# Best Management Practices for Controlling DBPs in NL:

#### What Works, What Doesn't,

and What Could?



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# Typical Water System



#### Disinfectant Use

#### Type of Primary Disinfectant: Newfoundland and Labrador



#### What Is a DBP?

□ [Precursor Material] + [Disinfectant] = [Disinfectant by-product or DBP]

Natural Organic Matter	Chlorine	THMs
Bromide	Ozone	HAAs
Ammonia	CIO <sub>2</sub>	HANS
Iodide		Bromate
		Chlorite/Chlorate
		Many Others

Other factors that play a role in the formation of DBPs:

 Water Temperature, pH, Contact Time, Disinfectant Dose

### Toxicological Effects of DBPs

Class of DBPs	Compound	Rating	Effects
THM	Chloroform	B2	Cancer, liver, kidney and reproductive effects
	Dibromochloromethane	С	Nervous system, liver, kidney and reproductive effects
	Bromodichloromethane	B2	Cancer, liver, kidney and reproductive effects
	Bromoform	B2	Cancer, nervous system, liver and kidney effects
HAA	Dichloroacetic acid	B2	Cancer, reproductive and developmental effects
	Trichloracetic acid	С	Liver, kidney, spleen and developmental effects
Inorganic compounds	Bromate	B2	Cancer
	Chlorite	D	Developmental and reproductive effects 5

# DBP Guidelines and Communities with DBP Issues

Compound	CCME/ Health Canada (2008)
Total THMs (mg/L)	0.100
Bromodichloromethane (mg/L)	0.016
HAA5 (mg/L)	0.080
DBP Type	Number of Communities with Issues
THM	124
BDCM	45
HAA (guideline of 0.06 ug/L)	184

#### DBP Behaviour in NL

			Region	Maxımum
	800 1	Provincal THM data summary: 2000-2005		THMs (ug/L)
	700	*	Eastern	573
	/00-	<del>♀</del> ¥	Central	688
	600-		Western	740
g/L)	500 -		Labrador	460
) jn	400 -			
ZHT	300 -		Region	Maximum
	200 -			HAAs, (ug/L)
	200 - 100 -	57.35	Eastern	HAAs, (ug/L) 1118
	200 - 100 - 0 -	57.35	Eastern Central	HAAs, (ug/L) 1118 1114
Med	200 - 100 - 0 - lian = 57.3	57.35 57.35 57.35 57.35 57.35 57.35	Eastern Central Western	HAAs, (ug/L) 1118 1114 2409

#### Average THMs by Location in Distribution System: 2000-2005



Seasonal Variation of THMs: 2000-2005



### Decision Making Framework for Selecting DBP Corrective Measures





#### Probable Causes



#### Corrective Measures



#### Corrective Measures- Policy

- Policy for POU/POE treatment- as temporary or emergency measure
- Policy to promote the use of alternative disinfectants- 95% of disinfection systems use chlorine
- Policy to promote PWDUs- Rural Drinking Water Safety Initiative





### Corrective Measures- Source- Watershed Protection

- 259 protected surface water supplies in province
- Protected under Section 39 of the Water Resource Act
- All development activity goes through a permitting process
- Most PPWSAs relatively pristine with little development activity
- No significant difference in mean THM levels from protected versus unprotected surface water sources- THM precursors occur naturally



#### Corrective Measures- Source- Coastal Influence

- The greater the distance from the coast, the lower the THM average
- Water sources should be sited as far from the coast as possible in locations sheltered from ocean saltwater spray, and prevailing coastal winds



### Corrective Measures- Source-Alternative Water Sources

#### Fox Roost- Margaree: Margaree Pond





Status of Watershed	Mean THM (Standard Deviation)
River	86.6 (± 58.36)
Pond	85.8 (± 65.14)
Lake	73.0 (± 55.29)
Brook	59.6 (± 51.67)
Reservoir	50.9 (± 50.74)
Canal	50.29
Spring	31.8 (± 4.71)
Drilled/ Reservoir	21.6
Drilled	15.7 (± 27.7)
Dug	6.73 (± 5.66)
Drilled/Dug	3.06 15

