Michigan Department of Environmental Quality

Report on Gaseous Chlorine Reduction Initiative in Michigan

March 2008

CDM DEQ Prein&Newhof

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Executive Summary

The use of gaseous chlorine is still routine in the State of Michigan with both water and wastewater utilities. However, many of these utilities are interested in alternative means of disinfection due to concerns over safety. Historic gaseous chlorine use, due to favorable cost-benefit analysis, now needs to include risk-benefit analysis. The primary issue in switching to an alternative method is the cost of the conversion and operation of alternatives. It is apparent that if a funding mechanism is provided, the use of gaseous chlorine could be reduced significantly. Other utilities are very satisfied with their experience with gaseous chlorine and are not interested in a change.

I. Introduction

CDM and Prein&Newhof are pleased to submit this report on the Gaseous Chlorine Reduction Initiative.

Contract Period: September 15, 2006 – March 31, 2008

A. Background

Public water/wastewater systems have historically used gaseous chlorine for disinfection purposes during treatment. Risk-benefit analyses show that the use of gaseous chlorine may cause the risk to neighboring populations to be unnecessarily high when compared to the use of other available disinfection methods. While gaseous chlorine currently meets the disinfection needs of public water and wastewater systems, a release of chlorine gas can present a danger. Low airborne concentrations are lethal if inhaled. In fact, gaseous chlorine was used as a chemical weapon in World War I.

While current standards and procedures provide for the safe use of gaseous chlorine, chlorine gas containers have become potentially attractive targets for international and domestic terrorism. A study done by the United States Naval Research Lab found that within the first 30 minutes of a 300 lb/sec release, a full 90-ton chlorine railcar is capable of killing 100,000 people in an urban setting (Boris, 2003).

A number of disinfection alternatives exist that could replace or reduce the use of gaseous chlorine, including ozone, ultraviolet light (UV), sodium hypochlorite, and mixed oxidant. Although these alternatives are more costly, the costs are not prohibitive inasmuch as gaseous chlorine is an inexpensive chemical – i.e., $0.40 per pound by rail car. These alternatives may not have been considered before homeland security became a high priority. With the risk of transportation, handling, and storage of chlorine gas, these alternative technologies have become more attractive—as well as more practical—for public water/wastewater utilities. The current use of different disinfectants in the United States is shown in **Figure 1**.

B. Scope

This project identified those water and wastewater utilities in Michigan that use chlorine gas for disinfection. After confirmation that traditional chlorine was still in use, utilities were contacted and asked to host a presentation and discussion on alternative disinfectants. The goal of this project was to provide utilities with information to make informed decisions that might lead to a reduction in the use of chlorine gas. This project focused on the risks associated with the immediate and catastrophic release of chlorine gas should an intruder successfully detonate an improvised explosive device (IED) in the proximity of bulk storage containers.

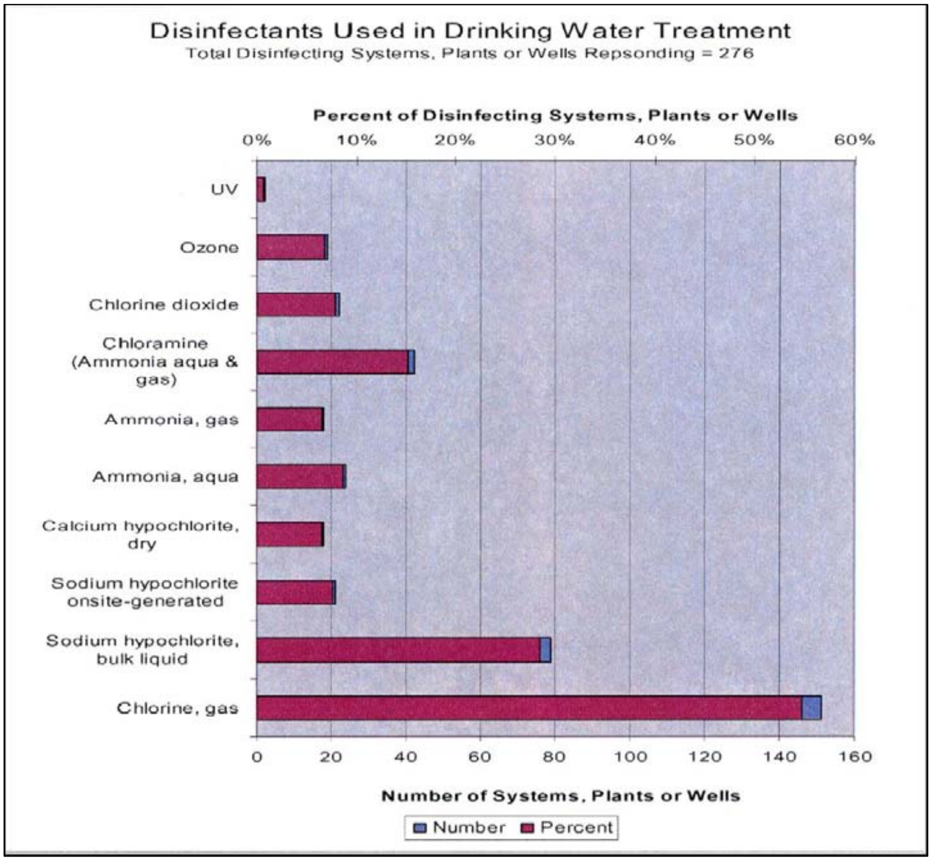


Figure 1. Frequency of Disinfectant Use in U.S. Drinking Water Treatment (AWWA, 2007)

II. Dangers and Risks of Gaseous Chlorine Disinfection

A. Overview

Since the events of September 11, 2001, the security of hazardous chemical transport and storage within the United States has received greater attention. Chlorine is an agent of specific concern. The gas's extreme volatility allows it to readily disperse into the atmosphere, and it is highly toxic. Specific handling requirements for chlorine are well-known.

Accidental or intentional release of chlorine gas may threaten utility employees and the public located downwind of the release. The gas can be deadly if inhaled and can cause chemical burns to the eyes and skin. Contact with chlorine gas at low doses in the atmosphere can cause a burning sensation in the eyes and on the skin. At slightly higher levels the effects of exposure can range from shortness of breath to permanent damage of the lungs. An IDLH (Immediately Dangerous to Life and Health) limit of 10 ppm has been established based on noted effects from accidental human exposures (CDC, 2005).

The acute toxicity and the extreme negative consequences of a chlorine gas release are dependent on the rate of the release, location of the release site, and local weather conditions at the time of the release. Obviously, the greatest risks reside in highly populated areas where the greatest number of people would be potentially exposed, and where the high population density can hinder an immediate evacuation of the area. A shelter-in-place strategy may be the only alternative to evacuation and is likely to be poorly effective in protecting citizens in the path of the chlorine plume.

B. Potential Threat Scenarios

Recognizing the risks associated with chlorine requires an understanding of how chlorine might be used as a weapon by terrorists. Collectively, the following incident scenarios form the basis of the threats:

- On-site storage of bulk quantities (up to 90-ton rail cars) of chlorine gas present an attractive target, particularly when located in or transported through heavily populated areas. It has been estimated that in many cases an intruder needs only 20 minutes to access the facility and set an explosive charge.

- The transport of bulk quantities of chlorine gas by rail cars and one-ton and 150-lb cylinders on trucks presents a potential target for terrorists. Rail yards and sidings, as well as parked, loaded trucks, are vulnerable to varying degrees.

- Chlorine containers could be stolen or ruptured in many locations beyond transportation routes.

- Commandeering a 150-lb cylinder and releasing the gas in an enclosed facility (e.g. mall, sports arena, buildings) could cause extremely high concentrations to be delivered indoors through ventilation systems.

- A coordinated attack by an organized force could target multiple sites simultaneously in a major metropolitan area. The consequences of a potential release of toxic clouds quickly would overwhelm emergency response capabilities and create an unmanageable patient load at local hospitals.

Each threat or scenario presents an associated level of risk related to the size of the potential population exposed and the environmental conditions in which the chlorine gas release occurs.

