CHAPTER THREE
DECISION APPROACH FOR CHLORAMINE CONVERSION

INTRODUCTION

Final disinfection with chloramines should be an integral part of the design, operation and maintenance of the water treatment facility as well as the distribution system and not simply an add on to the treatment plant. This is perhaps the most significant issue that has come to light since EPA's original Trihalomethane Rule became effective, causing numerous utilities to add ammonia to form chloramines. Thus, to support a more integrated, comprehensive approach in selecting a final disinfectant, the following steps have been developed:

- Review the Existing Situation and Identify Major Issues
- Establish System Goals and Specific Objectives
- Develop Alternative Approaches – Optimizing Source, Treatment and Distribution System Facilities and/or Optimizing the Final Disinfection Strategy
- Screen Alternatives and Decide Which Alternatives to Focus On
- Refine and Confirm Specific Final Disinfection Objectives
- Establish Evaluation Criteria
- Gather Additional Technical Information and Evaluate Stakeholders' Preferences
- Apply Evaluation Criteria and Rate and Rank Strategies
- Decide Whether or Not to Implement Chloramination
- Develop Implementation Plan

Details on each step are provided in the sections below. A flow chart has also been prepared to guide utilities through this step-wise approach to decision-making (Figure 3.1). An interactive version of the flow chart accompanies this text in CD format.

STEP 1 - REVIEW THE EXISTING SITUATION AND IDENTIFY MAJOR ISSUES

In this Step, the utility identifies that it has a problem or some need that it wants to address. Typically the need will fall into one of three categories: 1) Regulatory or Health; 2) Customer Concerns related to Health or Aesthetic Issues; and 3) Cost or Economics. Regulatory issues may be drinking water-related such as coliform occurrence, disinfection by-products, or they may be related to safety of the public or utility staff (i.e. transport of gaseous chlorine to booster disinfection sites within populated areas). Customer concerns may relate to taste or odor of the water that may be caused in part or wholly by the disinfection process. Costs or economics may be related to facility operation and maintenance that the utility is attempting to control. In this step, the utility would need to relate the issue of concern either directly or indirectly to the final disinfection process, i.e. the residual that is carried into and throughout the distribution system. If the issue is not at all related to the final disinfection process, then there does not appear to be a reason to continue with evaluation of the chloramination process.

STEP 2 - ESTABLISH SYSTEM GOALS AND SPECIFIC OBJECTIVES

In this step, the utility should establish goal(s) and, if possible, specific objectives that it desires to meet. For example, the goal might be to provide a high quality water that consistently meets the Stage II of the D/DBP rule for Trihalomethanes (THMs) and Haloacetic Acids (HAA_5). The specific objectives at the compliance sampling points might be to provide water that contains less than 40 µg/L of THMs and less than 30 µg/L of HAA_5. These levels are lower than the MCLs in the regulations. Likewise, the goal may be related to maintaining a disinfectant residual, or reducing HPC bacteria to a specified level at some given percentage of the sampling sites. Another goal might be to consistently provide an aesthetically pleasing water to the customers, and the objective might be to provide water that has a Flavor Rating Assessment (FRA) of 3 or less, which corresponds to a consumer response such as "I am sure that I could accept this water as my everyday drinking water." It may not be possible to establish specific objectives at this point in the study process but it would be advantageous to be as specific as reasonable recognizing that specific objectives may be further developed and refined as the study progresses. The main benefit of Step 2 is that it causes the utility and study team to begin to set some criteria against which future evaluations can be measured.

STEP 3 - DEVELOP ALTERNATIVE APPROACHES – OPTIMIZING SOURCE, TREATMENT AND DISTRIBUTION SYSTEM FACILITIES AND/OR OPTIMIZING THE FINAL DISINFECTION STRATEGY

The purpose of this step is to ensure that the utility has considered all options to address the issues of concern. This should be done in earnest because the switch to chloramines is a significant decision that has many implications for both the treatment process and the distribution system, and the utility should assure itself that a switch is both necessary and in the best interest of the utility and the consumer. Further, if the utility does decide that use of chloramines is the correct approach, then these early efforts are not wasted because they will provide the basis for the Implementation Plan (Step 10).

Chloramines should not be viewed as an inexpensive method to get around providing proper and adequate pretreatment of the water, or to address inadequate operation or maintenance of the distribution system; rather, chloramines should be considered in conjunction with other treatment or distribution system improvements. Chloramines will be widely used to help utilities meet Stage II of the D/DBP Rule. Concurrently, treatment modifications should be considered to better prepare the water for final disinfection by applying processes that will produce a water that is biologically and chemically stable. This will give either free chlorine or chloramines a better chance for success as the final disinfectant. The alternatives to be evaluated should include but not be limited to evaluating different sources of supply, and applying advanced treatments to produce a higher quality, more stable water such as enhanced coagulation, carbon filtration, membranes and other processes to remove organic precursor constituents that may be causing formation of DBPs or degradation of chlorine residuals. Wilczak et. al, 2003 lists many factors that influence chloramines demand and decay, including natural organic matter, turbidity, ferrous materials, auto decomposition, plus others. In the distribution system, the utility should consider both operational approaches such as managing water age, and maintenance activities such as flushing. If the condition of the distribution system is a contributing factor (i.e. the presence of unlined cast iron piping), then measures might include cleaning, relining, or replacing the problem piping.

