# CHLORINATION EQUIPMENT SELECTION GUIDELINES

### **PROVINCE OF NEWFOUNDLAND & LABRADOR**



## A GUIDE FOR THE SELECTION OF APPROPRIATE DISINFECTION EQUIPMENT FOR MUNICIPAL APPLICATIONS

## DEPARTMENT OF ENVIRONMENT & CONSERVATION DEPARTMENT OF MUNICIPAL AFFAIRS

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These guidelines were developed to address the issue of disinfection design and equipment selection for the Province of Newfoundland and Labrador. The two lead Departments involved were the Department of Municipal Affairs, Engineering Services Division and the Department of Environment & Conservation, Water Resources Management Division.

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## **CHLORINATION EQUIPMENT SELECTION**

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### **EXECUTIVE SUMMARY**

A Committee with representatives from the Departments of Environment and Conservation and Municipal Affairs was formed to research information on gas and hypochlorite disinfection equipment and prepare a report of their comparison and make recommendations on preferred types of equipment. The comparison would concentrate on gas and hypochlorite equipment as these two types of disinfection equipment are the predominant types in use in the province.

During the research phase it was determined that, in the past, equipment selection was based primarily on population only. This resulted in some communities with systems that were unsuitable, ineffective, and consequently, fiscally demanding to operate.

The criteria used in this report to compare both gas and hypochlorite equipment types are: (i) population; (ii) capital cost; (iii) operations and maintenance cost; (iv) life cycle cost; (v) flow rate; (vi) chlorine demand; (vii) operator requirements and knowledge; (viii) hazard/safety; (ix) water quality parameters; (x) corrosion; and, (xi) system optimization.

The report concludes that the selection of disinfection equipment for any community should be based on specific circumstances relevant to the community under consideration. The two main factors which have the most affect on the selection of disinfection equipment are flow rate and chlorine demand.

### PURPOSE

This document provides a generalized approach that is intended to be a concise yet inclusive coverage of design criteria to be considered by designers and owner/operators of water supply systems in choosing the most appropriate form of disinfection equipment for their needs.

It is recognized that many forms of disinfection are available and technologically viable for many applications in either a primary and secondary application or combinations thereof. However, chlorination is recognized as the most feasible and practical application and is used in its various forms throughout distribution systems across the province.

The purpose of this document is to provide relevant information to enable an informed decision of the most appropriate choice of either hypochlorite or gas disinfection equipment. This decision should not be made lightly or quickly or in isolation nor should it be based on rigid or prescriptive factors. Some of the factors are service population, affordability, system hydraulics, demographics & flow requirements, water quality, operational requirements, and safety issues. These factors and others need to be considered in a broad scope decision making approach that is inclusive of all pertinent factors.

### **BACKGROUND/HISTORY**

Funding programs of the Department of Municipal Affairs have been made available through Capital and Infrastructure Works Programs including the Disinfection Assistance Program. Funding for the installation of new disinfection equipment and the upgrading of existing systems have been given high priority in an attempt to help communities provide safe potable water for their consumers.

It has been the experience of the Department of Environment and Conservation and the Department of Municipal Affairs that a number of communities can not afford or are not willing in some cases to operate and maintain disinfection systems for a number of reasons. These range from the perception that chlorinated water causes cancer, it creates objectionable taste and odour problems and disinfection systems are too expensive to operate.

The unwillingness of communities to operate their disinfection systems is more prominent for groundwater supplies. Councils and consumers feel that groundwater does not require any treatment.

An engineering cost benefit analysis of gas versus hypo chlorination was undertaken in 1994. The study concluded that over a 10 year period, gas equipment would be more economical. This was based on a number of assumptions including the fact that the community would be fully serviced over the life cycle of the system and population would increase. These assumptions were misleading and incorrect and, as a consequence, a number of smaller communities were saddled with gas equipment that remained in service until problems were experienced. Also, based on these assumptions, gas equipment was sized to meet projected demands and resulted in oversized systems that could not adequately handle low flow conditions.

The issue of installing gas chlorination equipment for smaller communities that cannot afford to adequately operate and maintain them has again been brought to the forefront and is the basis for the formation of this committee.

