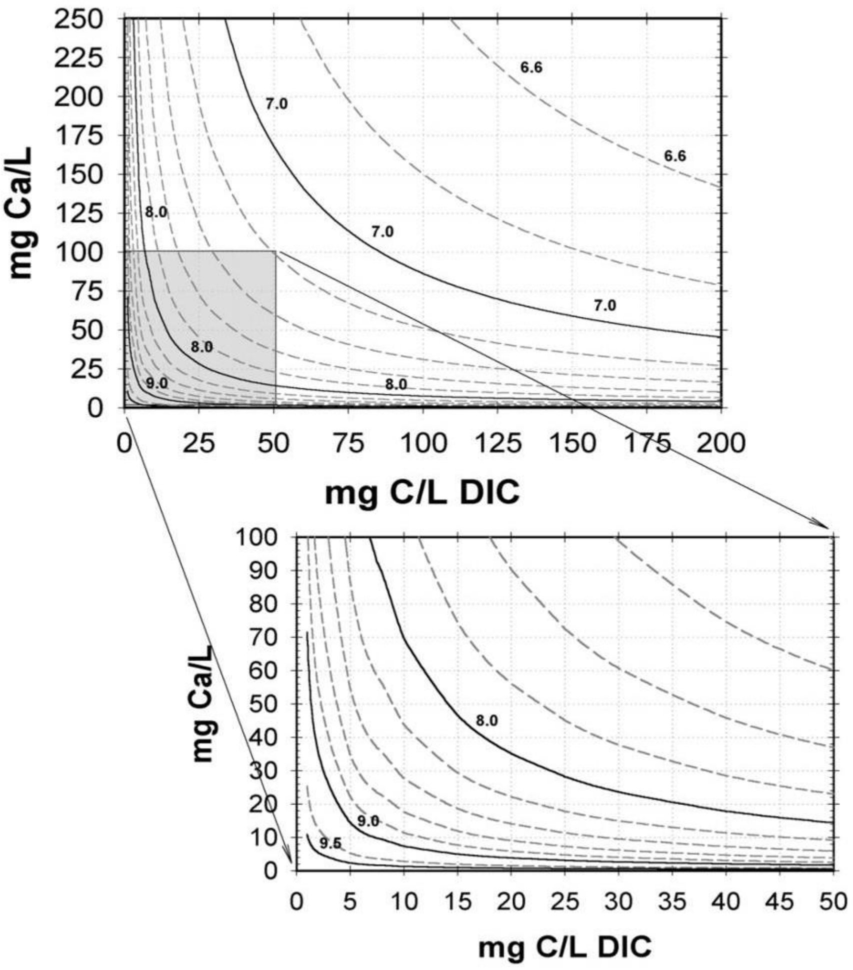


Figure 7: Determination of saturation pH for calcium carbonate precipitation (Step 4).

Once the dissolved inorganic carbonate levels and saturation pH for calcium carbonate precipitation has been established, the series of flowcharts presented below will guide the developer of the Corrosion Control Implementation Plan in the selection of the appropriate treated water pH and alkalinity adjustment system, as well as whether further supplementary corrosion inhibition should be considered (orthophosphate dosing) in order to minimise metal residuals in the treated water supply.

The developer of the Corrosion Control Implementation Plan shall utilise flowcharts A – E to establish the most appropriate methods to adjust pH and alkalinity in order to minimise water corrosivity and promote the formation of a carbonate passivation layer.

Where orthophosphate dosing is recommended as a supplementary corrosion inhibitor, the developer of the Plan shall refer to Section 6.11.1 for further issues which must be considered prior to the implementation of orthophosphate dosing.

