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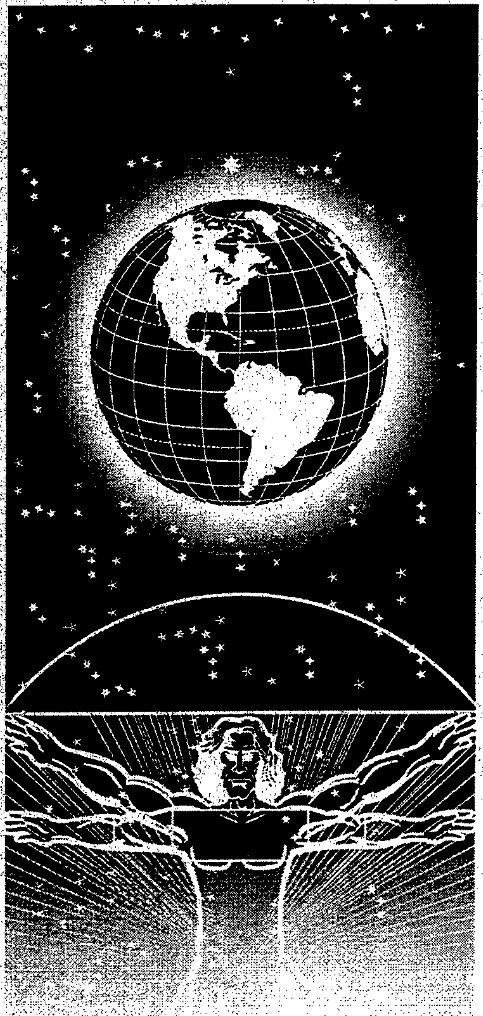

UNITED STATES AIR FORCE
ARMSTRONG LABORATORY

Desktop Corrosion Control Study for Howard Air Force Base, Panama

David M. Mihalick, Second Lieutenant, USAF, BSC

May 1997

Occupational and Environmental Health
Directorate
Bioenvironmental Engineering Division
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This report has been reviewed and is approved for publication.

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The Water Quality Branch of the Armstrong Laboratory, Occupational and Environmental Health Directorate, Bioenvironmental Engineering Division performed a Desktop Corrosion Control Study for Howard Air Force Base, Panama following Environmental Protection Agency (EPA) Guidance. A recent proposal suggested that the base should pursue the use of individual treatment units to reduce lead in first draw tap samples. Using the EPA seven step method for completing desktop evaluations, the recommended treatment option for Howard AFB is phosphate inhibitors.

Base personnel performed identification oriented sampling to isolate the source of lead in first draw samples. The sample results indicated that faucets contribute a majority of the lead to first draw samples. Consequently, any individual treatment unit that addresses the water prior to the tap would not solve the problem. Filters placed at the tap would be expensive and would require extensive maintenance. Phosphate inhibitors offer a relatively inexpensive treatment alternative. One factor complicating the use of phosphate inhibitors is that the base does not operate its own water treatment plant. The base receives water from a plant run by the Panamanians. The base must coordinate the addition of any chemical with the plant operators.

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TABLE OF CONTENTS

APPENDICES:

TABLES

Table No.

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DESKTOP CORROSION CONTROL STUDY FOR HOWARD AIR FORCE BASE, PANAMA

INTRODUCTION

Howard Air Force Base (AFB) is located in the Central American country of Panama. The base is located adjacent to the Panama Canal on its western bank. Howard AFB supports the 24th Wing of the 12th Air Force. The base provides an air component to United States Southern Command (USSOUTHCOM). Aircraft operating from Howard AFB include the C-21, the C-27, and the CT-43.

The scope of this project was to complete a desktop corrosion control study for Howard Air Force Base to determine the most effective and economical treatment to combat high lead levels in first draw tap samples collected under the Lead and Copper Rule (LCR). The Environmental Protection Agency (EPA) recommends using a seven step approach for completing desktop evaluations. The seven steps to follow, as presented in the LCR Guidance Manual are listed below.

1. Define existing conditions
2. Monitor Lead and Copper at points of entry and determine source water treatment needs
3. Define constraints
4. Identify corrosion control priorities
5. Eliminate unsuitable approaches
6. Evaluate viable alternatives
7. Evaluate each alternative based on four selection criteria
    a. performance
    b. feasibility
    c. reliability
    d. cost

This consult letter was requested by Capt Martin Alexis, Bioenvironmental Engineer at Howard AFB. Capt Alexis tasked the Water Quality Branch of Armstrong Laboratory, Occupational and Environmental Health Directorate, Bioenvironmental Engineering Division (AL/OEBW) with investigating the optimal corrosion control program for Howard AFB.

Information used in completing this study was gathered by personnel at Howard AFB. Other information was taken from a report accomplished by Parsons Engineering Science, Inc. and Roy

F. Weston, Inc. during an Air Combat Command sponsored study of drinking water systems. Additional background information was obtained from the United States Environmental Protection Agency (EPA) and from the New England Water Works Association (NEWWA). Some information on corrosion inhibitors was obtained from various companies. The table below provides a list of contacts:

Table 1. List Of Contacts

NAME	ORGANIZATION	PHONE NUMBER
Capt Martin Alexis	BEE (Howard AFB)	DSN 313-284-4701
Mr. Patrick H. Gill	Calgon Corporation	(412) 494-8000
Mr. Jerry Grossblatt	AquaSmart	1-800-278-2762
Mr. Greg McGiffney	Beck-Deerborne	(805) 635-7146
Capt Franz Schmidt	Chief, AL/OEBW	DSN 240-3305
Lt David Mihalick	Consultant, AL/OEBW	DSN 240-4938

The remainder of this consultative letter steps through the EPA seven step approach for performing desktop corrosion control studies. The three corrosion control techniques generally considered during desktop evaluations are pH/alkalinity adjustment, calcium hardness adjustment, and introduction of corrosion inhibitors (phosphates or silicates). Other options for controlling lead and copper include individual treatment units (filters) and infrastructure repairs and/or replacements.