#### **Chlorination System Types**

The majority of disinfection systems installed consist of either gas chlorination or hypo chlorination.

**Gas Equipment** – consists of 68 kg (150 lb) or 908 kg (2000 lb) containers, chlorinator, weigh scales, switchover modules, injectors, vacuum lines, solution lines, diffusers, booster pumps and a flow meter. Safety requirements are mechanical ventilation, passive ventilation, warning devices and alarms, panic hardware for doors, showers and eye washes. A separate air tight room is required for chlorination equipment. 100% of chlorine gas is available for disinfection

**Hypo-chlorination Equipment** – consists of a solution tank, a metering pump, a solution line and a flow meter, and possibly storage tank. Safety requirements include an eye wash station, protective clothing and goggles. A separate room is not required. Hypo chlorination solution is generally made at a 12% concentration so only 12% of the solution is available for disinfection. There is a powder version (HTH) that has 65% chlorine available for disinfection. This version is usually used in remote areas where there is no delivery during the Winter season. Therefore, the powder version is the preferred method of disinfection in remote areas due to the fact that sodium hypochlorite has a recommended shelf life of three months while the powder version remains at 65% until mixed.

#### **Related Public Water Supply Information**

All of the data below has been generated by the Department of Environment and Conservation's Public Water Supply Database as of April 2005 and Boil Water Advisories (BWA's) as of May 31, 2005.

- There are 533 Public Water Supplies
- There are 160 gas systems serving 348,846 population, 17 of these systems are on BWA
- There are 2 gas systems with hypochlorite booster stations serving 5,750, 0 are on BWA
- There are 284 hypo systems serving 57,421 population, 137 of these systems are on BWA
- There are 10 hypochlorite (powder) systems serving 4,946 population, 1 of these systems is on BWA
- Total number of chlorination systems = 456
- Total population serviced with disinfection systems = 416,963 Total BWA = 155
- % of systems that are gas = 35.5% % population served by gas = 85.04% = 354,596 residents
- % of systems that are hypo = 64.5% % population served by hypo = 14.96% = 62,367 residents

Of the 155 BWA's, there are 17 gas systems on BWA which make up 11% of the BWA or a population served of 10,998.

Of the 155 BWA's, there are 138 hypo systems on BWA which make up 89% of the BWA or a population served of 24,229

Most of the BWA's can be attributed to the inability of small communities to adequately operate their disinfection equipment. Otherwise, they are turned off due to taste and odour complaints or associated cost to operate. Surprisingly, some communities that are on the BWA list have upgraded systems, yet, they are refusing to operate them.

### **SELECTION CRITERIA**

The criteria used to assist with the selection process includes capital cost, operation & maintenance cost, life cycle cost, population, flow rate & chlorine demand, operator requirement & knowledge, hazard/safety, water quality parameters and system optimization.

### **Capital Cost**

Information was collected from Municipal Affairs database for the Eastern, Central and Western Regions' chlorination system upgrades dating back to 2001. Costs were averaged over the three Regions for both gas and hypo-chlorination upgrades. The items used to obtain these costs were building, electrical, mechanical and chlorination. The average cost for hypo-chlorination is \$104,000 while the cost for gas chlorination is \$206,000. Basically, capital costs for gas chlorination is double that of hypo-chlorination.

### O & M Cost

Three items being considered are chlorine cost, electrical cost and labour cost. Information was gathered from operators on time frames for operation while the electrical and labour costs were obtained from the town clerk or LSD Treasurer. The cost of gas chlorine per person per year is approximately 50% of the cost for hypochlorite. Electrical costs for gas are higher than hypochlorite systems due to the fact that there are more electrical components on gas equipment. Labour costs for hypo-chlorination is higher than that of gas chlorination. This is accounted for in the fact that hypo-chlorination equipment requires more visits per month for chlorine solution mixing and cleaning of the chemical pump lines and diaphragms while gas equipment usually requires monthly cylinder changes and bi-monthly line/diaphragm cleaning.

### Life Cycle Cost

General information was computed to create a table for life cycle costs. Data used to create this table was inflation rate, rate of return, interest rate, consumption growth rate, flow rate, dosage, capital cost, chlorine cost, and maintenance cost.