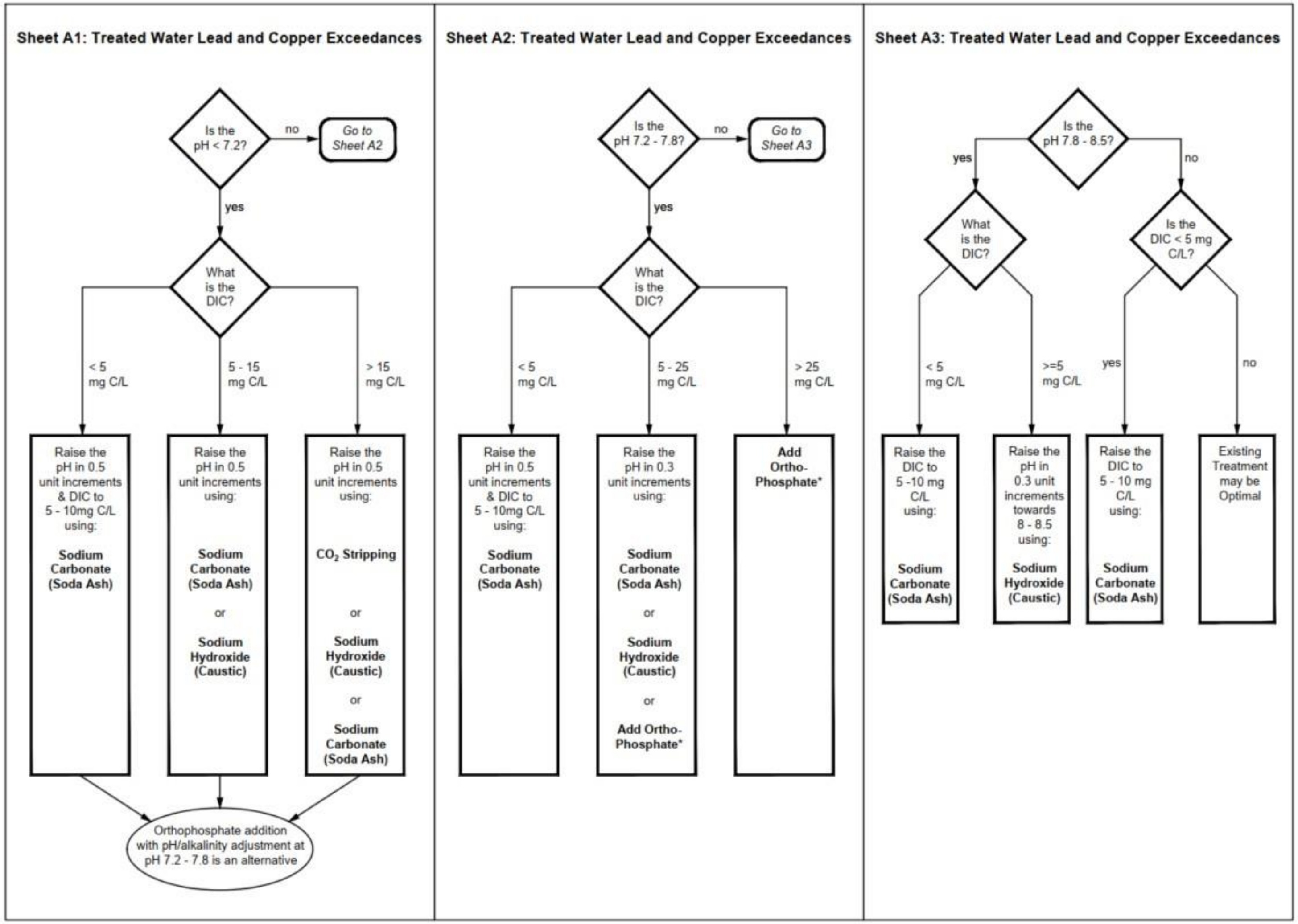


Figure 8: Lead and Copper Exceedances

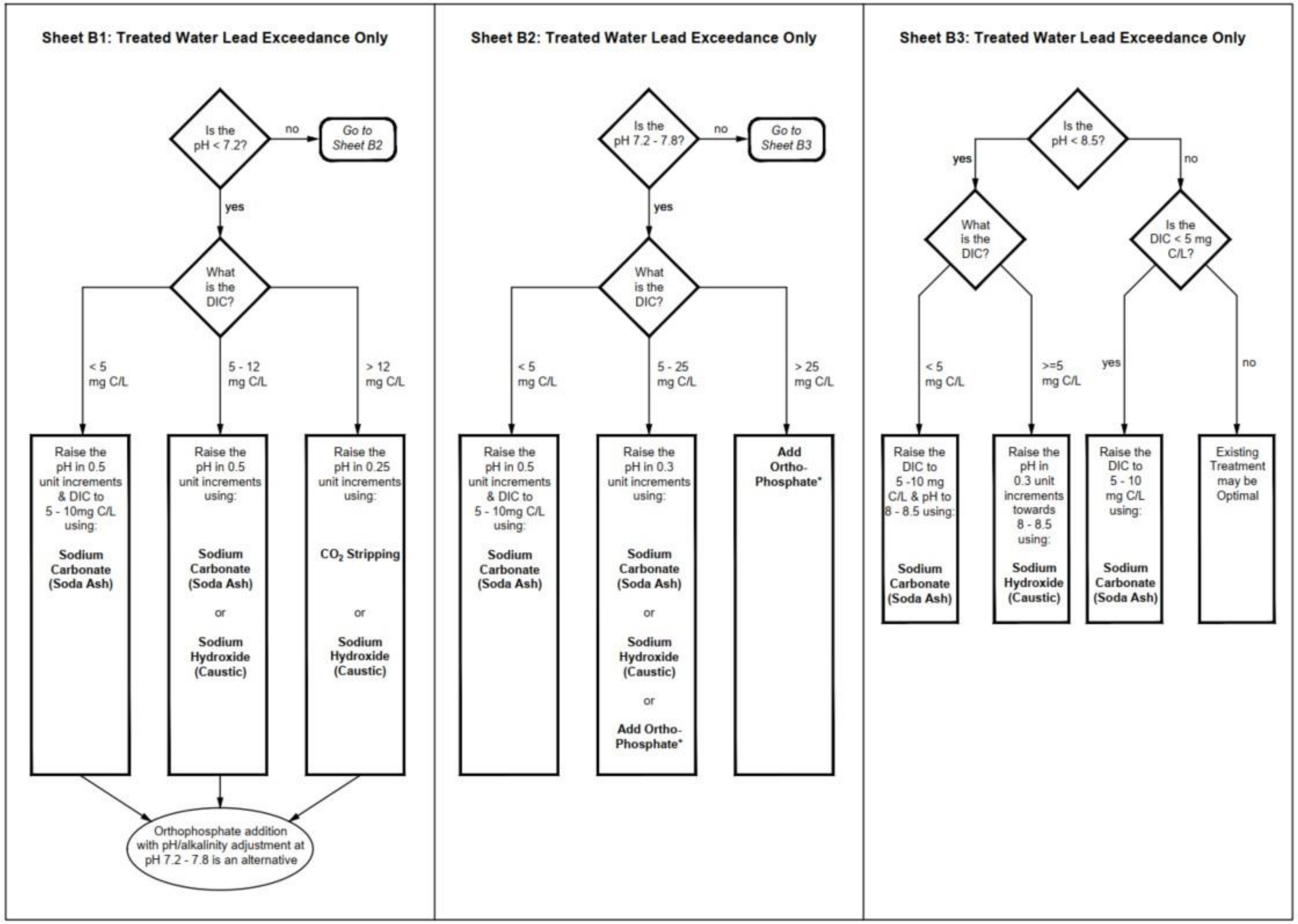