### Corrective Measures- Source-Alternative Water Sources

- DOC is the best available predictor of DBP formation potential
- Pick alternative water sources with DOC < 4.2 mg/L
- DOC high in watersheds with a large percentage of bog, marsh, fens, swamp, open shallow water
- The larger the percent of the watershed classified as exposed (rock, nonvegetated), the lower the THM levels



### Corrective Measures- Source-Alternative Water Sources

- Of 309 public surface water supplies, 114 (37%) have dams
- BMPs for reservoir flooding
  - Remove vegetation
- Stop mixing groundwater with surface water
  - DOC from surface water and bromide from groundwater
  - Port au Port West, Port au Choix

 Stephenville THMs > 200 ug/L, after switch to groundwater THMs < 20 ug/L

Ned's Pond, former water source for Stephenville, after water levels lowered



### Corrective Measures- Source- Relocate Intake

#### Ideal intake location:

- Off bottom of waterbody to ensure conduit openings are not clogged by silt, sand, gravel, debris
- Deep enough to ensure submersion during extreme low water events
- Relocating intake to deeper water can reduce water temperatures and DBP formation
- Optimal intake is one that permits varying the depth of water withdrawal to alternate with seasonal changes



#### Corrective Measures- Source

- Shallow ponds with long fetch lengths in the direction of prevailing winds prone to wave generation and agitation of bottom sediments leading to turbidity
  - Cow Head, St. Paul's, Brighton, King's Point
- Horizontal intake filtration berms have a negligible effect on reducing DBP precursors



# Corrective Measures- Chlorine Demand Management- Optimize Dosage

- Chlorine dosage should be kept as low as possible while maintaining required primary and secondary disinfection objectives
- Optimize disinfectant dose
  - Typical chlorine dose is 5 mg/L
  - Chlorine dose is high if over 7 mg/L or over 4 mg/L at first user
- Optimize location of chlorination system
  - Closer to first user- required contact time is 20 minutes
  - Downpipe of tank
- Adjusting chlorine dosage under different seasonal conditions may help reduce the formation of DBPs
  - Summer and fall see peaks in water temperature and DOC



## Corrective Measures- Chlorine Demand Management- Chlorine Boosters

- Booster chlorination strategy involves multiple coordinated doses of chlorine applied throughout the distribution system
  - Maintain chlorine residuals at ends of distribution network
  - Reduce single high chlorine dose
  - Reduce the total amount of chlorine used in the system per day
- 13 communities with chlorine boosters in NL
  - Tend to aggravate THM problem in most cases, however, in some instances appear to have reduced THM levels
  - Depends on operational factors
- Chlorine boosters may reduce DBPs if:
  - Installed at optimal locations
  - If overall chlorine use reduced
  - Chlorine dose is high and/or residuals over 4 mg/L in town

### Corrective Measure- Chlorine Demand Management- Dosage Control

- Majority of systems in NL have manual chlorine control with no working flow meter
- Other chlorine dosage control options:
  - Manual control with a metering device
  - Automatic control with metering device
  - Automatic control with a flow meter and/or chlorine residual analyzer
- Problems of O&M and fluctuating chlorine residuals with CI residual analyzers

- To control chlorine dosage all towns disinfecting with chlorine should use, at a minimum:
  - flow meter readings
  - manual chlorine residual readings

Water System Flow Meters: Newfoundland and



# Corrective Measures- Retention Time Management

#### Water Storage Tank Classification: Newfoundland and Labrador



Problems:

- Poor mixing of water
- Dead zones
- Excessive retention time
- Lack of water turnover
- Unnecessary storage

### Corrective Measures- Retention Time Management

#### Optimize tank location and type

- Beginning of system
- Elevated storage for pressure issues
- Adjust pump schedules to:
  - Change water level in tank and force turnover of water in tank
  - Increase velocity of inflow into tankvariable speed pumps
  - Reduce the volume of storage required
- Reduce storage capacity
  - Reduce maximum water level in tank
  - Remove storage permanently when no issues with supply or pressure