CORROSION CONTROL BACKGROUND

Adjusting the pH or Alkalinity of the water in the distribution system is known as a passivation mechanism. The goal of passivation is to form metal complexes at the pipe surface that are less soluble than complexes that would be formed otherwise. The complexes interact with the water at the pipe boundary and keep lead in the pipe. The intent of pH/alkalinity adjustment is "to induce the formation of less soluble compounds with the targeted pipe material" (LCR 1992). Introduction of corrosion inhibitors is another passivation technique, employing the same general principle as pH/alkalinity adjustment. Commonly used inhibitors are phosphates and silicates.

Calcium hardness adjustment is known as a precipitation mechanism because the intent is to precipitate calcium carbonate from the water in hopes of forming a protective layer on the pipes' interior surface. Ideally, the protective layer is thin and uniform so as not to restrict flow. Several indices exist which are intended to help predict the likelihood of precipitating calcium carbonate. The EPA recommends using the Calcium Carbonate Precipitation Potential (CCPP) in The Lead and Copper Rule Guidance Manual: Volume II. Another value commonly used in evaluating the corrosivity of water is the Langelier Index. It is very difficult to accurately predict the formation of a calcium carbonate layer throughout the distribution system. Calcium must be available at all points to ensure the entire system is covered. This is analogous to the need to maintain a chlorine residual throughout the distribution system. In order for disinfection to be effective, free chlorine must be present at all points in the system. Likewise, in order to precipitate an effective layer of calcium carbonate, calcium must be present throughout the distribution system. Finally, it is difficult to ensure that the layer formed is uniform. If the calcium carbonate begins to build up in spots, the flow will be restricted and pressure problems may result. The most appropriate corrosion control mechanism varies with water quality parameters and the distribution system characteristics. The EPA seven step approach guides a water system toward the optimal treatment technique.

EPA SEVEN STEP APPROACH FOR DESKTOP EVALUATIONS

Define Existing Conditions

Important water quality parameters to monitor in evaluating lead and copper corrosion problems include lead, copper, iron, manganese, magnesium, sodium, calcium, pH, alkalinity, temperature, conductivity, total dissolved solids, sulfates, chlorides, orthophosphate, and silicate. Phosphates and silicates need to be monitored if they are added to the water. The following table summarizes water quality information available for the preparation of this report. The values reported in Table 2 represent the most current information available.

Table 2. Water Quality Parameters [b]

Parameter	Units	Value
Lead	mg/L	[a]
Copper	mg/L	[a]
Iron	mg/L	<0.039
Manganese	mg/L	<0.0014
Magnesium	mg/L	5.0
Sodium	mg/L	9.17
Calcium	mg/L	17.9
pH	pH units	7.07
Alkalinity	mg/L	41.4
Temperature	degree C	28
Total Dissolved Solids	mg/L	121.33
Hardness	mg/L	38.60
Sulfates	mg/L	16
Chlorides	mg/L	unavailable
Orthophosphate	mg/L	n/a
Silica	mg/L	n/a

[a] Complete Lead and Copper Sampling Results were not provided in preparation of this report. Information was provided indicating that the base had exceeded lead action levels in Lead and Copper Rule sampling, but no specific sample results were provided.

[b] Values were taken from Table 1 in "Final Phase I Report For ACC Drinking Water Systems Compliance Evaluation and Requirements Identification at Howard AFB" by Parsons Engineering Science, Inc. and from conversations with Howard AFB personnel.

Source Water Treatment.

Howard AFB receives water from the Miraflores Water Treatment Plant. This plant provides water to all Department of Defense installations in the Panama Canal Zone, to the town of Vera Cruz, and to a significant area of Panama City. The plant has provided an uninterrupted supply of water for approximately 80 years. Water is drawn from the Panama Canal and from Gatun Lake. The water undergoes treatment at the plant and then is delivered to Howard AFB through a 16 inch lined cast iron pipe. The base has two 750,000 gallon storage tanks. The water at the plant is tested by both the Panama Canal Commission (PCC) and by Howard AFB personnel. There are no lead or copper problems reported with the source water.

Define Constraints

Realistic constraint definition is vital to a successful corrosion control program. A solution might appear effective when evaluated for its ability to eliminate lead and copper in first draw tap water; however, when evaluated considering its effect on other water quality goals, the distribution system, or wastewater considerations, the solution might prove ineffective. Tables 3-3a and 3-3b of the LCR Guidance Manual address possible constraints (Appendix A).

Table 3-3a indicates that pH adjustment before disinfection will reduce chlorine effectiveness. The minimum CT (concentration multiplied by contact time) value must be maintained after the pH is elevated. This may require increasing the free chlorine residual or the contact time. Otherwise, there is an increased potential for violation of the Coliform Rule with pH adjustment. If sodium based chemicals are used to alter pH/alkalinity, the effect on total sodium in the finished water should be considered. The EPA suggested maximum concentration for sodium is 20 mg/L (De Zuane, 1990). The optimal place for pH adjustment is somewhere after chlorination, as close to entry into the distribution system as conditions permit.