Figure 9: Lead Exceedances Only

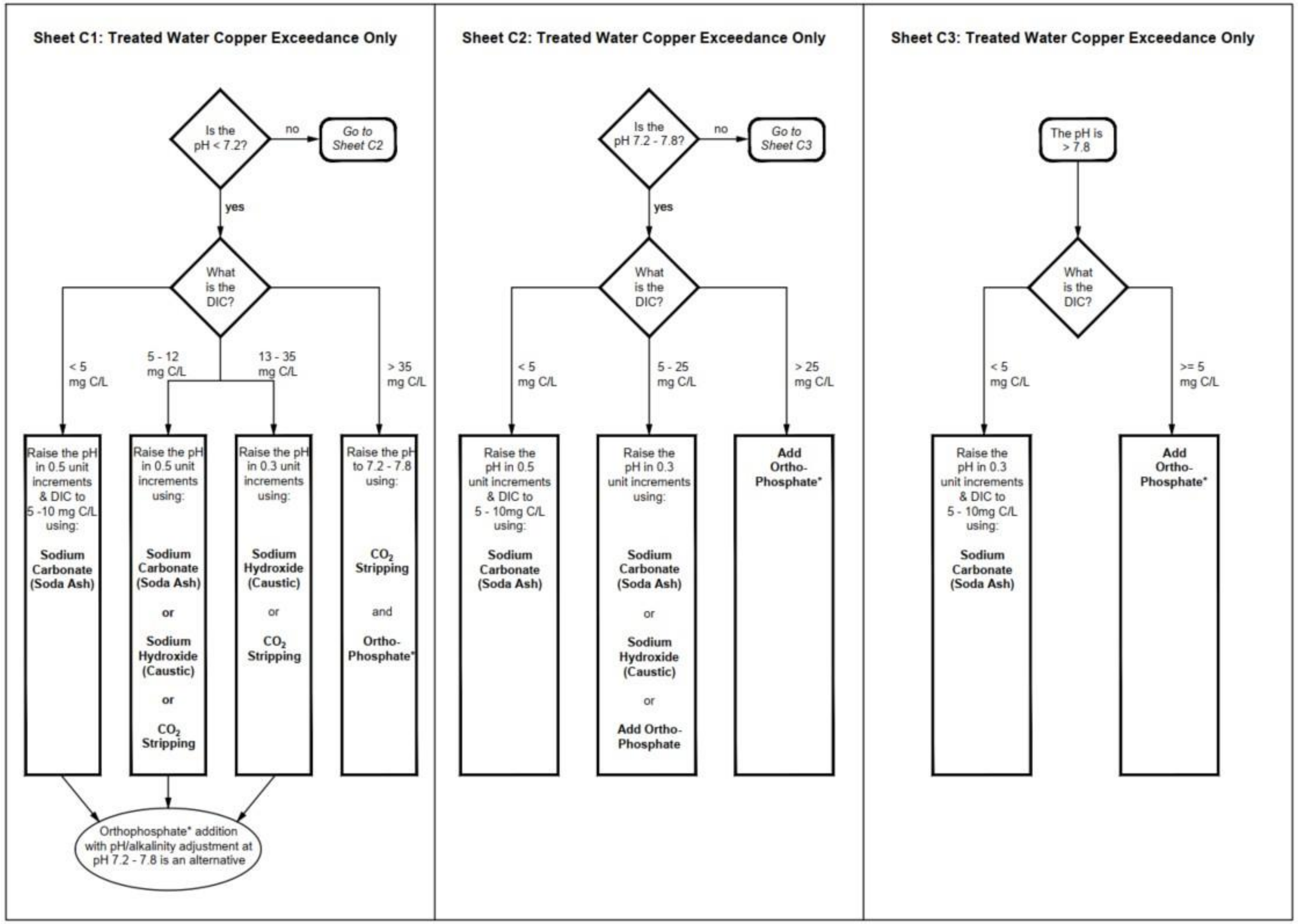


Figure 10: Copper Exceedances Only