# Corrective Measures- Retention Time Management- Increase Mixing

#### Common Fill Draw Line



- Replacing a common inlet/outlet with separate pipes
- Increasing the distance between the inlet and outlet

# Corrective Measures-Retention Time Management- CFD Modeling



St. Paul's Water Storage Tank: Dimensions: 12 x 5 m Inlets: 2 Outlets: 1

5.02469e-2 3.38497e-2 1.74525e-2 1.05534e-3

m/s

# Corrective Measures- Retention Time Management- Increase Mixing

Inlet jet deflected off baffles, walls or other obstructions



Install baffles Install paddle or impellor devices to improve mixing within the tank

# Corrective Measures- Retention Time Management- Increase Mixing



- Moving the location or orientation of the inlet
- Reducing the diameter of the inlet
- Installing a duckbill valve to increase the velocity of the inlet jet

### Corrective Measures- Retention Time Management- Tank Aeration

- Aeration is the process by which air is circulated through, mixed with, or dissolved in a liquid substance
- Some DBPs are volatile compounds that can be reduced through aeration
- Reductions of THMs of up to 70%
- Reduction of chlorine residuals



# Corrective Measures- Demand Management- System Flushing

#### Flushing of distribution systems can:

- Remove sediment built up in pipes
- Reduce water age in dead ends
- Increase water velocities in sections of pipe
- Higher disinfectant residuals
- Regular system flushing
  - Automated of manual
- Recommended best management practice & first response measure
- Continuously bleed system at dead ends

#### Flushing programs in Burgeo, Gander, and St. Lunaire-Griquet

- Very turbid water and solid biofilm cake in the flushed effluent
- Total chlorine dosage dropped after flushing (in one case by 65 percent)
- free chlorine residuals have improved





- Optimize valve placement
- Re-routing of flows through valving
- Pumping to re-circulate water
- Increase demand with new connections

Abandon or downsize mains to reduce surplus or overall capacity in system Increases water velocity Reduces retention time Clean, replace or reline pipe Old pipe > 25 years Cast Iron pipe





Corrosion and tuburculation in DI pipe

#### Loop distribution network

- Avoid branching
- Minimize dead ends
- Long linear systems common

#### Upgrade distribution system

- Reconfigure, replace, abandon pipe
- New intake
- Large occasional demand on system



#### System maintenance

- Flushing, reservoir cleaning, leak detection
- Swabbing or pigging
- Pump, valve, hydrant, flow meter maintenance
- Increase capacity of water treatment plant
- Regionalization
  - Regional System- Exploits Region, St. John's
  - Regional Operator- Northern Peninsula







#### Well Maintained

#### Poorly Maintained



# Corrective Measures- Alternative Disinfectants

#### Alternative disinfectants to chlorine:

- Less likely or do not form chlorinated DBPs (UV)
- Chemical destruction of DBP precursors through oxidation (ozone, CIO<sub>2</sub>, MIOX)
- Alternate disinfectants include:
  - Chloramines, Ozone, ClO<sub>2</sub>, UV, MIOX
- Disadvantages of alternative disinfectants:
  - More expensive
  - Some may still have to be used in combination with chlorine (UV, ozone)
  - Form non-chlorinated DBPs
    - bromate, chlorite/chlorate, cyanogen chloride, N-Nitrosodimethylamine (NDMA)

#### Corrective Measures-Alternative Disinfectants



Chloramines-Dunville





Ozone- Gander



#### MIOX- Heart's Delight-Islington

#### Corrective Measures- Treatment- Water Treatment Plants

- Removal of DBP precursors provides the best assurance that DBPs will not form
- A WTP will not reduce DBPs if not designed to remove DBP precursors (NOM) or if the treatment system has not been sized adequately