In the Project's Utility Survey, respondents were asked to identify and rate the perceived and observed benefits for choosing chloramines (Figure 3.2). In order of importance, the primary benefits were:

- The ability to meet future and current DBP regulations,
- Utilization of a more persistent (stable) disinfectant, and
- Reduction in taste, odors and customer complaints.

Additional benefits of chloramination identified by the survey participants included: (1) a reliable method to comply with the Total Coliform Rule; (2) the presence of bromide ion in the source water which may create brominated DBPs if free chlorine was used, and (3) the practicality and easiness of conversion.

Responses received regarding drawbacks to chloramination that were a concern during the decision making process are presented in Figure 3.3. Responses considered were from those utilities that were treating water and had converted to chloramines after 1980 (36 responses). The major and primary concerns in order of importance were:

- Discharge of chloraminated water to the environment,
- Potential nitrification,
- Impact on sensitive users (dialysis patients, fish hobbyists, specific industries),
- Public acceptance,
- Need for operational changes (e.g. flushing, additional monitoring), and
- Disinfection efficacy.

Additional drawbacks of chloramination identified by the respondents prior to the conversion were: a lack of manganese oxidation (compared with free chlorine); a lack of information about the effect of chloramines on red water and copper corrosion; storage and handling of another chemical (ammonia); difficulty of boosting chloramine residual at remote sites (chemical safety concerns associated with ammonia feed); requirements for additional analyses such as chloramine speciation (mono-, di- and tri-chloramines); higher lime dose required to maintain the higher target pH in the distribution system; potential formation of chloramine by-products such as NDMA in some waters; lack of information about disinfection efficacy of organic chloramines; effect of chloramines on hot water systems such as pools and spas; concern about disinfection of *Legionella* by chloramines; agreement of all stakeholders (state/provincial regulators, officers of health departments, retailers, etc.); potential increase in main flushing leading to an increase in water demand; and unfamiliarity with chloramines and the chloramination process.

The point here is to be global in the evaluation process before deciding up front that the solution is chloramines without a thorough look at other mitigation measures. The level of detail and effort that this step entails will be site specific and may include paper studies, laboratory investigations (such as bench scale testing discussed in Appendix D), pilot studies, and/or field demonstrations. Project utility survey findings show that many utilities used pilot-scale and bench-scale studies to predict DBP levels following conversion to chloramines. These studies were considered beneficial in making the decision to convert to chloramines. Almost 50% of those surveyed found that hiring a consulting company was beneficial in helping to design and conduct DBP formation studies.

This step concludes with identification of several alternative approaches to meeting the Step 2 goals and objectives.

STEP 4 – SCREEN ALTERNATIVES AND DECIDE WHICH ALTERNATIVES TO FOCUS ON

In this step, the Step 3 alternatives will be screened and a decision will be made on whether final disinfection should be retained for more detailed evaluation. Thus, this is a decision point on whether to move forward with further study of final disinfection. However, that does not mean that other mitigation approaches should be ignored. As indicated previously, the treatment and distribution system operation and maintenance are keys to the success of any final disinfection strategy. This screening step is not the final decision on final disinfection but rather retains final disinfection options as a strategy to be further developed in subsequent steps. If final disinfection changes are not needed, then the chloramines evaluation process stops here and does not carry forward.

STEP 5 - REFINE AND CONFIRM SPECIFIC FINAL DISINFECTION OBJECTIVES

Assuming chloramination remains a viable option, this Step will revisit the goals and objectives proposed in Step 2 to confirm or refine them based on the additional information that has been gathered. The objectives should be very specific such that the utility can measure success towards meeting these targets with a planned treatment or disinfection change.

Examples of final disinfection and related objectives might be similar to those summarized in Table 3.1. Since chloramines are normally effective at reducing DBP formation, it would be logical to establish targets for THMs and HAA_5 at levels below the regulatory MCL. Part of the rational for setting lower levels might be that it is advisable to have a safety factor in the event there are source water changes or a treatment upset, such that the utility will remain in compliance with the regulations. Obviously there could be other objectives than those listed in Table 3.1, such as reducing costs, or reducing/eliminating booster chlorine stations, etc. The point is that the utility should be as specific as possible in establishing objectives.

Table 3.1
Example final disinfection and related objectives

Parameter/issue	Example target level
THMs	40 to 60 µg/L at compliance points
HAA_5	30 to 40 µg/L at compliance points
Free chlorine disinfectant residual	0.2 mg/L in 95% of the distribution system samples
Chloramine disinfectant residual	0.5 to 1.0 mg/L in 95% of the distribution system samples
Taste acceptability	FRA of 3 or less at consumers taps

FRA - Flavor Rating Assessment

STEP 6 - ESTABLISH EVALUATION CRITERIA

Some suggested evaluation criteria are discussed in this section.