Additionally, if high levels of dissolved metals exist, raising the pH could cause the metals to precipitate. If the metals precipitate, the particulates can cause scaling of the plumbing, clogging of heat exchangers, or unacceptably high turbidity. This problem may affect users with specific water quality needs, such as health care facilities. If the water contains high levels of calcium or dissolved inorganic carbon (DIC), unintentional precipitation of calcium carbonate may result. DIC in excess of 15 mg/L can lead to an increase in lead and copper by forming soluble metal complexes (JNEWWA 1995). Some metals concentrations are reported in Table 2 above. Iron should not exceed 0.30 mg/L in finished water (JNEWWA 1995). High levels of iron can cause red water problems or laundry stains (De Zuane, 1990). Additionally, some filamentous organisms reside on iron and can cause taste and odor problems.

Table 3-3b indicates that phosphate based inhibitors can have detrimental effects on the water system. First, phosphate based inhibitors tend to deplete chlorine residuals throughout the distribution system. This affects the disinfection capacity. If this is a problem, additional chlorine can be added to satisfy the increased chlorine demand created by introduction of the phosphates. Second, some systems have experienced an increase in microbial growth after introduction of phosphate based inhibitors, resulting in unwanted biofilms. However, the EPA also reports in the LCR Guidance Manual that there is no direct evidence "available indicating that the introduction of phosphate based corrosion inhibitors would foster or encourage the growth of bacteria in the distribution system" (1992). This statement and Table 3-3b, which both come form the same document, are contradictory. Most sources indicate no direct link between the addition of phosphate inhibitors and microbial growth in the distribution system. Medlar and Kim state that "small systems should not rule out phosphate inhibitors unless biological regrowth has been a serious problem" (1994). If corrosion byproducts are released after the inhibitors are introduced, coliforms may be detected with greater frequency. It appears that corrosion byproducts, and not the inhibitor, may lead to increased microbial growth.

Finally, some inhibitors, like zinc orthophosphate, must be carefully considered because of the contaminants they can add to the wastewater. Use of zinc orthophosphate can increase zinc concentrations in wastewater treatment plant (WWTP) effluent or in processed sludge. Any final decisions must consider limitations in the WWTP discharge permit or other applicable regulations.

In addition to the above process constraints, a myriad of functional constraints exist. Addition of any chemicals to the system must be carefully controlled. If the chemical additions are manual, the operators will need proper training. If the chemicals are added mechanically, equipment must be purchased and monitored. Also, users with specific water needs, such as health care facilities or heating plants, must be notified of any changes in the treatment process. Finally, inhibitors may cause physical water quality problems. The result can be red water, dirty water, color, and sediment complaints because of the action of the inhibitor on existing corrosion byproducts. Although each corrosion control technique has certain drawbacks and limitations, they each offer benefits depending on the specific water quality.

Identify Corrosion Control Priorities.

There are no reported problems with lead or copper levels in water from the Miraflores Water Treatment Plant, therefore, source water treatment is not a priority. Additionally, there are no problems reported with copper at Howard AFB. Consequently, the priority at Howard is reduction of lead concentrations in first draw tap samples.

Eliminate Unsuitable Approaches

The *RTW Model for Corrosion Control and Process Chemistry* calculates the Calcium Carbonate Precipitation Potential of the water entering the distribution system at Howard as -16.91 (RTW, 1996). In order to bring the CCPP into the 4-10 mg/L range recommended by the EPA for precipitation of calcium carbonate, 21 mg/L of calcium carbonate would have to be added (RTW, 1996). This addition will increase the hardness of the water and may cause scaling problems. The Langelier Index calculated by the RTW model is -1.81 (See Appendix B for complete model results). The Langelier Index should be greater than zero for calcium carbonate precipitation to occur. Because the Howard water is undersaturated with calcium carbonate, precipitation will not occur unless the water quality is altered. Bringing the Howard water into the desired ranges for precipitation of calcium carbonate will require extensive operator control. For these reasons, calcium carbonate precipitation is not a viable option at Howard.

The second impractical alternative at Howard is individual treatment units. Howard AFB conducted sampling to determine specific sources of lead in drinking water. The idea behind identification oriented sampling is to collect pieces of water in the system for analysis (see Appendix C). The water in question must remain stagnant for at least eight hours. Samples must be collected in glass containers. The first 250 mL of sample approximately represents water standing in the faucet. The next 750 mL of sample represents the water standing in the pipes closest to the faucet, where there are usually lead soldered joints. The water is then run until it turns cold and a third sample is collected. This sample represents water from the service line. Finally, the tap is run for three minutes or more and a sample is collected to represent water in the main supply line. Often times, a large percentage of lead in first draw samples can be attributed to faucets and/or household fixtures. Brass faucets are known to contribute a significant portion of lead to first draw tap samples. Gardels and Sorg estimate that 60% to 75% of the lead leached from a common kitchen faucet is in the first 125 mL of the sample (1989). They further conclude that up to 95% of lead from a faucet is flushed out during the first 200-250 mL. Lee, et al., conclude that brass faucets contribute an average of one third of the lead in a 1 liter first draw sample (1989). Individual treatment units (i.e. under the house or under the sink filters) located prior to the source of lead would do nothing to solve the problem at Howard.

The results of the identification oriented sampling at Howard conclusively demonstrate that the majority of lead in first draw samples at Howard is from water standing in the faucet. The results are summarized below in Table 3. It is apparent that the majority of lead in these samples is contained in the first 250 mL. The three subsequent samples contain decreasing amounts of lead. At only 2 locations does any of the subsequent samples exceed the action level and in both cases the lead level drops sharply in the third sample. The implication is that the only type of individual treatment unit that would be effective at Howard is a filter placed on each tap. The cost for installation and maintenance of filters at every tap is impractical.