### Corrective Measures- Treatment- Water Treatment Plants

Heart's Delight- Islington	<b>Conne River</b>	Gander	Grand Falls- Windsor	Pasadena
pH adjustment	Dual media pre-filters	Pre-filters	Prescreening	Pre-filters
Coagulation/ Flocculation	Micro-filtration	Ozonation	Coagulation/ Flocculation	Tread filter
Sedimentation	Ultra-filtration	Rapid sand dual media filtration	Sedimentation	UV
Filtration	Sodium carbonate addition	Carbon filtration	Rapid sand dual media filters	Chlorination
Chlorination	Chlorination	pH adjustment	pH adjustment	
		Chlorination/ Chloramination	Chlorination	

#### Corrective Measures- Treatment- Water Treatment Plants

Deer Lake	Channel-Port au Basques	Happy Valley- Goose Bay	Lourdes	Ramea
Pre-filters	Prescreening	Permanganate, Alum, Cl Addition	Primary multi-media filtration	Prescreening
Thread filter	Coagulation/ Flocculation	Green Sand Filtration	Permanganate Addition	Pre-chlorination
UV	Sedimentation	Sedimentation (backwash)	Multi-media filtration	pH adjustment
Chlorination	Dual media filtration	Post- Chlorination	Chlorination	Coagulation/ Flocculation
	pH adjustment			Sedimentation
	Chlorination			Dual media filtration
				Post-chlorination

#### Corrective Measures- Treatment-Filtration

#### **Types**:

- Granular- sand, gravel
- Chemical- GAC, greensand
- Weave-wire screens
- Polymer membranes with very small pore sizes

#### Communities with prefilters (50-100 µm):

 Buchans, Embree, Steady Brook, Isle aux Mort, Lewisporte, Port Anson, Seal Cove

#### Pre-filtration units alone do not affect THM levels

Filter Type	Pore Size
Screen filters	>10 µm
Thread filters	>3 µm
Micro-filtration	0.1-10 µm
Ultra-filtration	0.001-0.1 μm
Nano-filtration	0.0001-0.001 µm
Reverse osmosis	<0.0001 µm

#### Corrective Measures- Treatment- pH Adjustment and Iron/Manganese Removal

- THMs increase with increasing pH
- HAAs increase with decreasing pH
- NL surface waters naturally low in pH
- pH adjustment has had little discernable impact on THMs, could have more effect on HAAs
- pH adjustment should always take place postchlorination

- Fe/Mn common in both surface and groundwater in NL
- Can be responsible for a large portion of chlorine demand
- Removal of Fe/Mn can reduce overall chlorine demand, reduce chlorine dosage required, and potentially reduce DBP levels
  - Long Harbour- THMs reduced by 43%

### Corrective Measures- Treatment-Advanced Treatment

#### Removal of NOM

- Enhanced coagulation (EC)
- Granular activated carbon (GAC) filters
- Reverse osmosis or nanofiltration
- Peroxide addition- to oxidize difficult to treat organics
- Removal of total dissolved solids
  - Reverse osmosis or nanofiltration
  - Electro-dialysis reversal (EDR)
  - Ion exchange (IX)

- MIEX® resin process
- Ceramic membranes
- Ozone and bio-filtration combined
- Filtration using iron-oxide coated media
- Adsorption filters
- Distillation

#### Corrective Measures- Treatment- Potable Water Dispensing Units (PWDUs)

- A PWDU is a small scale water treatment system that treats only a fraction of total water demand on a distribution system
- Intended to treat only drinking water portion of total water demand- 5 Liters/person/day
- Water is stored on site at some centralized location for manual collection by users





### Corrective Measures- Point of Use/ Point of Entry Treatment

- Must be ANSI/NSF certified for removal of contaminants of concern
- Consumer is responsible for maintaining the system
- For very small communities that cannot afford any water treatment
- As an interim solution while a more permanent solution is being put in place
- Where DBPs may be high for only limited periods during the year
- For houses located on parts of the distribution system that have extremely high residence times and known DBPs problems

#### Corrective Measures- Other

- Improved design of water distribution systems
  - Modeling

#### Operator education and training and certification

- 221 operators in 117 towns or band councils have at least Class I certification for either Water Distribution or Water Treatment
- Trained operators an essential component of any DBP control methodology
- Communities should require that their water system operators be certified
- Combination of corrective measures