C. Perceived Risks

Risk is typically quantified by a mathematical formula including those variables describing the consequences of an event and the probability that the event will occur. In general, the intentional or unintentional immediate release of chlorine gas has been described as a "high-consequence, low-probability" event. Because of the low probability factor, any one utility may find it difficult to justify the added expense incurred with adopting an alternative technology. Given the magnitude of the negative consequences and the aggregate probability of occurrence when one considers the sum of all utilities across the United States, the need to better manage this risk takes on a national perspective. This is particularly true when chlorine gas is stored or transported in highly populated areas.

As part of this project, 140 Michigan utilities were approached regarding their use of chlorine gas. Approximately one-fourth of the utilities are located in urban environments. In more rural areas, three factors contribute to substantially lower risk:

1. Typically, the maximum amount of chlorine stored at a rural utility is far less than in more urban utilities. Thus, with an actual release, the land area impacted and the concentrations of chlorine gas attained in the atmosphere are likely to be lower.

2. The population density is significantly lower. With the primary concern being one of human health impact, the number of individuals actually exposed to toxic concentrations of chlorine gas is also likely to be far less.

3. With a lower number of individuals being exposed or harmed, the attractiveness of using chlorine gas as a weapon wanes.

Relative to national security, these facts would suggest that the greatest risks are more likely to occur at larger, urban utilities. However, it does not preclude the fact that the theft of relatively smaller quantities of chlorine gas could produce lethal consequences if released within an enclosed facility.

In consideration of a state or national strategy for mitigating the risks associated with gaseous chlorine use, it would seem that the greatest risk reduction would be achieved by focusing first on utilities where high volumes of chlorine gas are stored or transported through more populated areas. Published accounts of "terrorism and chlorine use" would tend to support this conclusion (GAO, 2003).

The immediate release of chlorine gas from an exploded container is one of 15 scenarios used by the Department of Homeland Security to gauge preparedness of local, state and federal agencies. In this scenario, the assessed consequences included 17,500 casualties, 10,000 severely injured, 100,000 hospitalizations, and the need to evacuate an additional 70,000 residents. The impacted area (the specific location modeled was not cited) would be up to 25 miles downwind and could involve up to 700,000 citizens. An estimated 400,000 "worried-well" were predicted to likely seek medical attention, overwhelming hospital capabilities and perhaps delaying medical attention to those needing immediate help, as well as disrupting normal medical service Homeland Security Council, 2004).

In looking at the 10 greatest catastrophes likely to face the U.S. insurance industry, Risk Management Solutions, Inc. modeled the consequences of a rail yard fire and subsequent chlorine gas release from two 90-ton rail cars parked in a yard outside of Houston, Texas. The human health consequences were estimated at 600 dead, with 7,000 severely injured, and 250,000 having lesser injuries. The financial consequences included $1.5 billion in life and health care costs (Risk Management Solutions, 2004)).

On February 5, 2005, the Washington, D.C. City Council, citing the dangers of chlorine gas, voted to ban hazardous chemical shipments from the City's central district. This required rail lines to reroute shipments over less populated and sensitive areas. The railroads challenged the ruling and received an injunction. Thus, despite the acknowledged high risk, to this date shipments of chlorine through populated urban areas are permitted (Orum, 2007).

D. Current State of Security

According to the U.S. EPA, there are approximately 2,000 water facilities exceeding the 2,500-lb regulatory threshold set for quantity of chlorine gas stored onsite. As a whole, the industry has made a considerable investment in security.

Although water and wastewater treatment utilities are exempt from the new Chemical Facilities Security Act, recent legislation has been proposed to remove that exemption. Senate Bill 2920, entitled the Community Water Treatment Hazards Reduction Act of 2006, would have ordered water and wastewater treatment works that use chlorine gas to first conduct vulnerability assessments in order to determine whether they meet the bill's definition of a "high consequence" facility – one that poses a chemical exposure risk to 10,000 people or more. After the assessments are completed, those facilities identified as having a "high consequence" would have 90 days to begin the transition from using chlorine gas to an alternative treatment option.

It is also likely that all gaseous chlorine facilities will be required to implement specific physical and procedural security measures.

III. Procedures

Specific procedures were developed to inform utilities of the risks associated with gaseous chlorine and the benefits and disadvantages of alternatives. The three-pronged approach consisted of identifying and communicating with utilities still using chlorine gas, developing materials for presentation, and meeting with utilities. A summary of each follows:

A. Identification of and Communication with Utilities Using Chlorine Gas

The MDEQ provided a list of utilities that were believed to be still using gaseous chlorine. The original UASI (Urban Areas Security Initiative) list included 22 utilities and the non-UASI list included 95 utilities. UASI utilities are all located in southeast Michigan. Non-UASI utilities are located throughout the rest of the State. Each of these utilities was contacted via letter from the MDEQ. Then a follow-up call was made to each by the consultants.

Some of those on the list had already switched disinfectants and others were in the process of switching, thus eliminating 33 utilities. Since some meetings were not necessary, the consultants searched for additional utilities still using chlorine gas in an attempt to maximize the effectiveness of the study. A total of 28 additional utilities were contacted including six water treatment facilities and 22 wastewater treatment facilities. In all, a total of 140 water/wastewater treatment facilities were contacted. Of these, 33 had converted to alternative disinfectants, 28 new utilities using gas chlorine were identified, 11 refused to meet and 3 never responded leaving a total of 95 utilities that were involved in this project.

Figure 2 shows the number of utilities that already changed disinfectants, the number that plan to convert, the number that showed positive interest, and the number that refused to meet.

A final workshop was presented to the MDEQ water and wastewater regulators at the MDEQ headquarters on March 21, 2008.

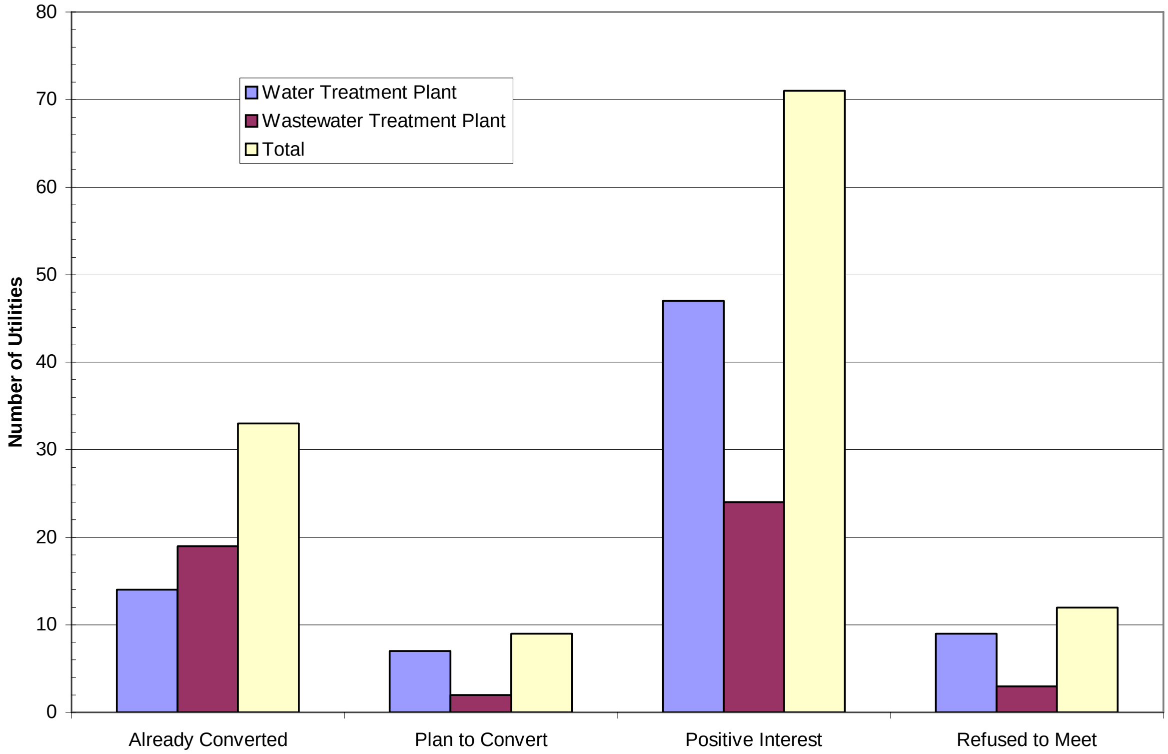


Figure 2. Level of Interest in Gaseous Chlorine Initiative

B. Presentation Materials

A suite of informative materials was developed for this project. These materials are attached in Appendix A.