Regulatory Compliance

There are three main regulatory drivers for considering chloramines in lieu of free chlorine as a final disinfectant: lower disinfection by-products, lower bacterial counts or coliform occurrence, and better disinfectant residual maintenance in the distribution system. The literature review, case studies and the Project survey all support these benefits in most cases.

Chloramination commonly generates THM levels that are 40 to 80 percent lower than free chlorination. For example, at the Zone 7 Water Agency in eastern Alameda County, California, discussed earlier, average THM levels were reduced by about 50%, from an average of 63 µg/L to 32 µg/L.

Utilities using chloramine often see reductions in coliform occurrences. As discussed in more detail in Chapter 2, the Virginia-American Water Company in Hopewell, Virginia, converted to chloramines in 1993 primarily to control coliform occurrences. Prior to this time, the system had experienced positive coliform samples at rates ranging from 10 to 40 percent even when free chlorine residuals averaged between 2 and 2.5 mg/L in the distribution system. Coliform bacteria have not been detected in the finished drinking water following the conversion. Likewise, the Indiana-American Water Company reported a 50% decrease in coliform bacteria and substantial reductions in HPC bacteria at their Muncie facility when the system converted to chloramines in 1993.

The focus of the Total Coliform and Surface Water Treatment Rules is to maintain adequate levels of disinfection throughout the distribution system to protect against bacterial regrowth and contamination from cross connections. Using chloramines as a final disinfectant helps utilities to meet requirements of the Total Coliform and Surface Water Treatment Rules. One of chloramines' greatest advantages is the ability to provide a long-lasting and more stable disinfectant residual throughout the distribution system. Regulatory issues are further described in Chapter 1.

Compatibility With Other Treatment Processes

The entire treatment process should be considered as the final disinfection scenario is being developed. Important aspects to consider include the need to have appropriate primary disinfection inactivation/removal credits for *Giardia* and *Cryptosporidium*. Utilities that chloraminate may use free chlorine, ozone, ultraviolet light or chlorine dioxide to achieve disinfection and oxidation of various compounds including those associated with taste and odor, iron, manganese, and color. For example, at the Eagle Mountain water treatment plant in Fort Worth, Texas, ozone provides the needed 4-logs of virus inactivation, whereas chloramine provides only 0.3-logs of virus inactivation. Ozone also results in lower chemical costs due to improved coagulation, and reduced taste and odors.

Although chloramines are most commonly formed near the end of the treatment process for the purpose of final disinfection, their ability to reduce DBP formation is key to their successful use for in-plant purposes as well. The potential use of chloraminated water for backwashing granular filters and carbon contactors needs to be considered because the disinfectant type and level can affect the efficiency of the processes when they are put back on line.

Organic material in the source and treated water can affect the stability of chloramines as the water travels through the distribution system. Although chloramines are generally less reactive than free chlorine, chloramines still decay and the amount and type of organic material can have a great influence on the bulk decay rate. Operational experiences gained at EBMUD in California has led to the following conclusions (Wilczak, Hoover and Lai 2003):

- A very high degree of TOC removal was required to reduce chloramine demand beyond that of conventionally coagulated water at the Upper San Leandro water treatment plant.
- Ozonation increased chloramine demand despite lowering the TOC levels.
- High doses of hydrogen peroxide added prior to ozonation increased chloramine demand and decay in spite of complete biodegradation of residual peroxide in the filter media.
- Filtration through GAC/sand media operated in a biological mode significantly increased chlorine demand.

Compatibility With the Distribution System

Implementing chloramines is not a substitute for good design, operation and maintenance of the distribution system. If there are multiple inlets of water to the distribution system, the utility needs to consider whether all sources will be chloraminated. This is important because mixing chlorinated and chloraminated water within the distribution system can create conditions that result in 1) different forms of chloramine, especially if pH differences are large; 2) break point reactions in which chloramine residuals are lowered; 3) adverse tastes and odors; and 4) higher DBP levels if free chlorine results. Blending issues and related utility case studies are further discussed in Chapter 2.

Portions of the distribution system with excessive water age may not be optimum for using chloramines. Long detention times may cause the system to be more prone to loss of chloramines residual and subsequent nitrification. Finished water storage facilities should be evaluated for dead zones where water age may be excessive and nitrifying bacteria may begin to grow. Water systems with long retention times do use chloramines, but they generally have water with low organic levels which reduces the bulk decay rate of chloramines. Flushing can be used to reduce water age on a temporary basis.

Nitrification Potential

One of the key criterion that will affect the success of a chloramines conversion is the susceptibility of the system to nitrification. The adverse impacts of nitrification include increasing nitrite and nitrate levels, reducing alkalinity, pH, dissolved oxygen, chloramines residuals, and promoting bacterial regrowth. The mitigation measures for addressing nitrification may be expensive, difficult to implement, and disruptive to the system. Factors favorable to nitrification occurrences include but are not limited to: warm water temperatures, long retention times in the system, presence of higher levels of organic material in the distributed waters, presence of excess ammonia, and presence of nitrifying bacteria. Additional information on nitrification is presented in Chapter 2. The reader should also refer to the AwwaRF guidance manual, *Nitrification Occurrence and Control in Chloraminated Water Systems* (Kirmeyer et al. 1995) and Nitrification Action Plans developed by utilities in California.