Tables "A" and "B" shown on pages 8 and 9 below are included in the report text as examples only. Copies of the worksheet files are available upon request or may be found at <u>http://www.env.gov.nl.ca/env/Env/waterres/Template\_CWWS.asp#mark</u>. These tables can be used by communities and consultants to input relevant data for any municipal water supply system.

### Population

In the past, design practice was based primarily on population and little emphasis was placed on other related factors such as water quality, chlorine demand, flow variance, etc. However, it has been determined that such a limited approach is inaccurate and too simplistic to provide adequate and representative design.

## Table "A" - Hypochlorination

Town of : Any Town

Hypochlorite Liquid

Commencement Year:	2005	
Annual Inflation Rate:	<b>1.0%</b>	
Rate of return	<b>5.0%</b>	
Annual Interest Rate:	1 <b>0.0%</b>	
Annual Consumption Growth Rate:	1.5%	
Average Flow Rate:	2.50	L/S
Dosage:	5.0	mg/l
Capital Cost:	\$ 104,000	
Cost of Chlorine per		
litre	\$1.24	
Concentration of Liquid Chlorine	<b>10.30%</b>	
Maintenance Cost 1st Year	2.340	

	Capital				Consumption	Cost per
Year	Cost	Chlorine	Maintenance	Total	СМ	СМ
2005	16,926	4,038	2,340	23,303	78,750	0.296
2006	16,926	4,300	2,363	23,589	79,931	0.295
2007	16,926	4,365	2,387	23,677	81,130	0.292
2008	16,926	4,430	2,411	23,767	82,347	0.289
2009	16,926	4,497	2,435	23,857	83,582	0.285
2010	16,926	4,564	2,459	23,949	84,836	0.282
2011	16,926	4,633	2,484	24,042	86,109	0.279
2012	16,926	4,702	2,509	24,136	87,400	0.276
2013	16,926	4,773	2,534	24,232	88,711	0.273
2014	16,926	4,844	2,559	24,329	90,042	0.270
PW Total	\$130,694	\$34,615	\$18,829	\$184,138	842,839	
PW			\$184,138			
Equivalent	Annual Cost		\$23,847			
Ave Cost P	er Cubic Meter		0.283			
Ave Cost pe	er 1000 Imp Gal		1.286			

Note:

1. Capital cost include building, electrical, mechanical & chlorination cost

2. Costs which are the same for both gas & sodium hypochlorite systems are not considered (i.e. power supply costs, building heating costs).

### Table "B" – Gas Chlorination

Town of : Any Town

### **Chlorine Gas**

Annual Inflation Rate:	1. <b>0%</b>	
Rate of		
return	<b>5.0%</b>	
Annual Interest Rate:	<b>10.0%</b>	
Annual Consumption Growth Rate:	1.5%	
Average Flow Rate:	2.50	L/S
Dosage:	5.0	mg/l
Capital		-
Cost: \$	216,000	
Cost of Chlorine per lb	\$1.00	

Maintenance Cost 1st Year

1,740

Year	Capital Cost	Chlorine	Maintenance	Total	Consumption CM	Cost per CM
2005	35,153	866	1,740	37,759	78,750	0.479
2006	35,153	923	1,757	37,833	79,931	0.473
2007	35,153	936	1,775	37,864	81,130	0.467
2008	35,153	950	1,793	37,896	82,347	0.460
2009	35,153	965	1,811	37,928	83,582	0.454
2010	35,153	979	1,829	37,961	84,836	0.447
2011	35,153	994	1,847	37,994	86,109	0.441
2012	35,153	1,009	1,866	38,027	87,400	0.435
2013	35,153	1,024	1,884	38,061	88,711	0.429
2014	35,153	1,039	1,903	38,095	90,042	0.423
PW	\$271,442	\$7,426	\$14,001	\$292,869	842,839	
Total PW		. ,	\$292,869			
Equivalent Annual Cost			\$37,928			
Ave Cost Per C	Cubic Meter		\$0.450			
Ave Cost per 1000 Imp Gal			\$2.046			

Note:

1. Capital cost includes building, electrical, mechanical & chlorination cost

2. Costs which are the same for both gas & sodium hypochlorite systems are not considered (i.e. power supply costs, building heating costs).