#### Solution Constraints



• To better match corrective measures with the needs of the community

### Integrated Decision Making Framework for Selecting DBP Corrective Measures

Expanded Decision Making F DBPs are over Consoling Ortholog Water Guadity Guidedines	ramework for Solinding DillP Cor	rective Measures								
Review Edisting		Corrective	latching Appropriate	1				Assessment of	Select Preferred Solutionist from Highest	Implement,
System for Probable Causes		Measures     (CM)	orrective Measures Probable Causes	]				Solution Constraints (CMs scored from 0-18)	Scoring Corrective     Measures	Nonitor and Review
		$\neg$		-						
Source	Demand	Policy	Policy	RTM	RTM	Alternative Disinfectants	Alt Disinfectant	Effectiveness inv the constant of order the		
1. Receiver contains flooded regelation	28. Large occasional demand on system	Policy of POUPOE beatrant	A=	Tank location and type -at beginning of system	21-23-34-25	Disinfection with chieven inves	A1	-moderale (1)- reser guideine -tigh (1)- betre guideine		
2. Shallowindake (< 1 m of	Wanthri	Policy to promote use of attemptive distributions		-multiple emister forks -elevated storage		Clainfection with spone	A1	Provid		
which or the low have point with long exposed frich length	121. Tank location/configuration	Policy to Pariside Philippe	AII .	Adjust pump ache date to: - optimize between demand and supply	17-12-23-24-15	Charlester with MICO.		-16gh (6)- >\$200,000 -moderate (1)- \$150,000-\$500,000		
3. Statisce weier source exposed to calibration influence	22. Delance between pumped	Source	Source	-force-formover of water in tenk -increase velocity of inflore into tenk		Bertheest	The strengt	-kev (2)- <\$150,000		
(vit las to ocean)	optimized with storage	Watershed protection Alternative valer substant	13456	Reduce storage capacity -take tark office	17-29-23-24-25	ureasznene Waler treate ert gilerte	6-5-7-9	Time Scale for Implementation		
DBP Precursors	22. High relation time in tank (> 24 fm)	-groundwater -surface water sources with DOC < 4.2 mg/.		-reduce maximum water level in tarik		-convertiel WTP -stradituritien		-moderate (1)- 1 to 12 months -short (2)- within a month		
<ol> <li>Many of high DOC surface water with groundwater</li> </ol>	24. Dead zones/poor mbing in	-and it shallow poods with long exposed hitsh lengths		Increase mong in tent: -separate interfacilies -before interface orientation of black	11/23/26/25	Point of application of CL in WTP sate effected in pre-delayted at	•	Remandence of Solution		
<ol> <li>High DOC is source value (&gt; 4.2 mg/L)</li> </ol>	25. Little verbriken in weder	Step mixing groundwater with surface water	4	<ul> <li>-sought of the second of the se</li></ul>		-no pre-chickration		-choit (0)- temporary -moderate (1)- confut life < 15 years		
8. High levels of brankle in	levels/tunever in task	Reserve): fooding: -and if fooding vegetated areas	145	-avoid shallfustion in tank -increase active volume in tank		Filmion -stadikalon or nanofitades	6579	permanent (2)- useful ille > 15 years		
2. High chickle dogs fished	0.6.10	<ul> <li>-ramove vegetation before to stang</li> <li>-ramove subscarged vegetation</li> </ul>		Tank evalue	17-23-34-25	-appropriately stand and standarted		Adverse Hydraulic Effects -elverse effect dt. visielies offete		
doze over 7 mgd, or over 4 mgd, at first point of use)	28. Poor operation and maintenance of system	Wind breaks around exposed coactal water assures with high BDCMs	24	Demand Management	Demand Ngmt	Installelengewere nemovel	7-9-10-29	-real impact (1) -positive effect (2)- system closer to ideal		
<ol> <li>Point of Clappitotion in WTP data this body into</li> </ol>	Other	Relocate intake to deeper water	2	Regular system fushing at dead ends	10512-12-15-17-09	-existence of the first for the systems		Advances Incount on Weiter Occility		
9. Higher chiedre use with	27. Maliple factors itsled	Figh quality water storage and recovery	A1	Continuously bleed system at deed ends	10512-12-12-16-17-09	-EC. RO, GAC for NOM -RO, EDR, LE for Brenide		-WD deferitorates (K)- parameters alreev deferitoration		
