DBP Control I

Lisa Crabtree, District Engineer

Abingdon Field Office

VDH-Office of Drinking Water

This presentation in 2 minutes

Disinfection of drinking water is good

What are disinfection byproducts (DBP)?

Potential health impacts of DBP?

How monitor & regulate DBP?

What to do about DBP?

When we're done

You should be able to:

1. Explain why DBP are undesirable
2. Describe TTHM and HAA5
3. Calculate LRAA & OEL
4. Name three ways to address DBP in a water system

Now is the time to focus

This presentation

Disinfection of drinking water is good

What are disinfection byproducts (DBP)?

Potential health impacts of DBP?

How monitor & regulate DBP?

What to do about DBP?

Disinfection protects public health

Disinfection inactivates pathogens in water

A pathogen is a bacterium, virus, or other microorganism (fungus, parasite) that can cause disease to its host

Public water supply disinfection practices:100 years and counting

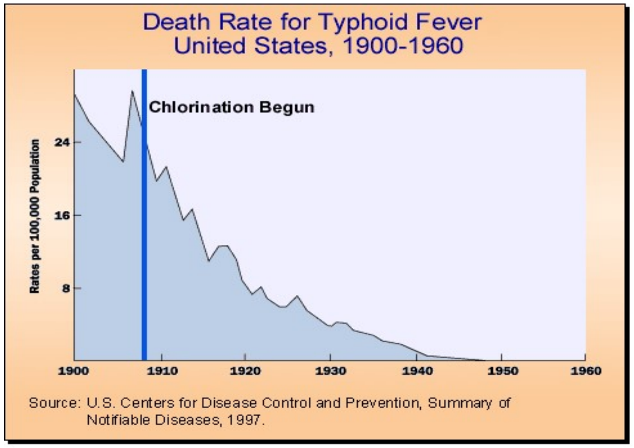
1902 - first continuous chlorination of municipal drinking water (**Belgium**)

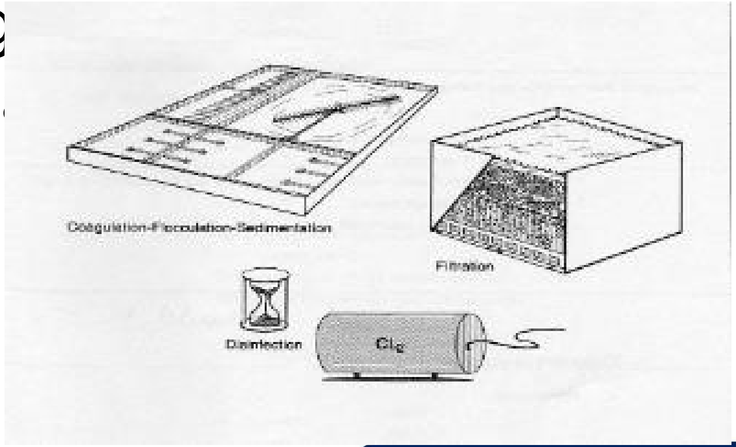
1908 - first continuous disinfection of municipal drinking water in **U.S.** *NaOCl*

1906 WTP use Ozone (**Nice, France**)

1914 - “It is a matter of common knowledg nowadays that the ultraviolet rays have . strong bactericidal power.”

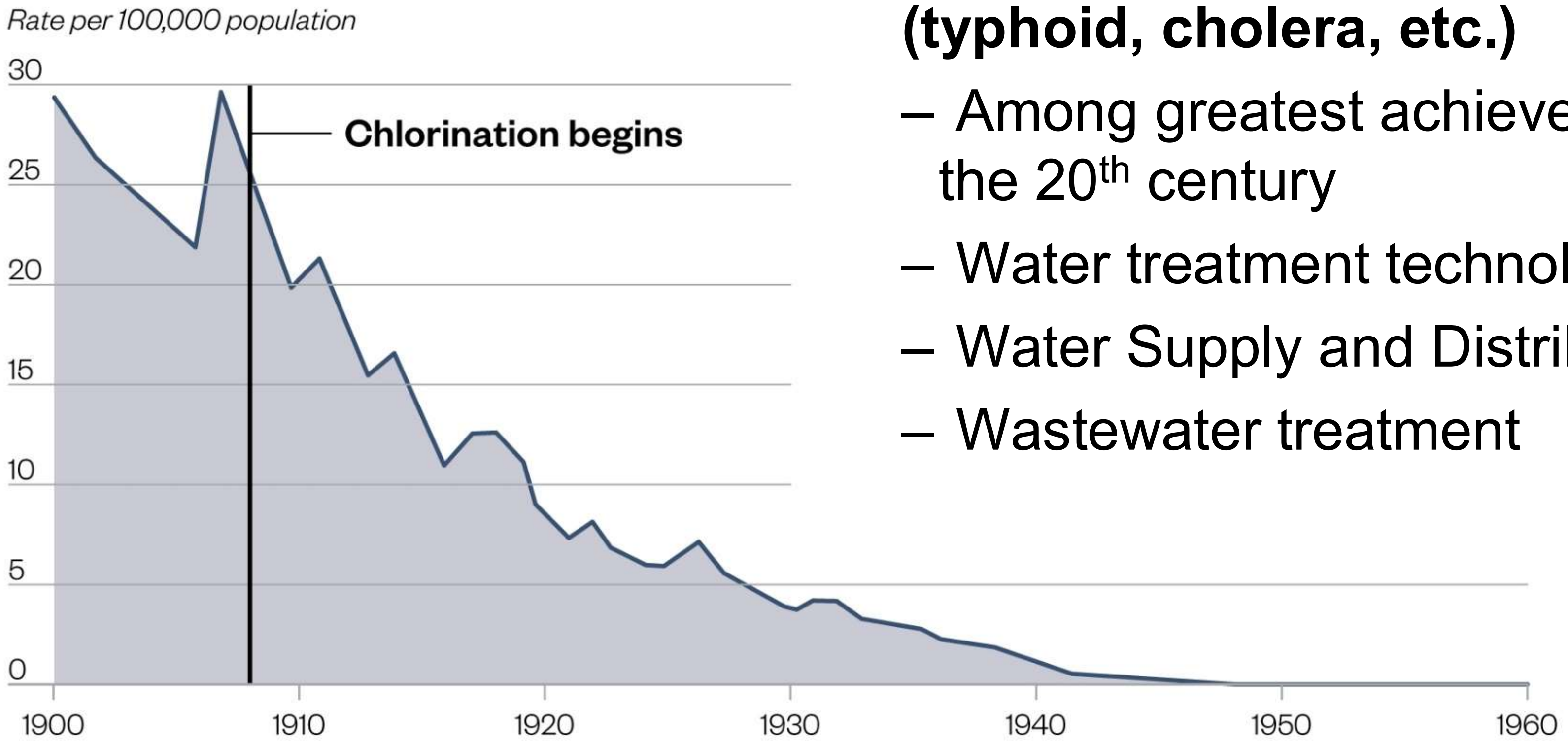
By **1930s** – filtration plus chlorine disinfection virtually eliminates waterborne illnesses in **US**