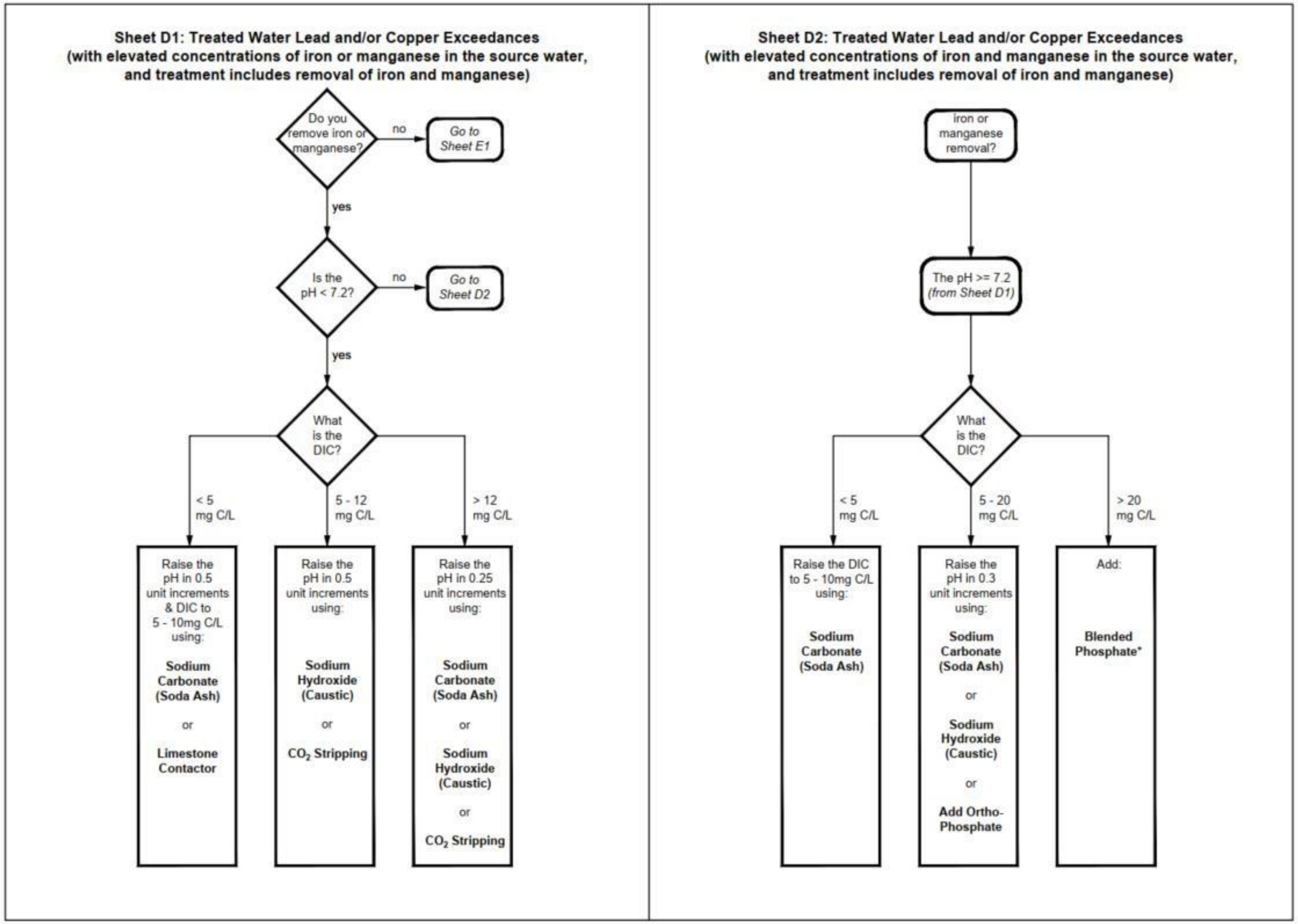


Figure 11: Lead and/or Copper Exceedances, iron/manganese in raw water (with removal)