Table 3. Identification Oriented Sampling Results

Sample #	Qtrs 17	Qtrs 42	Qtrs 570	Qtrs 29	Qtrs 91	Qtrs 071	Qtrs 181
1	.019	.022	.071	.047	.005	.023	.02
2	.006	.003	.048	.025	.002	.005	.004
3	.003	.002	.003	.005	.002	.003	.005
4	.002	.004	.001	.002	.002	.002	.002

Evaluate Viable Approaches

Phosphate inhibitors, silicate inhibitors, and pH/alkalinity adjustment are three viable corrosion control strategies for Howard. Each of these approaches has advantages and disadvantages given the water quality characteristics and distribution system materials at Howard.

Phosphate Inhibitors

The American Water Works Association Research Foundation (AWWARF) states that "polyphosphates are most effective in water of lower mineral content with a pH range of 6.5 to 7.5" (Lead Control Strategies, 1990). The AWWA goes on to state that the available information on polyphosphates indicates that they are ineffective in reducing lead levels, and could actually increase lead by complexation and solubilization of potentially protective films on pipes (Lead Control Strategies, 1990). The EPA states that "polyphosphates have demonstrated limited direct success toward lead and copper corrosion control" (LCR Guidance Manual, 1992). Holm and Schock corroborate the EPA conclusions regarding the link between polyphosphates and increased lead levels (1991). The main application of polyphosphates is the sequestration of dissolved metals, such as iron and manganese. Polyphosphates have been shown to sequester dissolved iron and manganese, eliminating colored water complaints. There are no problems reported with colored water at Howard. The reported values of iron and manganese are both low (see Table 2 above). Additionally, polyphosphates are commonly used to sequester calcium to reduce its ability to precipitate in the distribution system or in the water treatment plant. Calcium in softening plants is a problem because it can encrust filter media (LCR Guidance Manual, 1992).

Unlike polyphosphates, there are many examples of systems that have used orthophosphates to effectively control lead and copper. There are some specific water quality characteristics necessary for successful application of orthophosphates. The first important consideration when considering orthophosphates is pH. In order for orthophosphates to be effective the system should have a stable pH between 7.4 and 7.8 (LCR Guidance Manual, 1992). The NEWWA states that a pH of between 7 and 8 will allow for lead reduction using orthophosphate inhibitors. "The higher end of the 7 to 8 pH range is best for low DIC waters, and a slightly lower pH is optimal for high DIC water" (NEWWA, 1995). Howard AFB has a low to moderate level of DIC (5.9 mg C/L) and an average pH of 7.07.

The most appropriate solution for Howard AFB might be the introduction of a blended phosphate inhibitor. Blended phosphates are intended to provide the benefits of both orthophosphates and polyphosphates. There are many blended phosphates commercially available. Contacts for three companies that manufacture blended phosphates are provided in Table 1 above.

pH/alkalinity Adjustment

According to the LCR Guidance Manual the minimum solubility for both lead and copper occur at a pH over 9 and an alkalinity of 30-50 mg/L as $CaCO_3$. DIC can be estimated from pH and alkalinity. Using Table A-2 in Appendix A of the LCR Guidance Manual, the DIC of the Howard water is 49.3 mg/L as $CaCO_3$, or 5.9 mg C/L.

The AWWA Research Foundation reports that the minimum concentration of DIC necessary to provide sufficient buffering capacity is 2 mg C/L (Lead Control Strategies, 1990). According to this estimate, Howard AFB water has sufficient buffering capacity. Using the decision tree provided as Figure 6.9 in *Lead Control Strategies*, one arrives at either pH adjustment or phosphate inhibitors as the desired corrosion control mechanism at Howard (see Appendix D). While this decision tree only provides approximate guidance, it does appear that both of these methods would be effective techniques for reducing lead levels in first draw tap samples.

Small water systems with low (3-6 mg C/L) but sufficient (> 2 mg C/L) DIC, often use pH adjustment as a corrosion control strategy. There are some important constraints to keep in mind when considering raising the pH to such a high level. Many of these constraints are detailed above in step three of the EPA seven step approach. Dissolved metals, if present in sufficient quantities, can precipitate when the pH is raised. Information on the level of metals should be analyzed carefully before this option is considered. If pH is raised above 9, metals are likely to precipitate and cause problems with water color. Another disadvantage of raising pH is that disinfection capacity is reduced at an elevated pH. Either the concentration of chlorine used or the allowed contact time would have to be increased to allow for adequate disinfection when pH is increased. Further, trihalomethanes, a suspected carcinogenic disinfection byproduct, can increase when pH is high. A final disadvantage of raising the pH to above 9 is that people are likely to reject the taste of an extremely basic water. This is an important disadvantage at Howard because water passes through the base to Panamanian users.

Although there are many disadvantages associated with raising the pH, it should be noted that many small systems have experienced corrosion control success by elevating pH to something less than 9. For example, lead solubility in a water at pH 7 is ten times higher than in a water at pH 8 (Basic Chemistry & Corrosion Control Treatment, 1995). Therefore, the system might solve its problems by raising pH from 7 at the source to somewhere around 8 in the distribution system. Medlar and Kim suggest pH of 8.0-8.5 as a rule of thumb for pH adjustment based on the experiences of large systems (1994). Finally, one possible treatment strategy is the combination of pH adjustment and phosphate inhibitors. The base could try raising the pH to the range of 7.8. Then the base could perform a round of lead and copper sampling. If the pH adjustment solves the problem, then the base should maintain the pH at the elevated level. If lead problems persist, then the base can maintain the pH at the elevated level and add orthophosphate to inhibit lead corrosion.