Materials were developed, presented and discussed during utility visits. The list of materials is given in **Table 1.** Note that not all materials were used on all utility visits. All UASI sites received additional materials as well as the option of follow-up visits. Follow-up communication to address questions and concerns was encouraged and offered to all utilities. Due to the significant number of non-UASI utilities and limited grant funds, only some of these sites were given the option of follow-up visits.

Table 1: Materials Distributed to Utilities

Material	UASI	Non-UASI
Overview Presentation	X	X
Risk Fact Sheet	X	X
Alternatives Fact Sheet for Drinking Water Treatment Facilities	X	X
Alternatives Fact Sheet for Wastewater Treatment Facilities	X	X
CAMEO Risk Assessment	X	
Gaseous chlorine Decision Tool website	X	X
Demonstration of Gaseous chlorine Decision Tool	X	
Survey on Utility Information	X	X

The survey, presentation, risk fact sheet and alternative fact sheets were developed in partnership between CDM and Prein&Newhof so that all utilities received the same information package.

Additional materials were developed for use at the UASI utilities. A customized CAMEO (Computer-Aided Management of Emergency Operations, NOAA)) risk assessment was performed for each UASI utility with a variety of risk scenarios. The scenarios were based on the average and maximum amounts of chlorine gas on-site at any time and typical weather conditions as provided by the utility. Utilities were encouraged to select their own scenarios. Reports were delivered to the utility reflecting the results.

The CAMEO software predicts the potential zones for death within 60 minutes, potential permanent injury and expected temporary impairment of the population assuming they shelter inside a typical single-storied residence. The software also has the ability to utilize GIS to locate critical facilities such as schools and hospitals. The number of people exposed is based on census information; no information on transients, workers or international residents is included, thus creating a significant underestimate of potential impact.

CAMEO modeling uses chemical information from the U.S. EPA in conjunction with atmospheric calculations from NOAA to determine areas that exceed certain concentrations of gas inside one-story residential buildings. These concentrations can be defined as levels of concern (LOC). The LOCs used in the risk assessment are based on acute exposure guideline limits (AEGL). AEGLs are intended to describe the risk to humans resulting from once-in-a-lifetime, or rare, exposure to airborne chemicals. AEGLs for chlorine gas are defined by exposure time and by harm.

- AEGL-1 is the airborne concentration that could cause symptoms from exposure; however, the effects are not disabling and are transient and reversible upon cessation of exposure.

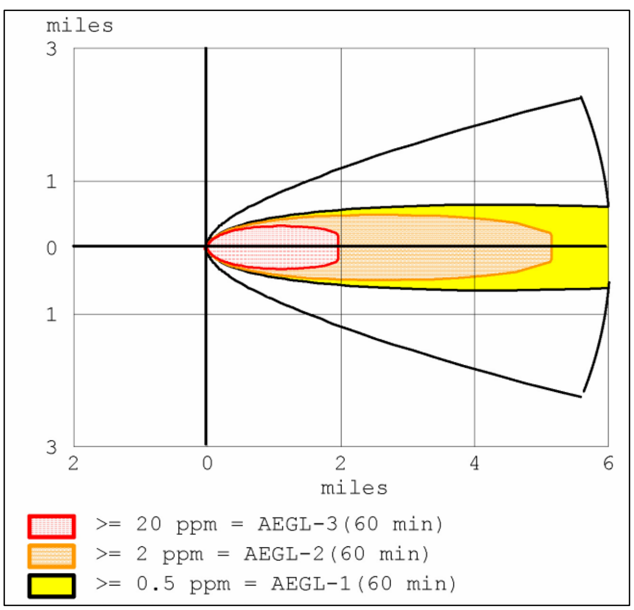
- AEGL-2 is the airborne concentration that could cause irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

- AEGL-3 is the airborne concentration that could cause life-threatening, adverse health effects or death.

Table 2: AEGLs of Chlorine Gas and Exposure Times

Chlorine AEGLs by Exposure Time					
ppm					
	10 min	30 min	60 min	4 hr	8 hr
AEGL-1	0.50	0.50	0.50	0.50	0.50
AEGL-2	2.8	2.8	2.0	1.0	0.71
AEGL-3	50	28	20	10	7.1

CAMEO only includes AEGL values with an exposure period of 60 minutes; other exposure times can be calculated on an individual basis, as necessary. All exposure mapping done for the project used a 60 minute value.



CAMEO overlays the levels of concern onto a map from the U.S. Census Bureau and then calculates the number of people who reside within the LOC.

Figure 3: A Typical Michigan Release of One 1-Ton Cylinder of Chlorine Gas Showing AEGL-1, -2 and -3 Levels of Concern.

When LOCs are overlaid on the Census Bureau map, other significant affected areas are shown, such as schools, hospitals and roadways. The population data inputs include residents only. People not accounted for include those at work, in cars or other forms of transportation, visitors, homeless and those in affected areas outside the United States. The population estimate based on residential data is understandably conservative. Significantly, the software can only plot reliable LOCs up to six miles downwind—a distance that was typically exceeded when modeling chlorine release from a water treatment facility using one-ton or 90-ton railcar containers.

For the UASI utilities, the Gaseous Chlorine Decision Tool was used to demonstrate an approach to full cost accounting versus benefit for selection of disinfection approaches. This is a software program available free of charge through www.nacwa.org. It allows a utility to individually evaluate a list of pre-established, non-economic criteria that rate the value of factors such as space availability, safety, public perception and other criteria. The software then provides economic information including O&M, capital estimates, chemical costs and other factors. The cost/benefit ratio is developed and used to rank the alternatives.

This software tool was demonstrated for each UASI utility. Utilities were encouraged to acquire and use the software to assist in decision making. It was noted that the software was developed in 2000, so the prices are likely out of date. However, there is still value in the exercise as it will indicate relative values of the alternatives. Since the software is not proprietary, utilities have the option of providing more current cost information.

C. Utility Meetings

The utilities were contacted by phone and/or email to solicit their participation in the program. Site visits were made to utilities to give a presentation, share informational materials and provide an opportunity for discussion. For non-UASI sites, one- to two-hour site visits were conducted; for UASI sites two hours were allotted for site visits. Several of the non-UASI utilities also met in groups, providing the added benefit of group learning—to gain knowledge from the experiences and questions of others.

Follow-up meetings were offered to all UASI utilities, and a limited number of non-UASI utilities. Five UASI utilities indicated interest in such follow-up meetings. The purpose of these meetings was to involve a broader segment of stakeholders in the decision making process. Such stakeholders included City Council or upper management for the utility. One follow-up document was prepared for a local emergency planning commission. All UASI and non-UASI utilities were encouraged to follow up with an email or phone call with questions and concerns.

Following many of the meetings, plant tours were conducted. This allowed for a more detailed, site-specific educational opportunity regarding the advantages and disadvantages of the various disinfectants.

IV. Results

Documentation and quantification of the outcome of meetings with utilities is important to provide some idea of the interest and effectiveness of the Gaseous Chlorine Reduction Initiative.

A. Survey

One method used to quantify the results was a survey developed for the utilities. This survey, provided in Appendix A, included a range of questions and was completed voluntarily. The questionnaire was completed by either utility personnel or the interviewer for each utility. The data received from the utilities was captured on a hard copy form and then entered into an Excel database for data analysis.

All information was treated as confidential. As a security measure, all utilities were assigned a unique identifier in order to not reveal the identity of the utility. Participation was voluntary, and some utilities elected not to participate in the program. In fact, 58 of the 95 utilities (61 percent) the consultants met with completed portions of the survey.

1. Containers

Of those that completed surveys, most used 150-lb cylinders (55%). Approximately 43 percent of respondents used one-ton cylinders and two percent used rail cars. Approximately two-thirds of the wastewater treatment facilities responding used one-ton cylinders (12 of 17), while most of the water treatment facilities (70%) used 150-lb cylinders. Note that some utilities had multiple sizes of chlorine storage containers. The results are presented in **Figures 4 and 5**

2. Gaseous Chlorine Impact

Several questions were asked regarding the impact of gaseous chlorine in the community. Utilities were asked whether they had any leaks in the past. Of the 59 utilities that submitted a survey, 10 reported having a leak in the past (six water utilities and four wastewater utilities).