Capital and Operating Costs

In comparing the use of free chlorine with chloramines, life cycle costs of all important elements should be considered. This is very site specific and it is difficult to make generalizations about costs. For example, the layout of the sources of supply and piping network dictate capital and operations and maintenance (O&M) costs associated with ammonia addition. The obvious costs are capital and O&M costs related to additional or revised treatment processes. However, additional costs associated with distribution system operation and maintenance may overshadow the obvious treatment component. Distribution system O&M costs may include labor, supplies and outside services for additional water quality monitoring, changes in water age management (i.e. increased pumping costs and/or increased flushing expenses). Detailed information on the costs of chloramination is provided in Chapter 4.

Customer Issues

In making a decision to use chloramines, the consumer is key to the decision and success of the implementation process. There are well-documented issues related to aquarium fish, hobby fish in ponds, patients on kidney dialysis, and other special water users that must be addressed to make this implementation process successful. The issues can be addressed in public outreach forums, written notifications, and technical bulletins for commercial and industrial users. The reader is referred to example public notification brochures included in Appendix E and Project survey results discussed later in this chapter under Step 7, Stakeholder Involvement section.

Environmental and Safety Concerns

The use of chloramines has certain environmental concerns associated with it that are more of a problem than free chlorine. Once formed, chloramines are more stable than the free chlorine and the prolonged exposure of certain aquatic organisms to chloramines is problematic. Specifically, discharges of flushing water or water inadvertently released to the environment from main breaks have resulted in fish kills and litigation. Receiving waters that contain certain sensitive species of fish or other organisms can be harmed by the presence of chloramines. The question for the utility at this point in the decision process is whether the utility's service area may have sensitive environments that need to be considered in this decision process. If it does, then the utility is advised to begin discussions with affected resource management agencies and environmental groups early in the process.

There are also safety issues that need to be addressed with the use of ammonia that is used to form the chloramines residual. For example, if aqua ammonia is to be used, it has a very low boiling point and requires special off-loading facilities and venting procedures that need to be considered. The issue for the utility at this point in the decision making process is that the location of chemical feeds may be an issue for nearby residents, including the size and safety features. Safety issues and concerns are further discussed in Chapter 4.

Both the safety features and environmental concerns are well documented but they are site-specific and need to be considered in the decision process.

Taste, Odor and Other Aesthetic Considerations

The taste and odor of the water will likely change if there is a change in the final disinfection process. In applications where the chloramines are being applied to increase the level of the disinfectant residual, receiving consumers may notice an increase in the chlorine taste of the water. This is because previously, the free chlorine residual may have been very low or not present. In instances where the taste or odor of free chlorine was very noticeable, the implementation of chloramines may bring about a reduced taste in the water. On the other hand, while chloramines are often used to reduce formation of known THM disinfection by-products, many unidentified by-products, measurable by TOX, are formed by chloramination and can affect the water's taste and odors (AwwaRF and Lyonnaise des Eaux 1995). The utility needs to recognize that every water is different and that some consumers are very sensitive to changes in taste and odor, and as such, testing should be done to ascertain the effect that chloramines will have on their particular water. Taste and odor issues are discussed further in Chapter 2. Additional information is provided in the Project survey results which show that 33 % of survey respondents experienced taste and odor issues after chloramination startup.

Ease of Implementation

From a technical level, many of the above criteria have addressed the technical challenges associated with implementing chloramine treatment in a water system. Policy level implementation is more difficult to define and is very site specific. Switching from free chlorine to chloramines has potential impacts on the aesthetics of the water, on the ability to discharge the water to receiving waters, and has health and safety considerations. Consequently, the utility needs to assess the political will and ramifications associated with its decision to implement chloramines.

STEP 7 - GATHER ADDITIONAL TECHNICAL INFORMATION AND EVALUATE STAKEHOLDERS' PREFERENCES

This Step contains two parallel subcategories - Technical Assessments and Stakeholder Involvement.

Technical Assessments

Before a utility considers switching to chloramines for either primary or secondary disinfection, a comprehensive assessment of operational and distribution practices should be conducted. Technical assessments may include laboratory or bench tests, pilot tests, field tests or distribution system monitoring. Examples may include chloramine decay testing to ascertain the bulk water decay rates and tests to evaluate the water's taste and odor with various levels of chloramines. An important aspect of this testing could be to gather information on the nitrification potential of the water and the system. In some instances, testing is performed in the distribution system to gain full-scale results. Such testing may cover several seasons as the source and treated water may change throughout the year.

Many utilities carry out extensive testing to ensure that source water chemistry, water treatment processes, and distribution system operations are suitable for the changes in treatment. Survey results show that 54% of utilities that converted to chloramines hired a consulting company, conducted bench scale experiments, or performed pilot plant experiments. Utilities described below reported that this preparation was useful toward implementing a successful switch to chloramination.