Silicate Inhibitors

The final viable corrosion control alternative to consider is addition of silicate inhibitors. Although the method by which silicate inhibitors control corrosion is not very well understood, some systems have experienced success using them. The main advantage reported for silicate inhibitors over phosphate inhibitors is that they are effective over a much broader pH range. Some researchers believe that the only advantage gained by adding silicate inhibitors, in regards to corrosion control, is the increase in pH (Basic Chemistry & Corrosion Control Treatment, 1995). Sodium silicate is cited by the EPA in *Control of Lead and Copper in Drinking Water* for its ability to raise pH (1993). Sodium silicates are very safe for operators to handle and require relatively simple pumps for feeding. Another advantage of silicates is that they can enhance the rate of iron and manganese oxidation and complex the oxidized metals to prevent development of red or black water (Basic Chemistry & Corrosion Control Treatment, 1995). In order for silicate to sequester soluble metals, it must be added simultaneously with chlorine (Robinson, et al., 1992).

All sources indicate that passivation with silicate inhibitors is a slow process. Silicates must be added for two or three years before effectiveness should be judged. This is an important consideration at Howard AFB because of the uncertainty over the future of the base. Some final notes on the use of silicate inhibitors are provided by the AWWA Research foundation. "Sodium silicates are poorly soluble in cold waters but are effective for inhibiting corrosion of galvanized steel and copper based metals in hot water systems. Too low a silicate dosage may intensify corrosion rates in some waters. Frequently, higher silicate dosages are required for lower pH conditions. Increasing the pH to between 7.5 and 8 with soda ash or caustic will lower the silicate requirement and the overall cost of inhibitor treatment" (Lead Control Strategies, 1990). All inhibitors can combine with other water components and must be applied in sufficient doses to satisfy any background demand.

Recommend Optimal Treatment

Blended phosphate corrosion inhibitors should provide the most effective and simple corrosion control treatment for Howard AFB. Phosphate inhibitors are relatively inexpensive. Feed equipment will cost approximately $1,500. Annual cost for the chemicals will be approximately $5,000 (more or less depending on the type of chemical chosen). Additional expenses (as required) will include safety equipment, installation and piping changes, engineering, and construction. If new facilities are required to house the equipment, they will add significant expense.

CONCLUSIONS

This report provides an evaluation of the lead problems at Howard Air Force Base, Panama. The report provides detail on why certain corrosion control techniques are not appropriate at Howard. The recommended treatment strategy for Howard AFB, based on available data, is blended phosphate corrosion inhibitors. Following are action items for Howard AFB based on current data:

1. Immediate: The base should implement a tap flushing program in the short term. Since the majority of lead is contained in the first 250 mL, residents should be advised to flush this portion of water each time the water is turned on. The water should be run for a designated period of time (30 seconds perhaps) at a high velocity. This is a simple short term solution to the problem.

2. Short term: The base should begin to gather information from companies that manufacture and distribute phosphate inhibitors. These companies can use Howard AFB water quality information and designate specific chemicals and chemical doses to control

the level of lead in first draw tap samples. AL/OEBW can help base personnel in contacting different companies.

3. Short term: The base should approach officials at the Miraflores treatment plant regarding the feasibility of installing an inhibitor feed system at the plant.

4. Short term: For taps that have known lead problems, faucets should be replaced as funding permits if corrosion control is not feasible in the near future. Any faucets that have lead problems and supply water to children should be given the highest priority for replacement.

Before any significant action is taken, every effort should be made to determine the future of the base. If the base is going to be turned over to the Panamanians, then investing large amounts of money in replacing infrastructure does not seem appropriate. The most effective treatment strategy at Howard might be to raise the pH in the range of 7.8-8.0. If this does not solve the problem, then the base could maintain the elevated pH and add a phosphate inhibitor. The reason this strategy is not recommended as the optimal corrosion control strategy is because the base does not control the source water. This option would require extensive operator interaction, which is impossible when the source water is controlled by a foreign country. Household treatment units, that treat the water as it enters the home and not at the tap, are not an option because most of the lead is coming from the faucets and these units would not reduce lead concentrations. Using a blended phosphate is a simple alternative with a high probability of success.

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APPENDIX A

Table 3-3a. Constraints Worksheet for pH/Alkalinity or Calcium Adjustment Treatment Alternatives

Adjusting pH/Alkalinity and/or calcium for corrosion control typically consists of increasing their levels to generate favorable conditions for lead and copper passivation or calcium carbonate precipitation.

A. National Primary Drinking Water Regulations Constraints

Rule	Constraint
Surface Water Treatment Rule	Reduces inactivation effectiveness of free chlorine if pH adjusted before disinfection.* Potential for interference with dissolved ozone measurements. May increase turbidity from post-filtration precipitation of lime, aluminum, iron, or manganese.
Groundwater Disinfection	Reduces inactivation effectiveness of free chlorine if pH adjusted before disinfection.* Potential for interference with dissolved ozone measurements.
Disinfection Byproducts	Higher THM concentrations from chlorination if pH adjusted before disinfection.* Reduced effectiveness of some coagulants for precursor removal if pH adjusted before coagulation.*
Coliform Rule	Potential for higher total plate counts, confluent growth, or presence of total coliforms when chlorination is practiced.
Radionuclides	In-plant adjustments may affect removal of radioactive particles if precipitation techniques are used for coagulation or softening. Removal of radionuclides during softening may be linked to the degree of softening. Modifying softening practices to achieve corrosion control could interfere with removals.