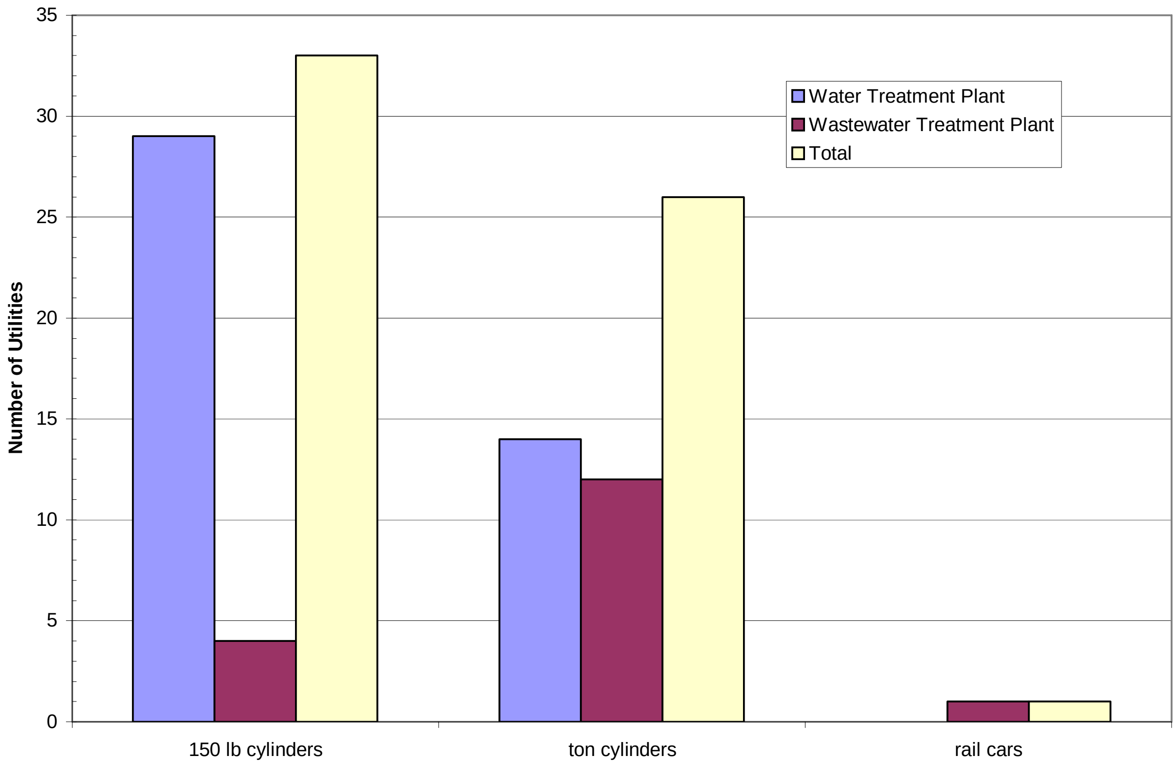


Figure 4 Gaseous Chlorine Inventory - Containers.

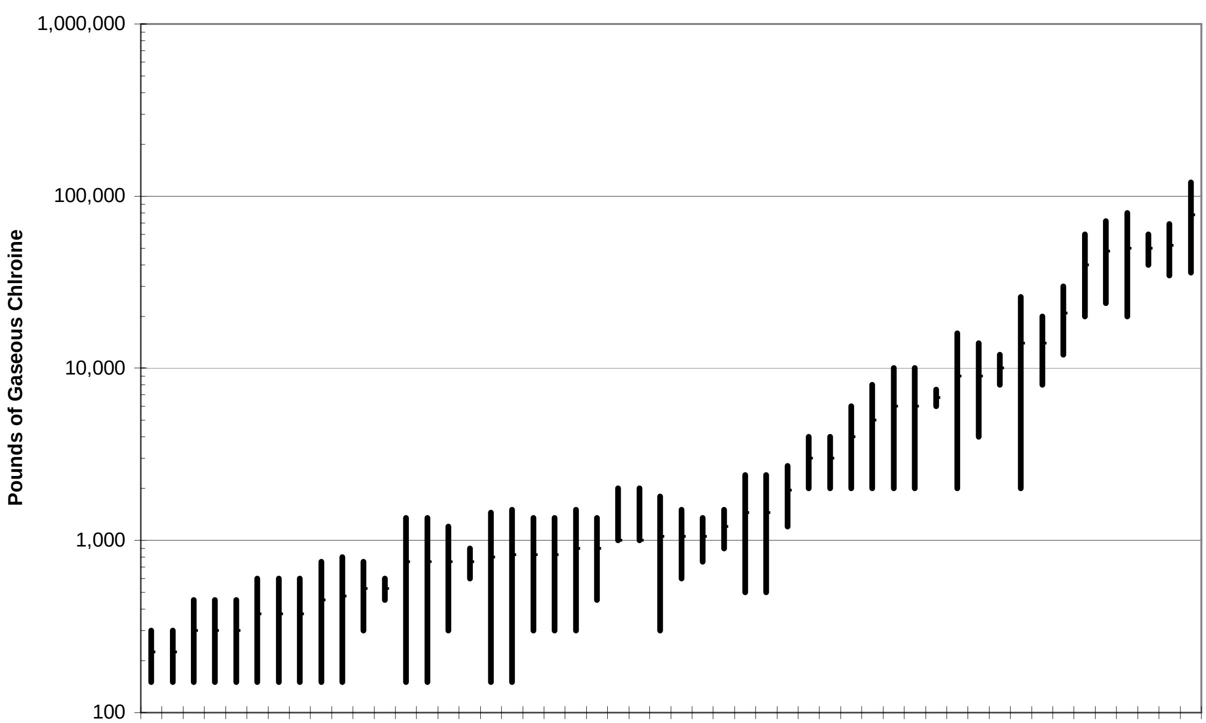


Figure 5. Gaseous Chlorine Inventory - Volume.

Non-UASI utilities were asked for the distance from the plant to the customer of the closest impact. The overall average was 1.3 miles for the 17 utilities that answered the question. The average for water and wastewater treatment facilities was 1.4 miles and 1.0 miles, respectively. According to the surveys, 11 utilities have gaseous chlorine near schools, six are near a hospital, three are near a stadium and three are near a theater.

Utilities were also asked what security plans they had completed. Results of the survey indicated that 35 had done a Risk Management Plan and 21 had done Process Safety Management Plans. Other plans mentioned include Vulnerability Assessment, Emergency Response Plans, LEPC Offsite Response Plan, Chlorine Safety Program, HAZWOPER, and Public Health Assessment.

3. Alternative Technologies Considered

The survey asked which alternative technologies had been considered by the utility. Of the respondents, 33 of the 58 had considered bulk delivered sodium hypochlorite, while 13 had considered on-site generated sodium hypochlorite. Twenty had considered ultraviolet (UV) light, and nine considered ozone. For wastewater treatment facilities, 11 had considered UV light, more than any other alternative combined. Since UV light is generally the most commonly considered alternative for wastewater treatment, this may be expected. **Figure 6** shows these results.