Melbourne, Florida Case Study.

Prior to implementation of ozonation at Melbourne, Florida, consulting engineers determined that chloramines were the most expedient remediation to meet the THM regulations (in the short-term). Effluent THM levels from the plant decreased 89% from 228 to 24 µg/L, and distribution system levels declined 94% from 503 µg/L to 31 µg/L following the switch from free chlorine to chloramines. Fluoride tracer studies to determine the CT for *Giardia* (Table 3.2) and virus (Table 3.3) inactivation showed that the plant was achieving acceptable disinfection, provided that a high chloramine residual was applied at peak flow (ammonia addition preceded chlorine addition). However, additional studies showed that adding chlorine 5 minutes prior to ammonia only increased THM levels by 10%, and provided superior microbial inactivation. Full-scale data with chlorine applied 5 minutes prior to ammonia show that THM levels are typically below 40 µg/L (Figure 3.4).

Table 3.2
Contact times for 0.5 log inactivation of *Giardia* at 25°C – Melbourne, FL

Description	Required contact time with 2 mg/L residual (min.)	Required contact time with 4.5 mg/L residual (min.)	Actual contact time (min.)
Avg. flow, baffled tank, SWTP only	62.5	27.8	164
Peak flow, baffled tank, SWTP only	62.5	27.8	132
Peak flow, unbaffled tank, SWTP only	62.5	27.8	79
Peak flow, baffled tank, SWTP & R/O plant	62.5	27.8	195

Temperature 25°C SWTP = surface water treatment plant R/O = reverse osmosis

Table 3.3
Contact times for 2.0 log virus inactivation at 25°C – Melbourne, FL

Description	Required contact time with 2 mg/L residual (min.)	Required contact time with 4.5 mg/L residual (min.)	Actual contact time (min.)
Avg. flow, baffled tank, SWTP only	107	47.6	164
Peak flow, baffled tank, SWTP only	107	47.6	132
Peak flow, unbaffled tank, SWTP only	107	47.6	79
Peak flow, baffled tank, SWTP & R/O plant	107	47.6	195

Temperature 25°C

Jackson, Mississippi, Case Study.

The City of Jackson, Mississippi, operates two water treatment plants, one drawing from the Pearl River and the other from Ross Barnett Reservoir, with a combined production of 30 MGD servicing 220,000 people through 881 miles of galvanized, ductile iron, cast iron, and PVC pipelines. A 1982 study done by Mississippi State University evaluated different treatment techniques and recommended the use of chloramines to meet the THM regulation. Bench-scale studies showed that a 1 to 2 mg/L chloramine dose to the raw water would eliminate coliform bacteria within 30 minutes. Raw water oxidant decay curves for chloramines dosages of 4 mg/L, 2 mg/L, and 1 mg/L determined the doses necessary to achieve specified residuals for different retention times (Figure 3.5). Other options tested included chlorine and chlorine dioxide disinfection scheme for control of color, turbidity, iron, manganese, and bacteria. These data were useful in determining the initial operating conditions for chloramines.

Florida Keys Aqueduct Authority Case Study.

The Florida Keys Aqueduct Authority provides potable water to the residents of Monroe County through a 130-mile long transmission pipeline and 650 miles of distribution system piping. The groundwater treatment process consists of lime softening, chloramine disinfection, filtration through five dual media filters, and fluoridation. In 1991, the Florida Keys Aqueduct Authority converted from free chlorine to chloramines to comply with THM regulations. To control complaints of rusty water, the alkalinity was increased to greater than 30 mg/L and because less lime was added, the pH decreased from 9.5 to 7.8. The modifications resolved the rusty water complaints, but affected the stability of the distribution system chloramine residual. Subsequent jar tests showed that the stability of the chloramine residual was best at pH 9.0 (alkalinity greater than 40 mg/L). At this pH, a plant effluent chloramine residual of 4.0 mg/L was expected to maintain a residual greater than 2.4 mg/L in the distribution system. These changes (pH 9, >2.4 mg/L chloramine residual) also helped to minimize nitrification problems.

Stakeholder Involvement

The utility should consider an approach in which stakeholders are woven into the process. The stakeholders may include representatives from the general public as well as special water users. Educating the public and special needs groups is necessary to avoid medical, environmental, and public relations disasters. Educational materials may need to be designed. Project survey findings discussed in Chapter 4 include information on successful community outreach strategies, types of customer inquiries received following chloramination startup, and utility staff perceptions of customer satisfaction before and after chloramines conversion. Examples of public notification brochures are provided in Appendix E.

STEP 8 – APPLY EVALUATION CRITERIA AND RATE AND RANK ALTERNATIVE STRATEGIES

This step involves evaluation of the alternative improvement projects identified in Step 3 using the evaluation criteria determined in Step 6. Additional technical information and stakeholder preferences gathered in Step 7 will be helpful to establish the ratings for each alternative. A summary matrix such as the example given in Table 3.4 can be used to organize the ratings for each evaluation criterium for each alternatives. A simple rating system involves rating each evaluation criterion on a scale of 1 to 5, with 1 being a poor rating and 5 being an excellent rating. For each alternative, the individual ratings are added together, and the alternative with the highest total score is the best alternative. Another approach would be a stakeholders meeting to discuss the pro's and con's of the alternatives for each criteria and reach a consensus on the ranking. The rating and ranking approach should be tailored to the specific utility.