Table 3-3a. Constraints Worksheet for pH/Alkalinity or Calcium Adjustment Treatment Alternatives (continued)

B. Functional Constraints

Increased potential for post-filter precipitation may give undesirable levels of aluminum, iron, or manganese.

Process optimization is essential. Additional controls, chemical feed equipment, and operator attention may be required.

Multiple entry points will require pH/Alkalinity adjustment at each entry location. Differing water qualities from multiple sources will require adjusting chemical doses to match the source.

The use of sodium-based chemicals for alkalinity or pH adjustments should be evaluated with regard to the total sodium levels acceptable in the finished water.

Users with specific water quality needs, such as health care facilities, should be advised of any changes in treatment.

Excessive calcium carbonate precipitation may produce "white water" problems in portions of the distribution system.

It may be difficult to produce an acceptable coating of calcium carbonate on interior piping for large distribution systems. High CCPP levels may eventually lead to reduced hydraulic capacities in transmission lines near the treatment facility while low CCPP values may not provide adequate corrosion protection in the extremities of the distribution system.

* Unless operating restraints dictate otherwise, the optimum location for pH adjustment is after disinfection and near the entrance to the distribution system. If quicklime is used to adjust pH, for example, it needs to be added prior to filtration so inert material does not accumulate in the clearwell or enter the distribution system.

Table 3-3b. Constraints Worksheet for Inhibitor Treatment Alternatives

Corrosion inhibitors can cause passivation of lead and copper by the interaction of the inhibitor and metal components of the piping system.

A. National Primary Drinking Water Regulations Constraints

Rule	Constraint
Surface Water Treatment Rule	The application of phosphate-based inhibitors to systems with existing corrosion byproducts can result in the depletion of disinfectant residuals within the distribution system. Additionally, under certain conditions phosphate-based inhibitors may stimulate biofilms in the distribution system.
Groundwater Disinfection	Same as above.
Disinfection Byproducts	No apparent effects.
Coliform Rule	If corrosion byproducts are released after the application of inhibitors, coliforms may be detected more frequently and confluent growth is more likely.
Radionuclides	No apparent effects.

B. Functional Constraints

Potential post-filtration precipitation of aluminum.

Consumer complaints regarding red water, dirty water, color, and sediment may result from the action of the inhibitor on existing corrosion byproducts within the distribution system.

Multiple entry points will require multiple chemical feed systems.

The use of sodium-based inhibitors should be evaluated with regard to the total sodium levels acceptable in the finished water.

The use of zinc orthophosphate may present problems for wastewater facilities with zinc or phosphorus limits in their NPDES permits.

Users with specific water quality needs, such as health care facilities, should be advised of any treatment changes.

NOTE: If pH adjustment is necessary to produce an effective pH range for the inhibitor, then the constraints in Table 3-3a would also need to be evaluated.

APPENDIX B

The RTW Model Ver. 3.0 ID: **Howard AFB, Panama**

STEP 1: Enter initial water characteristics.

Measured TDS	**121.33**	mg/L
Measured temperature	**20**	deg C
Measured pH	**7.07**	
Measured alk, as CaCO3	**41.4**	mg/L
Measured Ca, as CaCO3	**17.9**	mg/L
Measured Cl	**0**	mg/L
Measured SO4	**16**	mg/L

For CT and TTHM functions enter current:

Treated water pH		
Chlorine residual		mg/L
Chlorine or hypochlorite dose as chlorine equivalent		mg/L

STEP 2: Enter amount of each chemical to be added (expressed as 100% chemical). Press Alt+C to select chemicals for this list.

Alum 50% solution	**0**	mg/L
Carbon dioxide	**0**	mg/L
Caustic soda	**0**	mg/L
Chlorine gas	**0**	mg/L
Hydrochloric acid	**0**	mg/L
Hydrofluosilicic acid	**0**	mg/L
Lime (slaked)	**0**	mg/L
Soda ash	**0**	mg/L
Sodium bicarbonate	**0**	mg/L
Ctrl+C to add to list	**0**	mg/L

STEP 3: Adjust at Step 2 until interim water characteristics meet your criteria.

Theoretical interim water characteristics			Desired	Theoretical interim water characteristics			Desired
Interim alkalinity	41	mg/L	> 40 mg/L	Interim pH	7.07		6.8-9.3
Interim Ca, as CaCO3	18	mg/L	> 40 mg/L	Precipitation potential	-16.91	mg/L	4-10 mg/L
Alk/(Cl+SO4)	2.6		> 5.0	Langelier index	-1.81		>0

Press PAGE DOWN for additional initial, interim and final water characteristics if desired.

Calculated initial water characteristics

Initial acidity	57	mg/L
Initial Ca sat, as CaCO3	1160	mg/L
Initial DIC, as CaCO3	99	mg/L

Theoretical interim water characteristics

Interim acidity	57	mg/L
Interim Ca sat, as CaCO3	1160	mg/L
Ryznar index	10.69	
Interim DIC, as CaCO3	99	mg/L
Aggressiveness Index	9.94	

Theoretical final water characteristics after CaCO3 precipitation

Final alkalinity	N/A	mg/L
Final Ca	N/A	mg/L
Final acidity	N/A	mg/L
Final pH	N/A	
Final DIC, as CaCO3	N/A	mg/L

Press PAGE UP to review measured initial water characteristics, chemical addition quantities and additional interim water characteristics.

CT and TTHM Results

Required chlorine residual to maintain current level of giardia inactivation	N/A	mg/L
Estimated maximum total trihalomethane concentration change from current level	N/A	%

The RTW Model Ver. 3.0 ID: **Howard AFB, Panama**

STEP 1: Enter initial water characteristics.