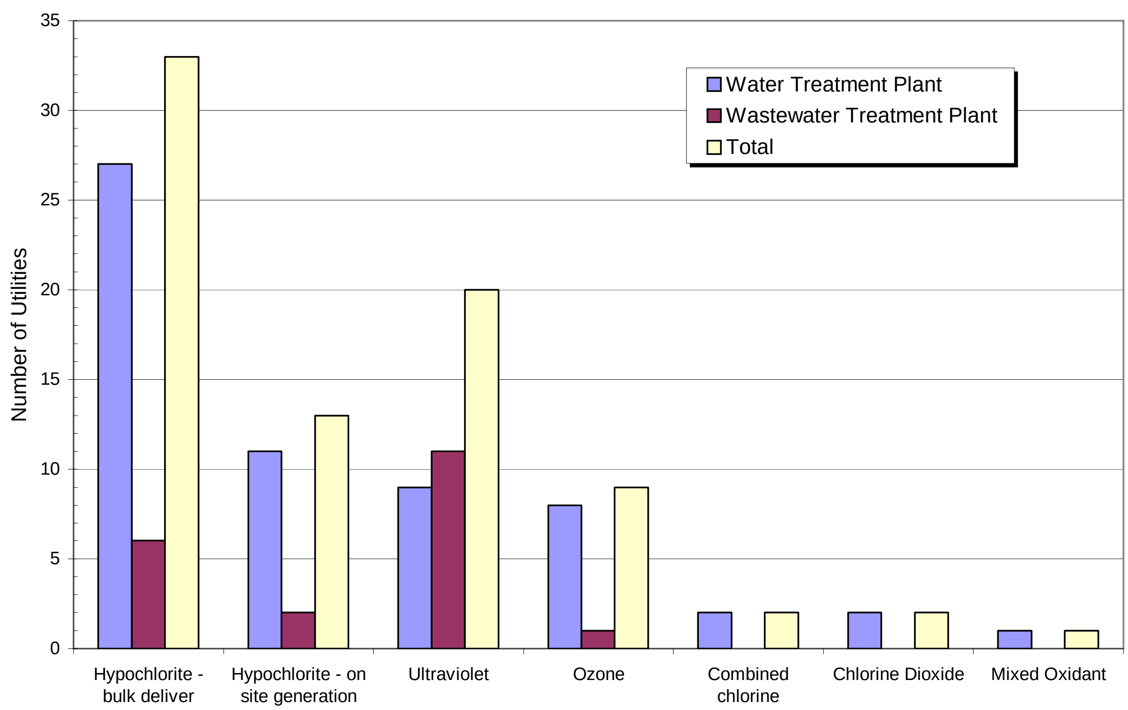


Figure 6. Alternative Technologies Considered.

4. Factors Affecting Change

One survey question asked what factors affected the utility's willingness to convert to an alternative disinfectant. Of the 58 respondents, 58 percent considered cost a factor affecting change, and the percentage was similar for both water and wastewater facilities. One result which was clear in the meetings was that many utilities do not have funds available to complete the switch to an alternative disinfection method.

Approximately 39 percent of respondents believed that regulatory requirements would be necessary for change to occur. For water treatment respondents, the percentage was higher than with wastewater plants; 51 percent versus 29 percent, respectively. Thus, wastewater treatment facilities could be considered more likely to change than water treatment facilities. This is most likely due to the ease of conversion to UV technology without follow-up de-chlorination for wastewater facilities, whereas water facilities are required to maintain chlorine residual in their distribution system. **Figure 7** presents the factors that affect change.

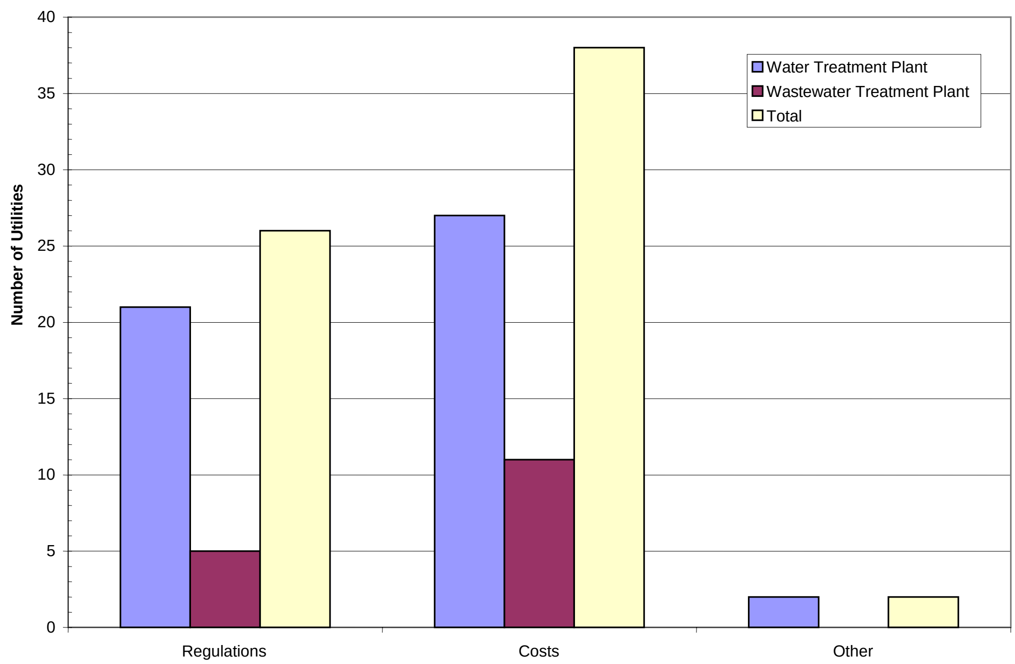


Figure 7: Factors Affecting change

5. Potential Obstacles

A list of potential obstacles that affect conversion to alternative disinfectants was also provided for ranking. Results of the top-ranked obstacles are shown in **Figure 8**. Both water and wastewater treatment facilities believe that cost is the primary obstacle. This includes capital costs, operational costs and labor costs, three of the highest obstacles listed. No other obstacle would be considered as significant;

however, about 22 percent are concerned about the effectiveness of the alternative, and 17 percent of water utilities are concerned about Disinfection Byproducts.

It is very evident from the survey results that cost is a significant obstacle for many communities. If the Department of Homeland Security wants to reduce the use of gaseous chlorine at public utilities, funding assistance should be considered.

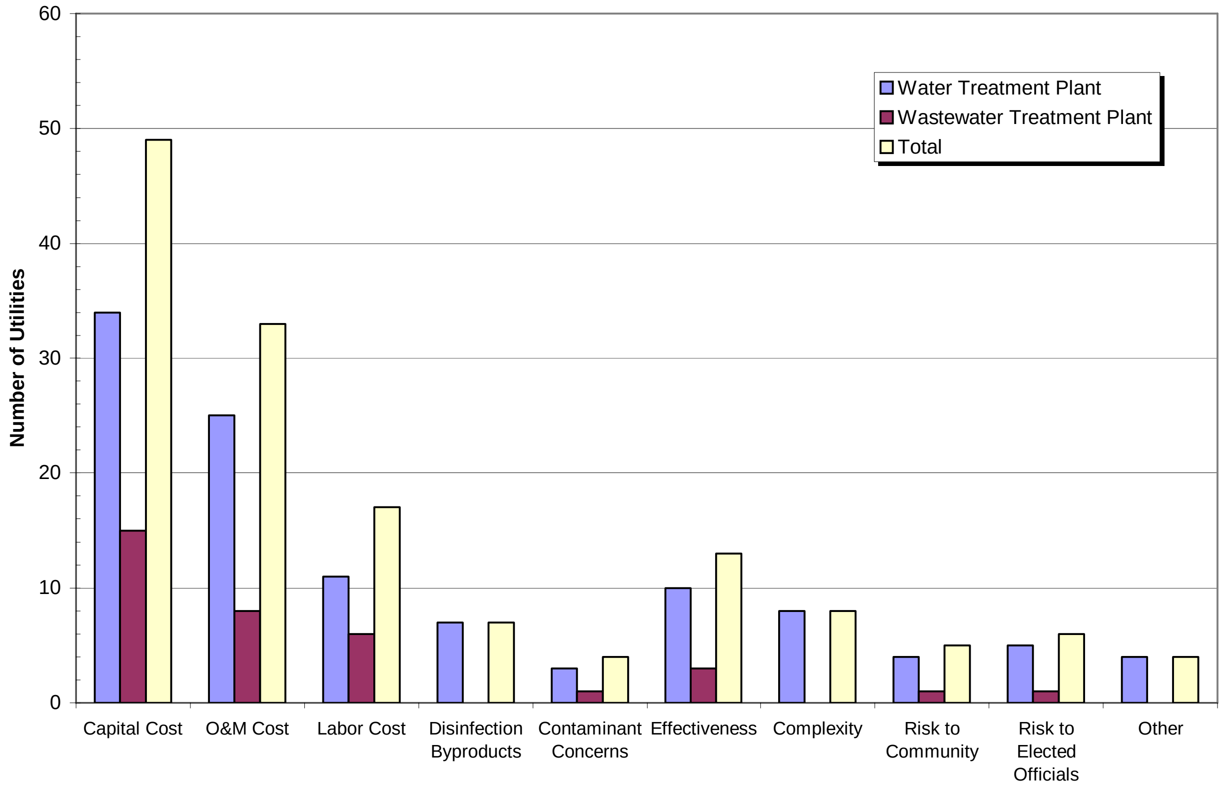


Figure 8. Obstacles for Converting.