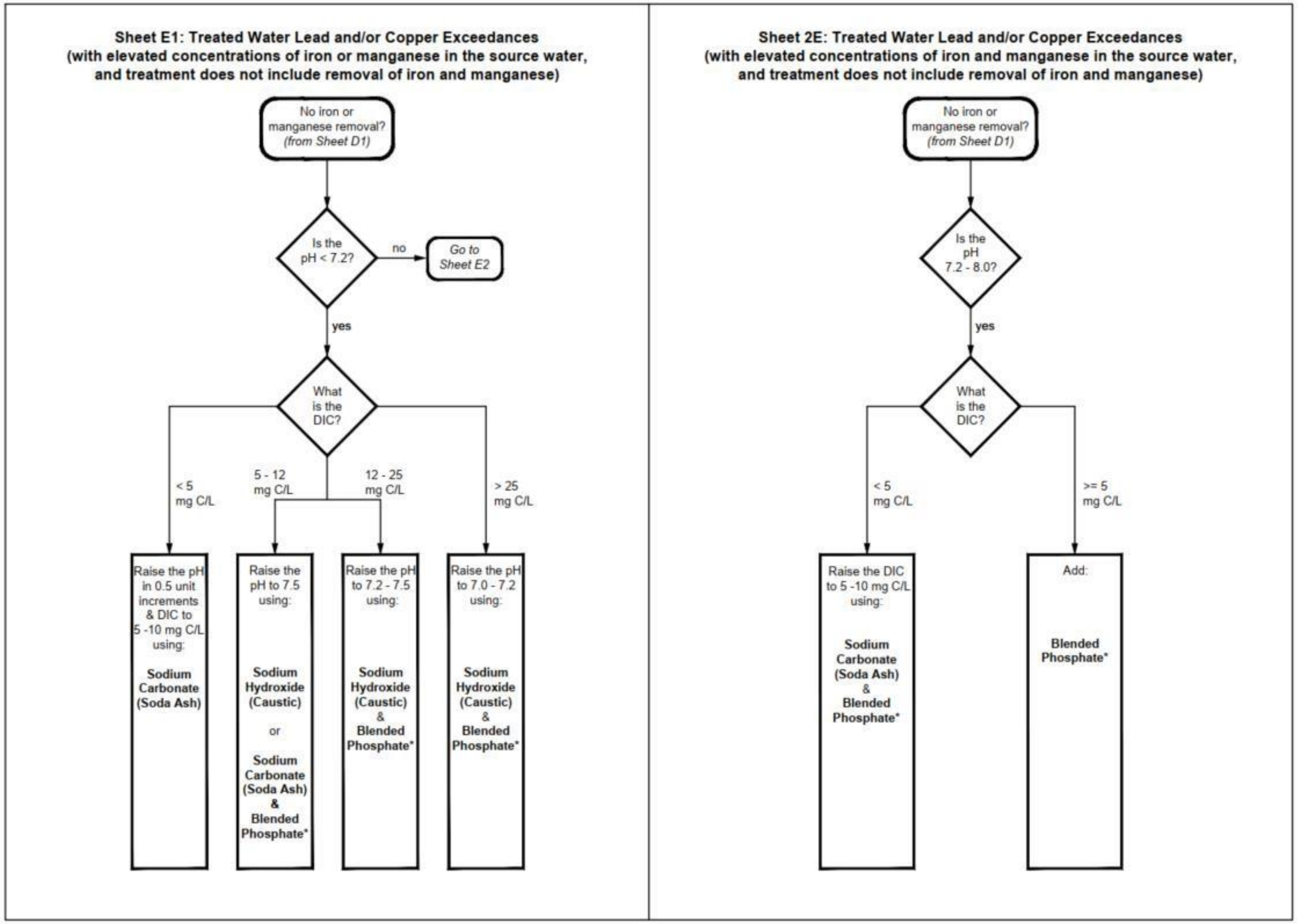


Figure 12: Lead and/or Copper Exceedances, iron/manganese in raw water (no removal)

6.9.3 Historical Data / Trend Analysis Method

Following roll out of the initial tranche of corrosion control measures to mitigate against plumbosolvency issues, Uisce Éireann will implement an intensive Operational Monitoring programme (see Section 6.12) in order to:

- Demonstrate the level of compliance with the parametric limit
- Ascertain the effectiveness of the implemented control measures
- Optimise chemical dose rates to maintain target pH in treated water entering the network
- If a corrosion inhibitor is used, optimise chemical dose rates to maintain appropriate orthophosphate concentrations in treated water entering the network
- If necessary, adjust target pH values and target orthophosphate concentrations

The data gathered during this Operational Monitoring programme shall be used as a model for future roll outs of corrosion control measures, and in tandem with the previously outlined Lead and Copper Action flowcharts, aid in the generation of the next tranche of CCIPs, particularly in relation to:

- Preliminary determinations of control measures
- Target pH and target orthophosphate (if used) concentrations in treated water
- Risks of fluorapatite and/or THM formation, as well as risk of manganese or iron precipitation

6.9.4 Laboratory Analysis Method

In the case where a Metal Residual Rating analysis as outlined in Section 6.8.3 is required for a particular WSZ, the Laboratory Analysis Method may be considered as an 'add-on' to the scope of works for the appointed external laboratory. In such cases, the external laboratory shall make a recommendation of the most appropriate control measure based on:

- Type 1 Testing: Investigation to examine the reduction of metal leaching following administration of of five differing orthophosphate doses (including 0) at each of three pH conditions
- Type 2 Testing: Investigation to examine the reduction of metal leaching following administration of four differing orthophosphate doses (including 0) at pH values of 7.0 and 8.0
- Type 3 Testing: Investigation to examine metal leaching potential at the pH of the received sample and without an orthophosphate dose

However, due to cost implications associated with laboratory analysis of multiple WSZs, both the ***Lead and Copper Action Flowchart*** and ***Historical Trend / Performance Analysis*** methods of determining appropriate control measures shall be exhausted before the **Laboratory Analysis Method** is commissioned. Note that all methodologies and test procedures proposed for use under the Laboratory Analysis Method shall be approved in writing by Uisce Éireann before any samples are issued to external laboratories for analysis.