Measured TDS	**121.33**	mg/L
Measured temperature	**20**	deg C
Measured pH	**7.07**	
Measured alk, as CaCO3	**41.4**	mg/L
Measured Ca, as CaCO3	**17.9**	mg/L
Measured Cl	**0**	mg/L
Measured SO4	**16**	mg/L

For CT and TTHM functions enter current:

Treated water pH		
Chlorine residual		mg/L
Chlorine or hypochlorite dose as chlorine equivalent		mg/L

STEP 2: Enter amount of each chemical to be added (expressed as 100% chemical). Press Alt+C to select chemicals for this list.

Alum 50% solution	**0**	mg/L
Calcium carbonate	**21**	mg/L
Carbon dioxide	**0**	mg/L
Caustic soda	**0**	mg/L
Chlorine gas	**0**	mg/L
Hydrochloric acid	**0**	mg/L
Hydrofluosilicic acid	**0**	mg/L
Lime (slaked)	**0**	mg/L
Soda ash	**0**	mg/L
Sodium bicarbonate	**0**	mg/L

STEP 3: Adjust at Step 2 until interim water characteristics meet your criteria.

Theoretical interim water characteristics			Desired	Theoretical interim water characteristics			Desired
Interim alkalinity	62	mg/L	> 40 mg/L	Interim pH	8.92		6.8-9.3
Interim Ca, as CaCO3	39	mg/L	> 40 mg/L	Precipitation potential	4.09	mg/L	4-10 mg/L
Alk/(Cl+SO4)	3.9		> 5.0	Langelier index	0.55		>0

Press PAGE DOWN for additional initial, interim and final water characteristics if desired.

Calculated initial water characteristics

Initial acidity	57	mg/L
Initial Ca sat, as CaCO3	1160	mg/L
Initial DIC, as CaCO3	99	mg/L

Theoretical interim water characteristics

Interim acidity	57	mg/L
Interim Ca sat, as CaCO3	12	mg/L
Ryznar index	7.81	
Interim DIC, as CaCO3	120	mg/L
Aggressiveness Index	12.31	

Theoretical final water characteristics after CaCO3 precipitation

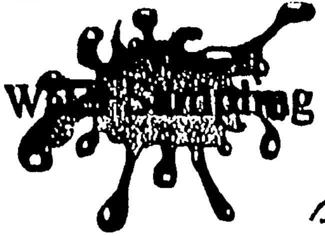
Final alkalinity	58	mg/L
Final Ca	35	mg/L
Final acidity	57	mg/L
Final pH	8.46	
Final DIC, as CaCO3	116	mg/L

Press PAGE UP to review measured initial water characteristics, chemical addition quantities and additional interim water characteristics.

CT and TTHM Results

Required chlorine residual to maintain current level of giardia inactivation	N/A	mg/L
Estimated maximum total trihalomethane concentration change from current level	N/A	%

APPENDIX C



Because no Mineral Deposits have formed inside pipe.

Objective

To Conduct and Evaluate Testing of Drinking Water

Sources of Lead in Drinking Water

- Cu Plumbing and Pb/Sn Solder (esp. in homes less than five years old)
- Pb Service Lines or Interior Pb Plumbing (typically in older homes)
- Pb as a Contaminant in the Water Supply Itself (rare, occurs only in about 1% of water supply systems)

Sampling Strategy

To Differentiate Between Various Possible Sources of Lead in the Water, Take FOUR Samples of the Water, as Follows.....

SAMPLES

1 • *FIRST* Sample "morning first draw" – 250 cc From Cold Water Kitchen Tap AFTER at Least 8 Hours of No Water Usage

2 • *SECOND* Sample – 750 cc IMMEDIATELY After First Sample Same Tap

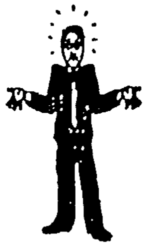
3 • *THIRD* Sample – 250 cc After Water Turns Cold or Otherwise Represents Water in the Service Line

4 • *FOURTH* Sample – 250 cc After Water has Run About 3 Additional Minutes After Third Sample or Otherwise Represents Water in the Main Supply System

What Next ?

- Send Samples to Your Lab for Analysis of Lead Content
- Results Should be Reported in Units of Parts Lead Per Billion Parts Water (ppb)

Make Sure Report is in these Units



Lead Ban - Enforced Use of Lead-Free (0.2%) Pipe, Solder, and Flux in Plumbing

LCCA - I'd Water Coolers that are not Lead Free, Bans Sale

Interpretation of Results

Note: AL = 15 ppb

#1 > AL, #2 > AL but #3 << AL	Lead is Coming From Internal Plumbing (i.e. Pipes or Connections); Water Probably Acidic Also
#3 > AL	Lead is Coming From Service Line
#4 > AL	Problem is Due to the Water Supply Itself

If only #1 > AL, Probably Coming From Fixture

Possible Solutions

Internal Plumbing	Let Water Run Before Using for About 30 Sec. After Periods of Inactivity; Always Use Water From Cold Tap (Warm Water is Corrosive); Never Make Baby Formula With Water From "Morning First Draw"
Service Line	Contact Water Company About Replacement of Service Line; Use Bottled Water for Drinking and Cooking
Water Supply	Contact Water Company

Regulations That Govern the Amount of Lead in Drinking Water

No HUD Mandate

- The Lead Ban
- The Lead Contamination Control Act
- The Lead and Copper Rule

L&C Rule - Conduct Tap Monitoring

Mandates Treatment of H_2O

- Corr. Ctl (pH)
- Source Treatment (Filtration)
- Education
- Svc Line Replacement