B. Risk Assessment Tool

Many utilities, including all those who responded in the UASI areas, expressed interest in the Gaseous Chlorine Decision Tool. The web site for ordering was supplied to all utilities.

The CAMEO risk assessment indicated a wide range of potential impacts for the utilities modeled, as shown in **Table 3**. Various scenarios were conducted with utility input. Representative scenarios shown in the table below are based on a typical amount of chlorine on-site. The “AEGL-3 Level of Concern Distance” is the maximum distance downwind covered by a potentially lethal concentration of chlorine based on the scenario. The “Residents in Area of Lethal Concentration” is the number of people residing in the downwind level of concern plot. The “Potential Impact Area” is the area (a circle with a radius equal to the AEGL’s Level of Concern Distance) that could be affected by the chlorine gas; the actual impact area is determined by wind direction and other lesser, yet variable, factors.

Table 3: CAMEO Modeling Results for different weather scenarios at a subset of participating utilities. Note that population impacts are residents only and do not include workers, transients or the international community.

Utility	Amount of Chlorine On-site	AEGL-3 Level of Concern Distance (miles)	Residents in Area of Lethal Concentration (AEGL-3)	Potential Impact Area (AEGL-3) (square miles)
Utility A	3 tons	1.8	6,000	10.2
Utility B	8 tons	2.4	134,341	18.1
Utility C	750 lbs	1.1	596	3.8
Utility D	1500 lbs	1.2	15,007	4.5
Utility E	2 tons	2.1	17,648	13.9
Utility F	4 tons	2.6	49,411	21.2
Utility G	90 tons	> 6.0	> 377,172	> 113.1
Utility H	1500 lbs	1.4	12,469	6.2

C. Qualitative Results

Based on the discussions at the utility meetings, some trends appeared. These results are not based on hard data, but on the opinion of the consultants:

- More experienced utility representatives tended to be less open to change. This could be due to a resistance to change near the end of their careers, or could be a reflection of the comfort level that they have developed with gaseous chlorine after years of working with it.

- Several utilities expressed dismay over this project in view of the lack of regulation of other nearby industries that use gaseous chlorine and/or the overall beneficial use of chlorine gas by our society as a whole.

- There was interest in and discussion of the potential Chemical Securities Act being proposed by Congress.

- Some utilities have added or upgraded gaseous chlorine disinfection systems in recent years, as the MDEQ is still permitting this. Given this recent investment, these utilities have no plans to switch in the near future. The utilities questioned why they would switch if the MDEQ still approves new/retrofitted systems.

- Most of those who have already switched to sodium hypochlorite (water plants) or ultraviolet disinfection (wastewater plants) indicated that they are satisfied with the new systems and they have performed well.
- At least one operator was hospitalized within the past six months for inhaling chlorine gas.
- Multiple utilities reported that they have had chlorine leaks. One even indicated that as a result of a leak, a visible "cloud" of chlorine gas made its way from the plant down the main street of the city. Efforts were made by the utility personnel to keep pedestrians from the gas until it dispersed, and no one was injured.
- It is apparent, particularly at smaller utilities, that security measures for gaseous chlorine bulk storage containers may not be effective or adequate.

The probability of switching to an alternative disinfectant was rated by the consultants for each utility. Based on the meetings and survey results, each utility was subjectively identified as fitting into one of four categories:

1. Utility is currently switching or already switched from gaseous chlorine to an alternative means of disinfection.
2. Utility will likely switch from gaseous chlorine to an alternative means of disinfection in the future regardless of funding or regulations.
3. Utility will likely switch from gaseous chlorine to an alternative means of disinfection if funding is available.
4. Utility will likely switch from gaseous chlorine to an alternative means of disinfection only if regulatory requirements compel them to do so.

Figure 9 presents the results of this evaluation. Of those utilities that were initially identified for this project, 42 have already switched or are in the process of switching to an alternative disinfectant. Of those that have not switched, more than two-thirds (78 percent) of those utilities are likely to view funding as the primary obstacle. It is apparent that most utilities recognize the dangers associated with gaseous chlorine and would like to switch to a better alternative.

Only 11 utilities (11 percent) of those who still use gaseous chlorine are likely to make the switch to an alternative means of disinfection if no funding mechanism or regulatory requirements occur. About 10 (10 percent) of utilities are not in favor of switching and would likely only switch if regulations demand it.

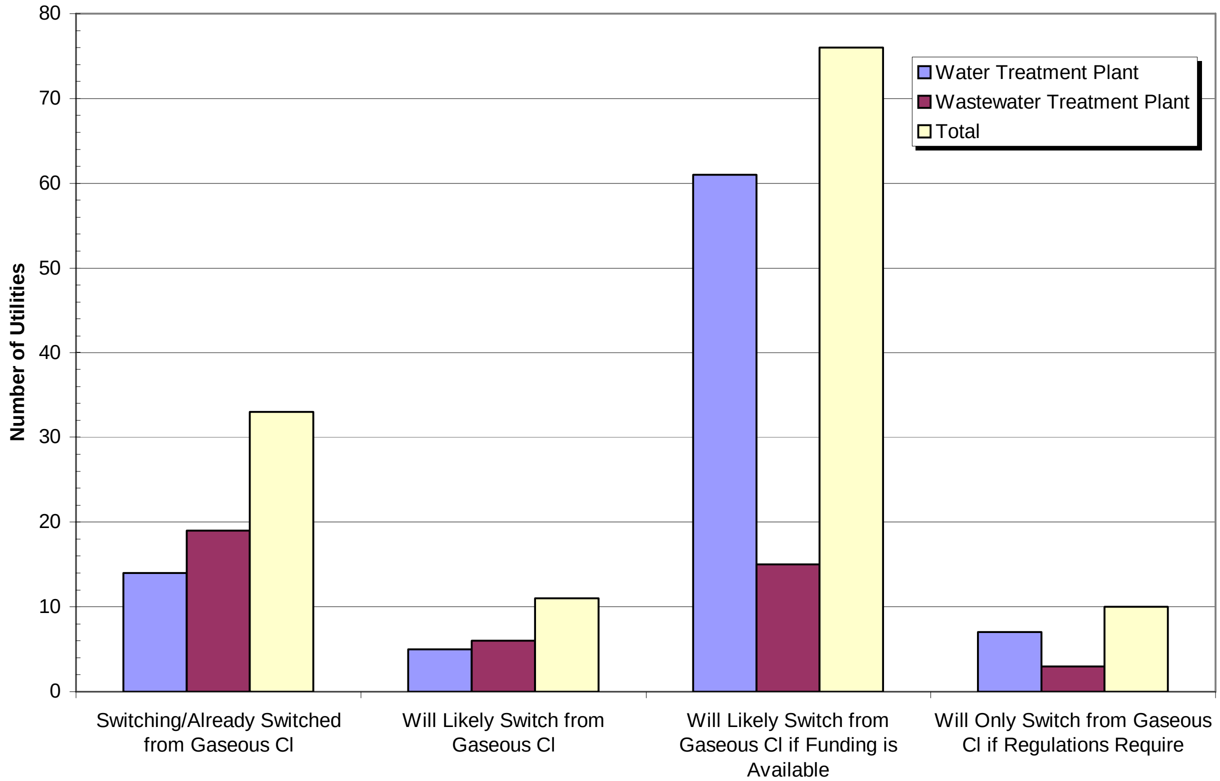


Figure 9. Evaluation Results.

V. Conclusions and Recommendations

The use of gaseous chlorine is still routine in the State of Michigan with both water and wastewater utilities. However, many of these utilities are interested in alternative means of disinfection due to concerns over safety. The primary issue in switching to an alternative method is the cost of the conversion and operation of alternatives. It is apparent that if a funding mechanism is provided, the use of gaseous chlorine could be reduced significantly. Other utilities are very satisfied with their experience with gaseous chlorine and are not interested in a change.