boartier system	28. Poor design of system	CDM	CDM	increase demand with new water connections	10512-12-12-15-17-08	Polable Water Dispensing Units (PMDUs)	A1	-no impact (1) -W2 improves (2)- parameters show		
(bulk <-0.5 c-1, wall <-1 mit)	28. High Federa (Fe > 0.3 mg/L) Mr > 0.05 mail (	Cylinite dehiriedari dasege II. -CI > 4.0 mg/L @ fatt star	10045679	Operational and Infrastructural	041	-ce in munity support		apprend		
11.H049H0-33	30. High per capita demand (>	-Cl > 8.2 mg/L (regularity) @ last user -booster on system		Optimize veive amongement	17	Point of Use	Point of Use	Acceptable to Stakeholders -egainst (3)- known or perceived latures dollfhood (1)- only area		
System Characteristics	500 Ligate	Re-locate chiefendion system: -cheerte fatueur	122456781621	-smoothe chariter of stud verves -locate shut valves in sneas of high demand		Point of usegoint of entry treatment	AB	-rappert (2)- no instans		
12. Long livear system (> 3 km)	>88.00	-dowspipe of tank		Re-routing of these in the system through vehicly	17	Training	Training	Meets all Necessary Regulations vibities resultions (D)		
12. Dranched system with multiple dead ends (> 3 DE)	12. Problems with chickne metiduals ( < 0.05 mg/L. > 4.0	Install chipshe boucher al optimal location II: -combined Clidose -categie Clidose -Cli 5-d directi -chipsheare	7-10	Pumping to recirculate water in the distribution system	17	Operator education and baining	AB-28	bordedine (1)- minor, temporary, insignificant violation		
14. Distance of chievination system to first point of use (>	-9A)	Chiprine dope control	1004567815	Abandoning or downstring mains	1-2-6-12-13-18	Cyres denast	ana a	Innets in galaxies (2)		
500 m or contect time > 40 min)		-automated flow or chiedre residual control -dedicated and cellified system operator		Clean, replace or relina: -aid pipe, cast iron pipe		Design	Design			
carbols on system				Loop distribution network	13	Exproved design of water distribution and treatment systems Assess DAPs for the Control of Stainfaction De-	20			
18. System is oversized (mox pipe v < 0.4 mR)				Upgrade disbibution system -reconfigure, replace, abandone pipe	2-18	Products				
12. High retention time in reterrink (n. 60 http:)				-new Intake System maktemence		Combination	Combination			
18. Pipe material and age (> 25 ym, cast iven)				-facting, reservoir cleaning -overthing or pigging -pump, flowmeter maintenance		Contribution of controllive measures where a single Citils ineffective	A			
19. Water treatment plant is understand				increase capecity of water treatment plant	19					
				Regionalization regional system or regional operator	A8					

#### Decision Making Framework and BMPs

- Developed as an iterative process
- Developed based on:
  - known DBP formation behaviour and best management practices used to deal with DBPs in other jurisdictions
  - assessment of DBP characteristics and response to existing corrective measures in NL
  - modeling of water distribution systems with DBP problems in NL

### Three Main Products from BMPs for DBPs Report

- 1. Best Management Practices for the Control of Disinfection By-Products
- Decision Making Framework for the Selection of DBP Corrective Measures
- Checklist of Community Information for DBP Management
- Audience: Government, Towns, Consultants
   Available on Water Resources web site soon

# Key Messages

- The majority of communities with DBP issues are very small and small towns in rural NL
- There is a risk trade-off with water disinfection between microbial pathogens and disinfection byproducts
- Corrective measures to address DBP issues must not fix one problem only to create a dozen more
- There is no standard solution that will address the issue of high DBP levels in drinking water for all communities
- Every distribution system is unique and responds differently to different possible corrective measures

#### Thank You