The Lead Ban

(1986)

- Safe Drinking Water Act Amendments
- Prohibits Use of Pipe, Solder, or Flux in Public Water Systems That is Not "Lead-Free"
- Requires State Enforcement of Prohibition and Special Public Notice Requirements for Lead
- Define "Lead-Free" Materials *
- Designates Lead Solder as Hazardous (if > 0.2%)
- Requires Warning Labels on Lead Solder

* Lead Free Means Solder That Contain No More Than 0.2% Pb and Pipes and Fittings Contain No More Than 8.0% Pb

The Lead Contamination Control Act

(1988)

- Requires the Identification of Water Coolers That are Not Lead Free
- Mandates the Repair or Removal of Water Coolers with Lead-Lined Tanks
- Bans the Manufacture and Sale of Water Coolers That are Not Lead Free
- Mandates the Identification and Resolution of Lead Problems in Drinking Water in Schools
- Authorizes Additional Funds for Lead Screening Programs for Children

The Lead and Copper Rule

(1992)

- Mandates Treatment When Pb and/or Cu in Drinking Water Exceed Certain Levels
- Supply Water Should Be Lead Free (non-enforceable)
- Conduct Tap Monitoring of Homes With High Risk of Pb/Cu Contamination
- Requires Treatment of Water (if more than 10% of tap monitoring results exceed AL)
  - ✓ Corrosion Control Treatment
  - ✓ Source Water Treatment
  - ✓ Public Education
  - ✓ Service Line Replacement

APPENDIX D

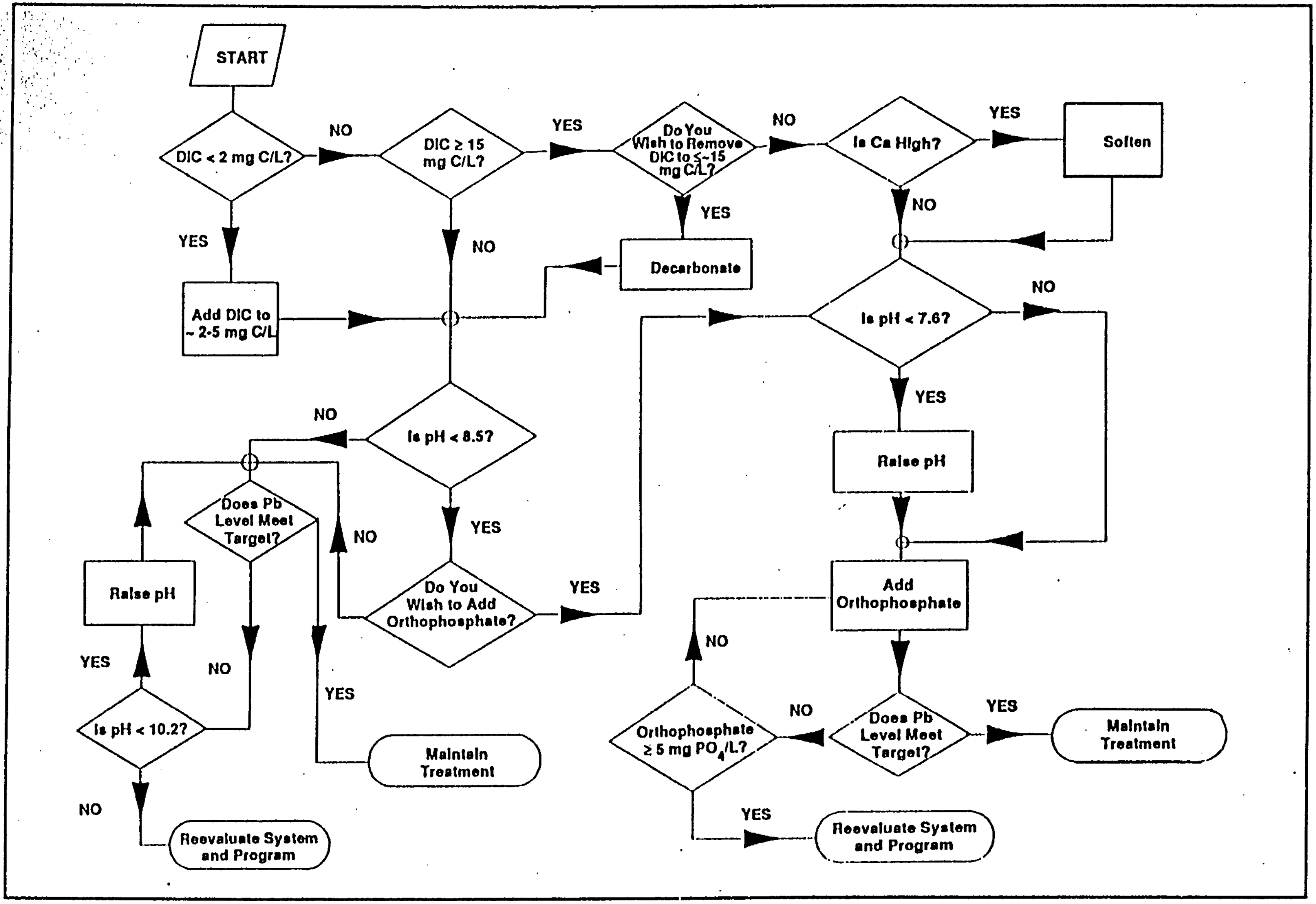


Figure 6.9 Approximate decision tree for the selection of treatment options among pH, DIC, and orthophosphate dosage