Table 3.4
Example ranking of alternatives

Evaluation criteria	Alternative 1	Alternative 2	Alternative 3
Regulatory compliance			
Compatibility with other treatment			
Compatibility with distribution system			
Nitrification potential			
Capital and operating costs			
Customer issues			
Environmental and safety concerns			
Taste, odor and other aesthetic concerns			
Ease of implementation			

STEP 9 - DECIDE WHETHER TO OR NOT TO IMPLEMENT CHLORAMINATION

This Step involves making the decision on whether or not to implement chloramination, based on the ranking of alternatives in Step 8 and on other qualitative factors. The decision process and conclusion should be summarized in a written report and communicated to utility staff, decision makers, and stakeholders as appropriate.

STEP 10 - DEVELOP IMPLEMENTATION PLAN

This Step involves developing a written Implementation Plan which will likely require input from engineering, operations, maintenance, and other stakeholders. The Plan should detail the specific sequential steps that will be undertaken. It may be necessary to develop standard operating procedures for new or revised operations (i.e., change in treatment) and possible emergency conditions (i.e., response to nitrification). The key to a successful implementation plan is communication. First, confirm that management agrees with the decision process and the approach to implementation, and that they are informed about the implementation process. Next, distribute the written plan to all involved parties and utility departments. Implementation should be an on-going process. As data are collected, the original implementation plan should be evaluated and improved as necessary. Data should include not only water quality and operational data, but also customer and employee feedback. Chapter 4 contains guidance on implementation procedures for preliminary engineering, detailed design and start up of ammonia storage, handling and feed systems.