6.10 CORROSION CONTROL IMPLEMENTATION PLAN (CCIP)

As detailed in Section 6.7, Uisce Éireann will commission the preparation of a Corrosion Control Implementation Plan (CCIP) for each WSZ on the prioritised list. The CCIP will be specific to that WSZ. The following section outline when a CCIP is required, a more detailed description of what the CCIP shall contain, implications to be considered when orthophosphate dosing is recommended within the CCIP, and how the CCIP should be used following its completion.

6.10.1 When is a CCIP Required?

As shown in the flowcharts of Section 6.7, Uisce Éireann shall commission a CCIP for all WSZs that have been identified as having a risk rating score ≥ 4 for concentrations of metal residuals, the cause of which is suspected to be related to the corrosivity of treated water entering the distribution network. The first tranche of CCIPs will specifically target lead exceedances.

However, there are also a number of other circumstances in which a CCIP should be commissioned, which include a change in raw water source, or an alteration to a treatment process. Uisce Éireann may request the preparation of a CCIP if any one (or more) of the following circumstances is detected, planned or scheduled:

- If corrosion of the distribution network or domestic plumbing systems in the WSZ is observed/reported;
- If metal release issues have been identified by the detection of metals in excess of parametric limits (lead, copper, iron) in the final water at the point of compliance (the consumer’s tap);
- Significant changes in source water quality, requiring an adjustment to the treatment process;
- If a change of raw water source is being considered;
- If a significant change to the water treatment process is being considered, such as;
    - Any process changes that result in a change to the pH / alkalinity of the treated water
    - Introduction of a new coagulant to the treatment process
    - Introduction of a new acidic chemical to the process (such as fluoride, sulphuric acid, etc.)
    - Introduction of a new basic chemical to the process (such as lime, sodium hydroxide, etc.)
    - Change in the chemical or chemical concentration used for maintenance of a disinfection residual

6.10.2 Contents of a CCIP

Following a high-level desk-top review, each CCIP will outline the preliminary corrosion control measures required to achieve and maintain metal residual compliance at the consumers tap. At a minimum, every CCIP commissioned shall contain the following details:

- Demarcation of the WSZ, the scheme headworks and the location of treated water storage facilities and the sub-zones supplied from them;
- Identification of the extent and spatial distribution of corrosivity control challenges presented by the WSZ network, particularly in relation to lead, but also to copper and iron where required;

- An overview of the water treatment processes supplying the WSZs, and the water quality parameters (physical and chemical) of treated water distributed to the WSZ;
- An assessment of available sampling results for raw water chemistry to establish the effects of existing treatment processes on its chemical properties, when compared with treated water chemistry;
- An assessment of available sampling results for treated water chemistry to;
    - determine the corrosive potential of the treated water
    - determine the effect that upstream treatment processes are having on the corrosive potential;
    - determine the potential efficacy of pH & alkalinity adjustment in the reduction of corrosivity;
    - establish the need, or otherwise, for the addition of a further corrosion inhibitor;
- A preliminary recommendation of the appropriate control measures to minimise corrosion in the distribution network, and a scope for the implementation of such control measures;
    - Targeted replacement of pipework vulnerable to corrosion by treated water
    - The use of pH/Alkalinity correction as corrosion mitigation treatment in its own right
    - The universal or targeted dosing of a corrosion inhibitor (orthophosphate) at the WTP, storage assets or at selected locations on the distribution network to enable the formation of an inner passivation layer (assuming the current treated water already has appropriate and stable pH and alkalinity levels).
    - A combination of the above, where pH/alkalinity adjustment systems are implemented as a necessary precursor to orthophosphate dosing, in order to ensure the optimal water quality conditions are present to facilitate the formation of an inner passivation layer.
- Identification of the most appropriate locations for control measure installation (i.e. at the WTP, storage assets or at selected locations on the distribution network)
- An estimated optimum target pH, and if a supplementary corrosion inhibitor chemical is proposed in tandem, an estimated orthophosphate dose;
- Proposed process alterations to reduce the TOC concentration of treated water;
- Risk analysis of the potential for recommended control measures to exacerbate the formation or concentration of the following:
    - fluorapatite in treated water when in combination with fluorine residuals;
    - disinfection by-products (THMs) as a result of increased pH
    - Iron or manganese residuals

6.10.3 Using a CCIP

The CCIP shall be included as Background Information to tender documents for subsequent works contracts. For the purposes of pricing, all Contractors shall base their tender pricing schedules on the corrosion control measures recommended in the CCIP.

Following contract award, and once more detailed site inspections have been completed, value engineering workshops for each tranche of the corrosion control programme shall be held. If required, site-specific refinements (i.e. chemicals to be used, proposed doses, target pH, location of facilities, etc.) to the corrosion control measures recommended in the CCIP may be proposed during the value engineering workshops.