### Note:

Of all the input data, the factors that have the greatest influence on Equivalent Annual Cost are flow rate, dosage, and capital cost. Please consult the Regional Offices of the Department of Municipal Affairs in your area for a workable copy of the worksheet.

### Flow Rate & Chlorine Demand

Gas chlorination equipment has a low level control limitation for systems requiring less than 0.68 kgs per day (1.5 lbs/day). Although flow control may be governed at these low dosage levels, stability and sensitivity of adjustment control is considered difficult and should be avoided.

Hypo-chlorination equipment does not have these limitations and are preferred for low dosage regimes.

### Chart "A" – Dosage vs Flow



### Note:

Area below curve represents hypo-chlorination and area above represents either gas or hypochlorination.

### **Operator Requirement & Knowledge**

The satisfactory operation and maintenance of both gas and hypo-chlorination equipment depends a great deal on the knowledge and experience of the operator. The question that we wish to explore is whether there is a significant difference in the complexity of operating gas chlorination and hypo-chlorination types of equipment. What are the prerequisites necessary in order to receive adequate training and education to proficiently operate each system successfully? Are there any underlying differences that would make one system preferred for a specific sized application? And, are there any specific limitations or challenges that one type of system would present that would result in it not being preferred over the other?

It is understood that in many small systems the operator is required to perform multiple tasks. They are usually hired locally and based on their ability to operate the Town's heavy equipment such as the snow

plough, backhoe, loader, and truck. They are expected to be mechanically inclined in order to make needed repairs and maintenance on the entire Town's equipment. Their duties range from snow clearing to garbage collection, and may include road maintenance and repair, maintenance of recreational facilities, and operation of the water and sewer systems and related infrastructure. They are front line managers to carpenters to labourers to operators. Previous knowledge and experience in operating water supply systems and in particular, chlorination systems, usually is secondary in importance and the operator is expected to learn on the job with minimal training.

It is within the context of this reality, for small systems in particular, that we must explore the realm of selecting and recommending one particular type of equipment over the other.

The Operator Education and Training Section has provided training sessions in the operation and maintenance of both gas and hypo-chlorination systems over the last number of years. Of the 162 gas systems in the province, 124 have received training and of the 294 hypo-chlorination systems, 251 have received training. A total of 193 operators of gas systems and 2470perators of hypo-chlorination systems have received training as of May, 2005.

There is some difference in training requirements between the two types of equipment, but it is not significant. Operators of hypo-chlorination equipment need to know about solution mixing, solution degradation, strength of received product, etc. Gas system operators deal more with the mechanical/physical operation of their equipment, and safety is more of a concern. However, both training modules can be provided to any community in the province within a reasonable period of time. Therefore, selection of either gas or hypo-chlorination equipment would have little bearing on operator education and training requirements.

### Hazard/Safety

Chlorine gas and hypochlorite are classed as hazardous materials and as such should be treated that way. Each type of disinfectant has its advantages and disadvantages. The transportation/handling; mixing; storage; exposure as well as other types of complementary equipment were reviewed. Chlorine gas can be considered a higher hazard/safety risk as compared to hypochlorite.

Chlorine is the disinfectant of choice for the majority of water systems in the Province. We have a small number of powdered chlorination systems (powder is mixed with water to create hypochlorite) while the remaining chlorination systems are either gas or hypochlorite. Table "C" on page 12 below was created from information obtained from Federal and Provincial Departments responsible for regulating chlorine as well as industry suppliers.

ITEM	GAS CHLORINE	HYPO CHLORINE
Hazardous Material	Yes, 100% chlorine	Yes, 10 – 12% chlorine
Transportation	All gas must be shipped	Transportation of up to 500
_	under Transportation of	kilograms not covered
	Dangerous Goods Act.	under Act. Over 500
	Carriers must be certified,	kilograms is covered under
	vehicles placarded,	the Act.
	cylinders must be upright	
	and either attached to	
	vehicle or in a proper rack.	
	Vehicle carrying capacity	
	determines amount shipped.	
Mixing	No	Yes
Storage	Sealed room with gas	Controlled room
	detectors and controlled	temperature and no
	temperature.	exposure to direct sunlight.
Exposure Risk	Extreme	Moderate
Ventilation	Mechanical	Passive
Detectors	Yes	No
Eyewash	Yes	Yes
Breathing Apparatus	Require full face	Some individuals may
	compressed oxygen system,	require ½ face mask
	i.e., Scott Air Pac	
Handling	Wear rubber gloves,	Wear rubber gloves,
	coveralls and eye protection	coveralls and eye protection
Repair Kits	Yes	No
Community Exposure	Yes	Nil