The Chemical Security and Safety Act bill introduced in March 2006 required certain plants to use safer technologies if practical alternatives exist. Water and wastewater treatment facilities were exempt from the regulation. It is anticipated that this exemption will be removed in 2008 and that utilities will have to implement the provisions of the Act. It is not yet clear if implementation will be through the Department of Homeland Security or the U.S. EPA. In either case, utilities using gaseous chlorine will need to plan for new regulations. Therefore, it is predicted that increasing interest in alternative disinfectants will continue. It is important that the regulating agencies provide for financial assistance for implementation of alternative disinfectants if they desire a reduction in gaseous chlorine use in the United States.

The following is a list of recommendations:

1. Continue to actively track and respond to regulatory initiatives on the use of gaseous chlorine (i.e. Chemical Facilities Security Act).

2. An evaluation of funds should be completed to determine the most effective use of available funds to reduce risks. Alternative studies that could be an effective use of funds include:

- Studies at utilities having greatest risks (i.e. those involving the storage and transport of large quantities in urban areas). For instance, it would be useful to study rail car routes through urban areas and assess their security in transport.

- Training or improvements in safety procedures at smaller facilities currently under the threshold quantity of chlorine, which may have little to no security/safety measures in place.

- Training for all water professionals on the risks of gas chlorine and evaluation procedures to be used during treatment plant design for new or rehabilitated facilities (possible MIAWWA or AWWA seminar).

- An engineering study of high-risk facilities to determine the cost and most appropriate alternative technologies.

- A study for all utilities that use gaseous chlorine to evaluate the need for implementing security measures to reduce the vulnerability of gaseous chlorine containers. This could include an evaluation of vulnerability assessments and recommendations for updating the VAs.

3. MDEQ staff to continue to support the careful evaluation of the continued use of gaseous chlorine during permit review for new facilities. Encourage MDEQ leadership to make this evaluation a routine part of sanitary surveys.

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Appendix A: Informational Materials

Utility Survey Form

Original
Date: Dates Revised:

MDEQ GASEOUS CHLORINE REDUCTION PROGRAM

All questions contained in this questionnaire are strictly confidential.

Facility Name: **Address: City:**	**Unique_ID:**
Facility Type: Water Wastewater SDWIS or NPDES ID:_____________	**Capacity MGD (Design/Peak Summer/Winter Average):**
Interviewer(s) :	
Interviewee(s):	

INITIAL CONTACT

How contacted: Phone Call Individual Meeting Group Meeting Location:_____________________		
Level of Interest (Select all that apply, add notes)	Refused to meet	Positive interest
	Already converted	Send information
	Plan to convert	Follow Up Meeting/Call Date:
Current Chlorine Usage		
What type of containers do you use? 150# Bottles 1 Ton Cylinders Rail Cars :_____________________		
How much do you use?	Average_Flow:	Summer:
	Maximum_Month:	Winter:
Storage	Maximum_Inventory_Onsite:	Maximum_Delivery_Order:
	Minimum_Inventory_Onsite:	Minimum_Delivery_Order:
Notes:		
Regulatory Issues		
Which documents have you prepared? Process Safety Management (PSM) Risk Management Plan (RMP) Other :_____________________		
Have you ever had a chlorine gas release?	Date:	Impact to non-staff:
	Impact to staff:	Other:
What facilities are likely to be impacted by a catastrophic release?	Schools/Hospitals/Stadiums/Theaters:	Residences:
	Worst Case Radius/Population Impact Estimates: ____________miles Wind Direction: ________ Speed: ______mph ________casualties ________fatalities	Commercial/Industrial:
Notes:		

Do you have a chlorine gas scrubber installed? Capacity:________________	. Yes	. No
Would you like more information on chlorine gas risks?	. Yes	. No

Please turn to next page

ALTERNATIVE DISINFECTION EVALUATIONS

Have you ever considered alternative disinfection technologies?	. Yes	. No

Yes/No	**Technology**	**When did you consider/ why not implemented?**
Yes	Hypochlorite – bulk delivery	
Yes	Hypochlorite – on-site generation	

☐ Yes	Ultraviolet	
☐ Yes	Ozone	
☐ Yes	Combined chlorine (chloramine)	
☐ Yes	Chlorine dioxide	
☐ Yes	MiOX	
Other		
What are the obstacles you see to converting to an alternative disinfection technology? (Please rank)		
Rank	**Reason**	**Notes**
	Cost-Capital	
	Cost-O&M	
	Cost-Labor	
	Disinfection byproduct concerns	
	Contaminant concern (impure chemicals)	
	Effectiveness of alternative	
	Complexity of alternative	
	Risk of chlorine gas is acceptable to community	
	Risk of chlorine gas is acceptable to elected officials	
	Other	

Will you consider disinfection alternatives in the future?	☐ Yes	☐ No

Please turn to next page

DECISION-MAKING		
Facility/Political/Community – have any of the following expressed concerns with chlorine gas? If so, please describe.		
Facility staff/management	City Council/Mayor/City Manager	Community Organizations/Citizens
What factors need to happen before you would seriously consider a change?		
Regulations:		
Costs:		
Other:		
Who are the key decision-makers that need to agree to make a change?		

Name / Role / Organization	**Main criteira they will use to decide on change**
Plant:	
Management:	
Community:	
Political:	
Financial:	
Other:	

<u>Which of the above decision-makers know, or should know, about the gaseous chlorine information and risks? What can we/you do to educate them?</u>

FOLLOW UP INFORMATION

Are you aware of the MDEQ chlorine gas website?	. Yes	. No
Would you like the chlorine gas risk sheets sent to you?	. Yes	. No
Would you like a copy of the chlorine gas risk presentation for your use?	. Yes	. No
Would you like a follow up meeting or call with MDEQ or the consultant?	. Yes	. No

Follow up actions (initial and date as applicable): 1) Website sent 2) Risk sheets sent 3) Presentation sent 4) Call or meeting made

RISK FACT SHEET

Attack Involving Liquefied Chorine Gas Storage Containers

CAMEO (Computer Aided Management of Emergency Operations), an EPA developed suite of software, was used to estimate the health impacts from an instantaneous release of chlorine gas from common sized shipping and storage containers. The resulting plume of toxic gas would move downwind and collect in low lying areas before slowly dissipating. Depending on wind conditions, temperature, land structures and other variables the width of the toxic plume could be expected to range from about 1/8th to 1/4th of its length. If no wind is present, the plume would assume a circular shape as it passively dissipated. Death, permanent injury, and reversible injuries can be projected at the following distances downwind of the release.

Maximum Distance of Impact from Instantaneous Chlorine Release

Amount Released	Lethality	Permanent Injury	Reversible Injury
1 x 150 lb cylinder	0.38 miles	1 mile	1.8 miles
3 x 150 lb cylinders	0.5 miles	1.3 miles	2.3 miles
1 x One ton cylinder	0.85 miles	2.1 miles	3.6 miles
3 x One ton cylinders	1.3 miles	3.1 miles	5.3 miles
1 x 90 ton railcar	6 miles	See footnote	

The model assumes a total and sudden release of liquefied chlorine gas from standardized containers and measures airborne concentration indoors. The model uses inputs based on reasonably expected local conditions. The location is specified as southeast Michigan where unsheltered single level homes average 0.46 air change per hour. The plume is calculated based on 60-minute acute exposure guideline levels (AEGLs) where the concentration is expected to exceed the AEGL threshold for any amount of time during a 60 minute period. Weather conditions are specified as 36º F, wind SW at 2 mph, cloudy and 75% humidity. Statistically, the model is not capable of plume predictions beyond six miles in length with a high degree of confidence, however; estimates of the impacted area can be obtained by extending the footprint based on the first six miles as drawn by the model.

- The White House appointed Homeland Security Council in July, 2004 proposed a number of catastrophic disasters for use by Federal, State, and local emergency preparedness personnel in developing appropriate response capabilities. One scenario dealt with an instantaneous release of chlorine gas at a chlorine storage facility. The report indicated that in a heavily populated area up to 35,000 people could be exposed to lethal concentration of chlorine gas, with about one-half (or 17,500) deaths occurring before or during treatment. An additional 100,000 individuals would be hospitalized. As the modeled area of impact could extend 25 miles downwind of the release it was estimated that some 400,000 “worried” individuals could overwhelm the health care system as they sought medical attention.