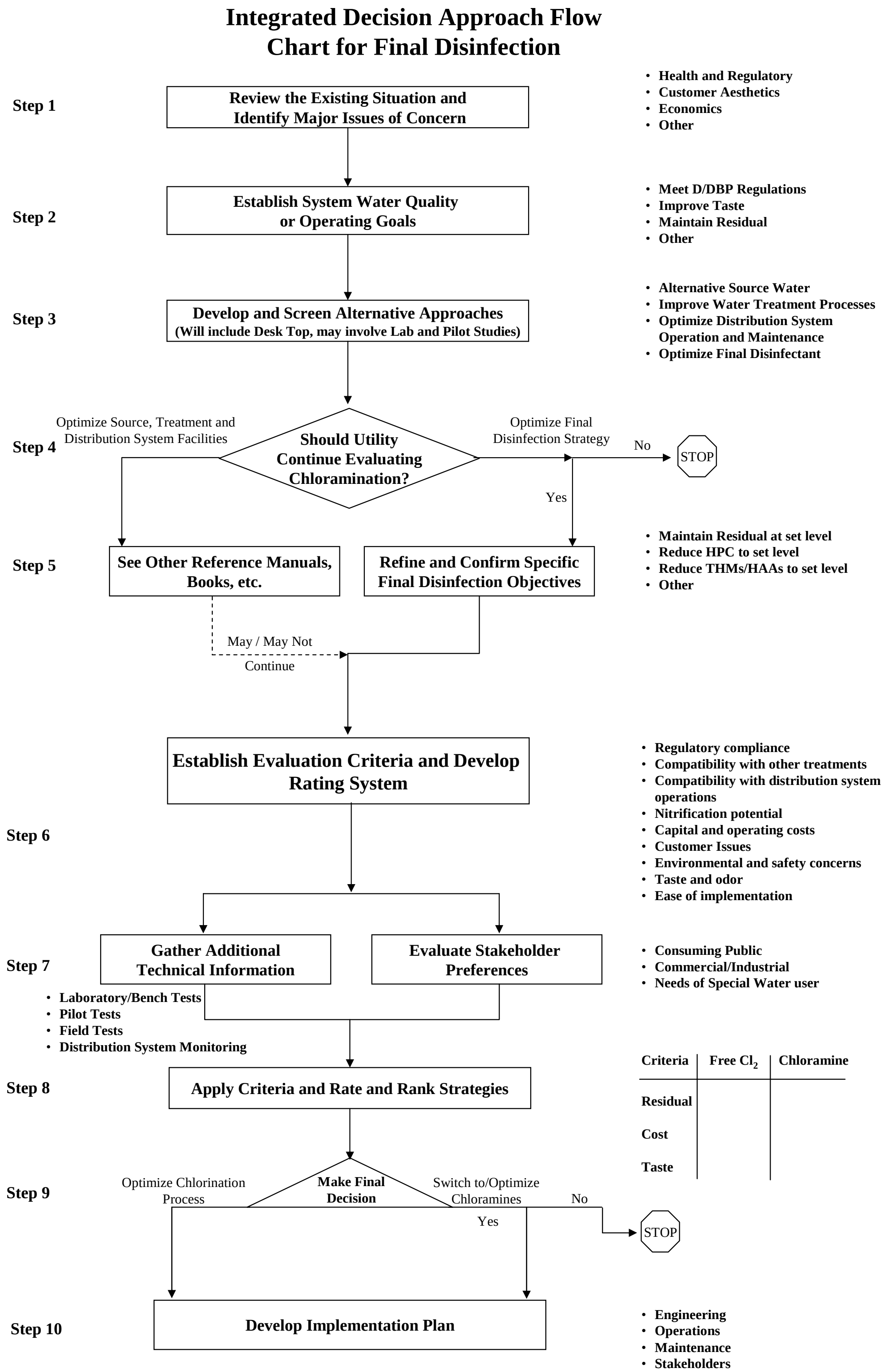

Figure 3.1 Integrated decision approach flow chart for final disinfection

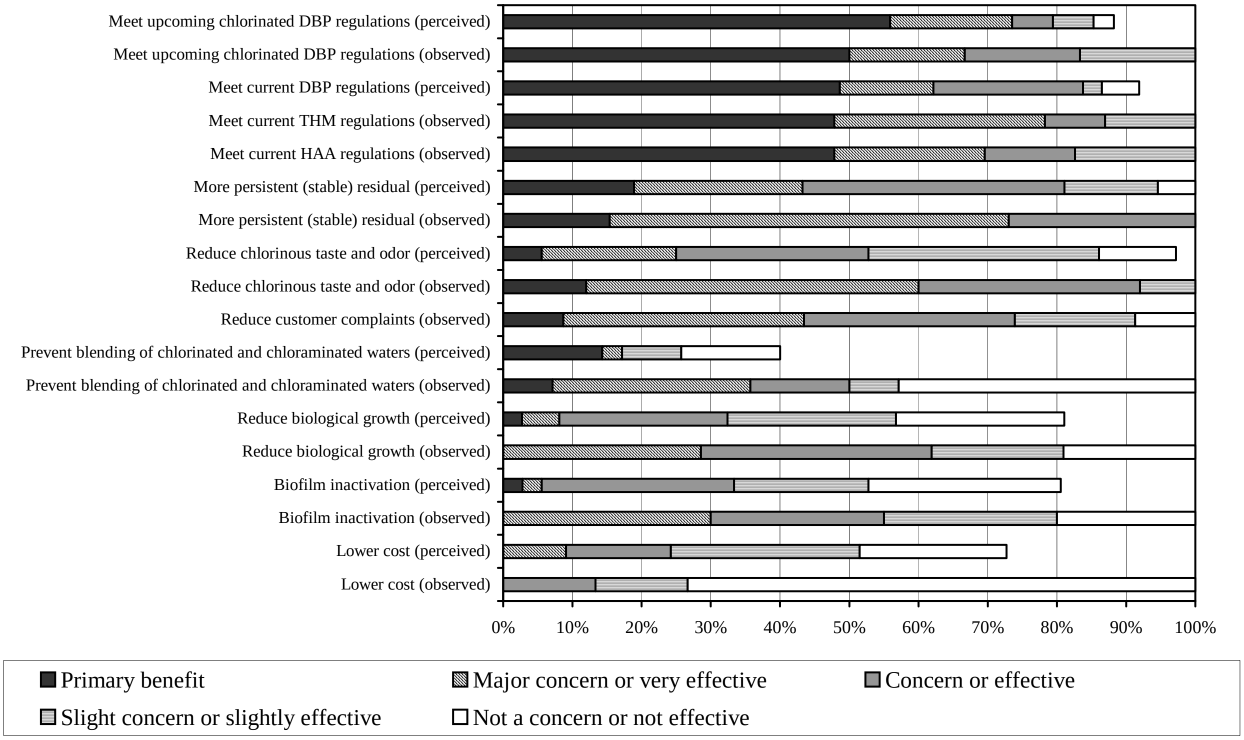

Figure 3.2 Perceived and observed benefits for choosing chloramines

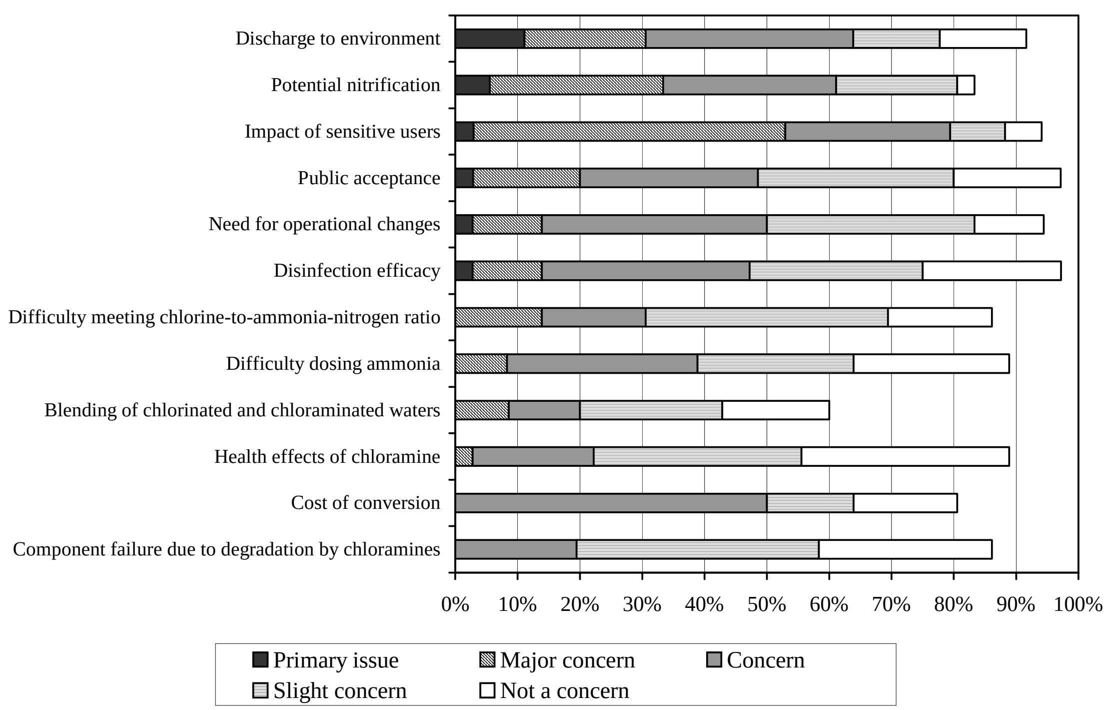

Figure 3.3 Perceived drawbacks for choosing chloramines that were a concern during the decision making process (36 responses considered)