All process works necessary to implement the recommendations of the CCIP, including refinements made during value engineering workshops shall be executed in accordance with the Level 7 Chemical Treatment for Corrosion Control specifications:

- **TEC-900-11-01** Chemical Treatment for Corrosion Control: TW pH & Alkalinity Adjustment
- **TEC-900-11-02** Chemical Treatment for Corrosion Control: Orthophosphate Dosing

6.11 EXECUTION OF CCIP

The appointed Contractor shall comply with the requirements as set out in the following documents when proposing solutions to implement the control measures as identified under the Corrosion Control Implementation Plan:

- **TEC-900-11-01** Chemical Treatment for Corrosion Control - Treated Water pH / Alkalinity Adjustment
- **TEC-900-11-02** Chemical Treatment for Corrosion Control - Orthophosphate Dosing
- **TEC-600-06** Chemical Storage Systems

6.11.1 Orthophosphate as a Control Measure - Considerations

During the development of the CCIP, orthophosphate may be proposed as a supplementary post treatment corrosion inhibitor to mitigate against the presence of metal residuals at the point of compliance (the consumer’s tap). If orthophosphate is proposed as part of a corrosion control measure, the following assessments must be made in accordance with Section 6.7.4 (Flowchart D) to evaluate the potential environmental impact on its environs:

- An Environmental Assessment (EAMS)
- An Appropriate Assessment (AA Screening Report)
- WSZ Health Assessment (HAM)

As well as potential impacts on the environs adjacent to the installation location, the above assessments should also consider the following when orthophosphate is proposed as a corrosion inhibitor:

- Possible water and wastewater leakage pathways, discharging phosphorous residuals into groundwater;
- Treated wastewater and stormwater overflows, discharging increased total phosphorus residuals into inland waterways
- Wastewater treatment facilities, their capabilities to reduce orthophosphate concentrations and final effluent discharge locations
- the proposed location of orthophosphate dosing systems, given that only a certain proportion of a WSZ may be at risk of lead (or copper and iron) corrosion. In such cases, universal dosing of orthophosphate

at the water treatment plant is not appropriate, due to the increased potential for environmental impact, as well as the TOTEX associated with the installation and operation of such systems. Instead, targeted dosing of identified high-risk areas shall be considered, and dosing should be implemented at appropriately located storage assets or points on the distribution network.

Should each of the assessments conclude that the use of orthophosphate constitutes an acceptable level of risk, the proposal shall then be put forward for final assessment by the Corrosion Control Mitigation Advisory Group. Should the group approve the proposal, the CCIP may be included in as Background Information to tender documents for subsequent works contracts.

6.11.2 Jar Tests

The Contractor shall confirm and/or refine the chemical concentrations, doses and storage requirements as outlined in the CCIP for the selected pH correction chemical and, if deemed necessary, the orthophosphate, by completing a series of jar tests which shall replicate the proposed corrosion control measures. The jar testing programme shall be carried out on 7 number water samples taken 4-8 days apart over a period of 28-56 days.

Where no alterations to the process upstream of the corrosion control measures are proposed, the jar tests shall use treated water from the supply to determine optimum chemical concentrations, doses and storage requirements for the proposed chemical(s). Where upstream alterations are proposed, the jar tests shall mimic such alterations, and shall model the existing or proposed treatment process, paying particular attention to all activities which will affect pH levels (alkalinity adjustment, coagulation, oxidation, etc.).

Results of all jar tests are to be submitted to Uisce Éireann, or their representative, prior to proceeding with detailed design. The Contractor may be requested to complete additional jar tests, or provide supplementary information / results if the submitted data is deemed insufficient by Uisce Éireann.

The Contractor shall also ensure that the storage and dosing correction system for the selected pH chemical shall be capable of maintaining the pH of the final treated water at an operator selectable target set point, as set out in the Corrosion Control Implementation Plan.

6.11.3 Capability of Corrosion Control Measures

Regardless of the target pH and required orthophosphate concentration, all chemical treatment systems proposed for the implementation of corrosion control measures shall, at a minimum, be capable of maintaining the treated water pH and orthophosphate concentrations within the ranges as set out in Table 14 below.

Corrosion Control Parameter	Capability Range of Control Measure
Treated Water pH Value	7.0 – 8.5
Treated Water Orthophosphate Concentration	0.00 – 1.50 mg/L

Table 14: Performance capability of Corrosion Control Measures

6.12 OPERATIONAL MONITORING

Following commissioning and performance testing of the implemented corrosion control measures, Uisce Éireann will implement an intensive Operational Monitoring programme in order to:

- Demonstrate the level of compliance with the parametric limit (lead, copper, iron, etc.)
- Ascertain the effectiveness of the implemented control measures
- Optimise chemical dose rates to maintain target pH in treated water entering the network
- If a corrosion inhibitor is used, optimise chemical dose rates to maintain appropriate orthophosphate concentrations in treated water entering the network
- If necessary, adjust target pH values and target orthophosphate concentrations
- Build a database of appropriate chemical treatments, target pH values and target orthophosphate concentrations for particular treated water characteristics to be used for future design and implementation of corrosion control measures