- In testimony provided by the US Naval Research Laboratory it was indicated that a terrorist attack against rail cars located in a specific urban area could impact a 50 square mile area and result in 100,000 deaths within 30 minutes.

- In modeling the release of liquefied chlorine gas from a 100 pound cylinder at one of the US National Laboratories. At downwind distances of 2.5 miles individuals were expected to incur serious and irreversible injury. At downwind distances up to 5.6 miles individuals could expect reversible health effects related to mucous membrane irritation.

- In March 2005, in Asia a chlorine-carrying truck was involved in an accident that caused a release. Twenty-nine deaths were reported and 350 people were hospitalized.

Alternative Disinfection Considerations
Drinking Water Treatment

Chlorine Gas	
Advantages	*Potential Disadvantages*
Inexpensive	Cost is increasing
Tradition	Forms regulated DBPs
	Operator safety
	Transportation risk
	Public safety
	Needs scrubber system
Bulk Liquid Hypochlorite	
Advantages	*Potential Disadvantages*
Easy to use	Decays with light exposure and temperature
Supply readily available	Scaling of piping and feed system creates routine maintenance
Eliminates process safety management required by gas chlorine – reducing staff time	Trace contaminants (bromate)
	Requires bulk and day tanks for storage
	Chemical and maintenance costs greater than gas chlorine
On-site Generated Hypochlorite	
Advantages	*Potential Disadvantages*
Easy to use	Generates hydrogen gas which must be vented
Production chemicals readily available	More maintenance intensive than bulk hypochlorite
Eliminates process safety management required by gas chlorine – reducing staff time	Chemical and maintenance costs greater than liquid hypochlorite
No bulk storage needed	Significant capital costs
Avoids truck shipments of hazardous chemical	

UV	
Advantages	*Potential Disadvantages*
Small footprint	Water distribution systems still require chlorine residual
Reduced dependence on chemicals and truck shipments	Validation procedures for CT credit in water treatment not finalized
Provides additional log removal credit for water plants needing additional Cryptosporidium protection	Electrical cost
Easy to use	Lamp replacement cost
Ozone	
Advantages	*Potential Disadvantages*
Taste and odor control in addition to disinfection	Capital expense (must generate on site)
May reduce regulated DBPs	Cost of O&M
Ability to meet CT for water treatment	Complexity of O&M
Oxidation of wide range of compounds	New regulated DBPs (Bromate)
More powerful disinfectant, some disinfection of protozoans	No disinfectant residual
Combined Chlorine (with bulk or on-site generated hypochlorite)	
Advantages	*Potential Disadvantages*
Easy to use	Nitrification
Inexpensive	Fish owners and dialysis unit notification needed
Reduces regulated DBPs	Potential new unregulated DBPs
Eliminates taste and odor of free chlorine	
Chlorine Dioxide	
Advantages	*Potential Disadvantages*
Easy to use	Hazardous chemicals
Reduces regulated DBPs	New regulated DBPs formed

Alternative Disinfection Considerations
Wastewater Treatment

Chlorine Gas	
Advantages	*Potential Disadvantages*
Inexpensive	Cost is increasing
Tradition	Need to dechlorinate discharge
	Operator safety
	Transportation risk
	Public safety
	Needs scrubber system
Bulk Liquid Hypochlorite	
Advantages	*Potential Disadvantages*
Easy to use	Decays with light exposure and temperature
Supply readily available	Scaling of piping and feed system creates routine maintenance
Eliminates process safety management required by gas chlorine – reducing staff time	Requires bulk and day tanks for storage
	Chemical and maintenance costs greater than gas chlorine
On-site Generated Hypochlorite	
Advantages	*Potential Disadvantages*
Easy to use	Generates hydrogen gas which must be vented
Production chemicals readily available	More maintenance intensive than bulk hypochlorite
Eliminates process safety management required by gas chlorine – reducing staff time	Chemical and maintenance costs greater than liquid hypochlorite
No bulk storage needed	Significant capital costs
Avoids truck shipments of hazardous chemical	
UV	
Advantages	*Potential Disadvantages*
Small footprint	Not effective if turbidity present
Reduced dependence on chemicals and truck shipments	Electrical cost
Easy to use	Lamp replacement cost
Eliminates dechlorination feed system	

Utility Presentation

Water and Wastewater System Gaseous Chlorine Reduction

Michigan Department of Environmental Quality

U.S. Department of Homeland Security

Non-UASI and UASI

CDM DEQ Prein&Newhof

Introduction

- Purpose
  - To show why conversion from gaseous chlorine is a benefit.
  - To explain what is involved in converting.
  - To discuss your plans and concerns.
  - To answer your questions.

CDM DEQ Prein&Newhof

Why convert from chlorine?

Public Safety Expectations have changed since 2001.

A. Chlorine gas is a deadly hazard
   i. Heavier than air
   ii. 2 ppm can cause harm
B. Chlorine releases kill people
C. Chlorine gas can be a weapon

CDM DEQ Prein&Newhof

Wastewater Treatment Plants

- UV disinfection eliminates chlorination <u>and</u> dechlorination
- Fewer Compliance Issues
  - (PSM, SARA Title 3, OSHA, etc.)
- Possible operational cost savings

CDM DEQ Prein&Newhof

Parameters for Comparison

- **Microbes Affected:** ***E. Coli*** **is easy.** ***Giardia*** **&** ***Cryptosporidium*** **are hard**
- **Disinfection Byproducts: THMs, HAAs, Chlorites, Bromates,**
- **Residual: Disinfection in the System**
- **Taste & Odor Control: Mid-weight Organics**
- **Cost & Reliability: Familiarity is good**
- **Safety: Gases tend to escape**

CDM DEQ Prein&Newhof

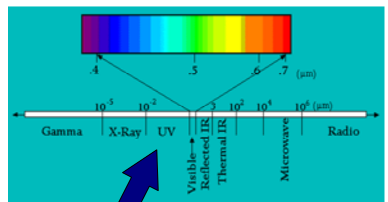
Conversion Options Drinking Water

- Liquid Sodium Hypochlorite (most common)
- Ozone
- Ultraviolet
- Chlorine Dioxide
- On-site generation Sodium Hypochlorite from salt

CDM DEQ Prein&Newhof

Conversion Options Wastewater

- UltraViolet
- Other alternatives



CDM DEQ Prein&Newhof

Examples of Converted Plants in MI

- Converted Water Treatment Plants
  - Ann Arbor
  - Big Rapids
  - East Lansing
  - Holland
  - Lansing
  - Ludington
  - Muskegon
  - Muskegon Heights
  - Owosso
  - Schoolcraft
- Converted Wastewater Treatment Plants
  - Wayne County Downriver (Wyandotte)
  - Ypsilanti Community Utilities Authority
  - Ann Arbor
  - Grand Rapids
  - Lansing
  - Chelsea
  - Milan
  - Frankenmuth

CDM DEQ Prein&Newhof

Converted Plants

CHELSEA-CONVERTED CHLORINE TANK

CDM DEQ Prein&Newhof

Conversion Options

MUSKEGON-SODIUM HYPOCHLORITE PUMPS

HOLLAND-SODIUM HYPOCHLORITE PUMPS

CDM DEQ Prein&Newhof

Conversion Options

HOLLAND-DAY TANK

MUSKEGON-DAY TANK

Frequently Asked Questions

1. How much does it cost to convert?

Size of Plant	*Project Cost Range*
Up to 1.0 mgd	\$5,000 – \$400,000
1.0 mgd – 5.0 mgd	\$400,000 – \$1.5M
Over 5.0 mgd	\$0.5M +

Frequently Asked Questions

2. Will there be grants to cover the costs?
   a) Possible DHS Funding
   b) DWRF program (WTP) or SRF (WWTP)
3. Will the DEQ force utilities to convert?
   a) No plans to at this time.
4. What are the experiences of utilities that have converted?
   a) Generally positive.

CDM DEQ Prein&Newhof

The Next Steps

- Feedback to MDEQ for non-UASI and UASI
- Feasibility Study/Tools for Evaluation
- Design
- Construction Permit

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Water and Wastewater System Gaseous Chlorine Reduction

Michigan Department of Environmental Quality

U.S. Department of Homeland Security

Non-UASI and UASI