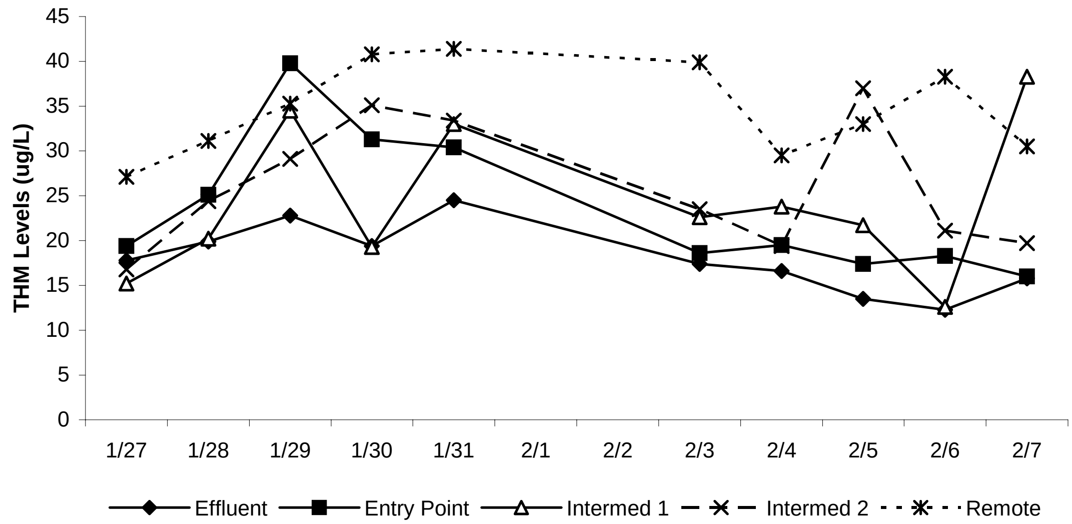

Figure 3.4 City of Melbourne, Florida, full-scale THM levels at different points in the distribution system. Chlorine was applied 5 minutes prior to the addition of ammonia.

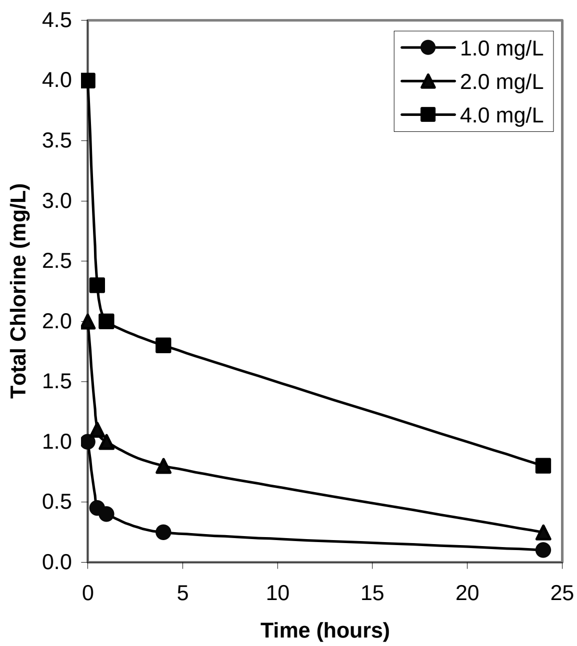

Figure 3.5   City of Jackson, Mississippi, raw water chloramine decay curves. Lines represent doses of 1.0, 2.0 and 4.0 mg/L chloramines.