6.12.1 Duration of Operational Monitoring

Where orthophosphate dosing forms part of the corrosion control measure, international experience shows that it is likely to take between 6 and 24 months of corrosion inhibitor dosing with orthophosphate before the anticipated internal coating of service pipes becomes effective. Uisce Éireann will therefore carry out Operational Monitoring for a period of 24 months following commissioning of the system. For the initial 6 months of this 24-month period, Uisce Éireann will, in order to set a performance baseline for future system optimisation, operate the corrosion control system using the initial dose rate as agreed following:

- Execution of the CCIP;
- Site specific process evaluation as completed by the Contractor during detailed design;
- Value engineering workshops;
- Completion of commissioning;

6.12.2 Sampling and Monitoring for System Opimisation

For WSZs where orthophosphate forms a part of the corrosion control measures, Uisce Éireann will seek to optimise the orthophosphate dose to achieve the least possible concentration required to maintain the protective passivation layer. In order to optimise the combination of orthophosphate dosing and pH correction, Uisce Éireann will undertake a sampling and monitoring programme for the first 6 months while the system operates at its initial agreed dose rate(s). The sampling and monitoring programme shall comprise:

- Daily samples at point-of-entry to the distribution network to be tested for key background water quality parameters affecting the formation of the passivation layer post orthophosphate addition (pH, alkalinity, orthophosphate concentrations)
- Weekly samples at point-of-entry to the distribution network to be tested for key background water quality parameters affecting the formation of the passivation layer post orthophosphate addition (DOC, iron, manganese and temperature)
- 30-minute stagnation sampling (30MS) of water from the consumer tap at a number of known exceedance locations, taken bi-monthly for the first 6 months, and monthly thereafter.

During this period, Uisce Éireann will also monitor the environmental impact of raised phosphorous levels in drinking water at the agreed initial dose rate and its dissipation to the environment via surface and sub-surface pathways on the WSZs. Environmental impacts, if any, observed during this period will be compared with the findings of the EAM, AA Screening and NIS reports to ensure compliance with same.

Monitoring Parameter	Monitoring Location	Monitoring Frequency	Monitoring Period	Target
TW pH	Point of Network Entry	Daily	1 – 6 Months	± 0.2 pH Units of CCIP Recommendation
TW Alkalinity	Point of Network Entry	Daily	1 – 6 Months	As per CCIP Recommendation
TW Orthophosphate Conc.	Point of Network Entry	Daily	1 – 6 Months	As per CCIP and/or Agreed Target
TW DOC Concentration	Point of Network Entry	Weekly	1 – 6 Months	As per CCIP Recommendation
TW Temperature	Point of Network Entry	Weekly	1 – 6 Months	n/a
TW Iron Concentration	Point of Network Entry	Weekly	1 – 6 Months	n/a
TW Manganese Conc.	Point of Network Entry	Weekly	1 – 6 Months	n/a
30-min Stagnation Sampling	RDT at Consumer's Tap	Bi-monthly	1 – 6 Months	Gradual reduction in metal concentrations

Table 15: Summary of samples/monitoring required during the initial 6 months of operation

6.12.3 Orthophosphate Optimisation Plan

Following 6 months of orthophosphate dosing at the initial dose rate, Uisce Éireann will prepare an Orthophosphate Optimisation Plan and report on how the formation of the desired passivation layer is progressing. The report will also assess any environmental impacts which may have been observed in that time, and compare such findings with the content of the EAM, the AA Screening and NIS reports to ensure compliance.

The report will demonstrate the efficacy of the corrosion control measures within the sections of network with previous history of metal exceedances, and if required, will outline proposals for adjustment of doses. If no dose adjustment is deemed necessary, the system will continue to operate at the established maintenance dose.

6.12.4 Sampling and Monitoring for Metal Limit Compliance

Following completion of the initial 6-month operational period, and if required, the adjustment of the orthophosphate dose based on the recommendation of the Orthophosphate Adjustment Plan, RDT sampling will continue to be carried out on a monthly basis at agreed locations on the WSZ distribution network to monitor the progress of the development of the passivation layer. The requirements for RDT sampling are outlined in Table 16 below.

Monitoring Parameter	Monitoring Location	Monitoring Frequency	Monitoring Duration	Target
30-min Stagnation Sampling	RDT at Consumer's Tap	Monthly	6 – 24 Months	< Parametric Limit for metal contaminant

Table 16: Summary of samples/monitoring required following 6 months of operation

7 REPORTING (IF REQUIRED)

8 REFERENCE DOCUMENTS

Document Name	*Document Number*	*Location*
Piping & Instrumentation Diagram	TEC-100-006	**Knowledge Base**
Asset Hierarchy Rules and	TEC-100-011	Knowledge Base
Asset Tagging Standard	TEC-100-013	Knowledge Base
General Mechanical and Electrical Specification	TEC-200	Knowledge Base
Instrumentation, Control and Automation Specification	TEC-400	Knowledge Base
Commissioning, Testing and Handover – General Specification	TEC-600-05	Knowledge Base
Chemical Storage Systems – General Specification	TEC-600-06	Knowledge Base

9 GENERATED DOCUMENTS

Document Name	*Document Number*	*Location*
Treatment for Corrosion Control - Treated Water pH	TEC-900-11-01	Knowledge Base
Chemical Treatment for Corrosion Control –	TEC-900-11-02	Knowledge Base