# **Table "C" – Chlorine Gas to Hypo-chlorite Safety Comparisons**

### Water Quality Parameters & Corrosion

When first determining the amount of treatment required for a new water system or the upgrade of an existing water system, then the pH of the raw water must be measured along with the approximate degree of saturation of calcium carbonate in the water using the Langelier Saturation Index. The Langelier Saturation Index will indicate the potential corrosiveness of the water to be treated.

The pH of the raw water and the potential corrosiveness of the water are extremely important when the only form of treatment to be provided is disinfection using chlorine.

Most surface waters in the province have very little alkalinity while some groundwaters have excessive amounts of hardness. Based upon past experience, it has been shown that waters with low alkalinity disinfected with gas chlorine have a tendency to lower the pH which in turn causes excessive corrosiveness in the distribution system. In groundwaters which have pH higher than 8, the disinfecting capability of chlorine at these high pH levels is compromised. The use of sodium hypochlorite in groundwaters may raise the pH of the water even higher which will affect disinfection. In such cases, the pH of water may have to be lowered.

### **System Optimization**

There are a small number of municipalities in the province that have a combination of partially looped and partially ribboned systems. A ribbon system consists of a relatively long waterman that terminates at one or more dead ends whereas a looped system does not have any dead ends.

Common characteristics of ribbon systems include:

- Low flow rates.
- Long resident time to the extremities of the system.
- Chlorine depletion part way through the system.

In order to achieve a satisfactory free chlorine residual at the ends of the system it is necessary to inject chlorine at a high dosage rate at the pumphouse, the amount of chlorine required is directly related to the water quality and the flow rate.

Common problems associated with ribbon systems:

- Undesirable taste and odour problems associated with chlorine especially at the households close to the beginning of the system.
- Elevated disinfection by-products (DBP's) throughout the system.

#### Possible solutions:

The installation of a booster chlorination station somewhere close to the center point of the system is recommended to help alleviate the aforementioned problems.

The chlorine dosage at the pumphouse could be reduced, undesirable tastes and odour problems associated with chlorine will be reduced or eliminated, contact time and chlorine depletion will be reduced and THM levels will be lowered.

### CONCLUSION

- The report researched a number of criteria factors and it was concluded that flow rate and dosage demand have the greatest affect on the disinfection equipment selection process.
- It has been determined that population alone can not be used as a sole selection criteria, although desirable, as multiple variables come into play such as chlorine demand, flow variance, leakage, and, industrial/commercial requirements
- Gas chlorination equipment has limited dosage control at or below 0.68 kg or 1.5 lb per day.
- Capital cost of gas chlorination equipment is approximately double that of hypo-chlorination equipment.
- The purchase cost per person for sodium hypochlorite is approximately 3.8 times that for chlorine gas.
- Calcium hypo-chlorination or HTH powder is more suited and recommended for remote areas based on transportation and hypochlorite storage or shelf life limitations.
- Operator education and training is not a distinguishing factor in selecting type of equipment.
- The level of certification training as recommended by the Association of Boards of Certification (ABC) is equivalent for both types of equipment, however, familiarity and proficiency of the operator is considered greater for the gas equipment due to more complex components.
- Both hypochlorite solution and chlorine gas are hazardous materials, however, gas equipment requires greater safety awareness, housing, and process control provisions.
- Chlorine gas will lower the pH of water and may require review for possible corrosion concerns.
- It is suggested to use Chart "A" as well as Tables "A" & "B" to determine which type of equipment may be most suited for a particular application. Critical input data would include chlorine demand of the proposed source water and flow regime. The most cost effective equipment type should be selected. In some cases, where life cycle cost may be comparable, decisions may be based on preference related to other subjective factors.