Death rate for Typhoid Fever

United States, 1900-1960



Source: U.S. Centers for Disease Control and Prevention, Summary of Notifiable Diseases, 1997.

Control of Waterborne Disease (typhoid, cholera, etc.)

– Among greatest achievements of the 20th century

– Water treatment technologies

– Water Supply and Distribution

– Wastewater treatment

Role of primary disinfection

(at the WTP)

- Inactivate microorganisms prior to and through distribution
- Satisfy CT Requirements
- Typically -- free chlorine, ozone, chlorine dioxide

CT – What is it?

CT is the product of the disinfectant contact time (T, measured in minutes) and disinfectant concentration (C, measured in mg/L

No longer based on “30 minutes”…

Role of secondary disinfection

(distribution system)

- Controls regrowth of microorganisms in system
- Protects against contamination from leaks and corrosion in distribution system
- Indicator of water quality
- Either free chlorine or chloramines

This presentation

Disinfection of drinking water is good

What are disinfection byproducts (DBP)?

Potential health impacts of DBP?

How monitor & regulate DBP?

What to do about DBP?

What are Disinfection Byproducts?

Disinfection Byproducts (DBP) are chemicals formed in drinking water by the addition of a disinfectant, such as chlorine, chloramines, chlorine dioxide and ozone, reacting with organic chemicals in the water.

Surface water sources of natural organic material (NOM)

- Rain events wash organic matter into receiving body.
- Flooding reverses flow gradients in upper aquifers
- Cavities and fissures in Karst conditions allow surface intrusion
- Poor sanitary conditions, i.e., broken seals, abandoned wells, poor locations, result in intrusion
- Groundwater with high NOM content indicates the intrusion from Surface Water
- Sedimentation, biogrowth, or poor flushing practices

DBP Formation

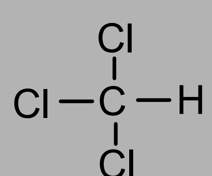
$\underbrace{Cl_2 + NOM}$ ⟶ Chlorinated Organics

Reduce these to minimize formation

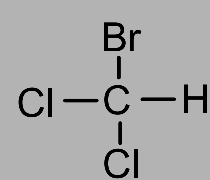
- TTHMs
- HAAs
- many others

Also affected by: pH, temperature, time

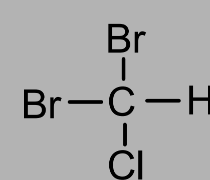
The THMs



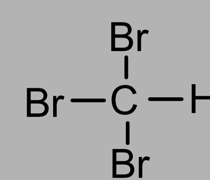
Chloroform



Bromodichloromethane



Chlorodibromomethane



Bromoform

What affects DBP concentrations?

The concentration of organic chemicals in the source water and treated water

More organics within the WTO and distribution system = increased potential to form DBPs.

Location & amount of disinfectant added to the source water and treated water

Adding chlorine-based disinfectants to raw (untreated) source water will immediately begin the reaction to form DBP which normally do not always get removed by the coagulation, flocculation, sedimentation and filtration processes. Furthermore, adding chlorine-based disinfectants at higher dosages will increase the reactions for forming DBP.

Treatment process including coagulation, flocculation, sedimentation and filtration

Optimizing the coagulation, flocculation, sedimentation and filtration process to settle or filter out organics should reduce the potential to form DBP.

What affects DBP concentrations? (continued)

Disinfectant concentration throughout the distribution system

Maintaining a high disinfection residual throughout the distribution system will increase the potential to form DBP.

The water age within a distribution system

Longer time in contact with disinfectants = higher potential to form DBP.

Biofilms in storage tanks and distribution systems

Biofilms are another source of organics within storage tanks and distribution systems, can react with disinfectants to form DBP

Water temperature

Warmer water has higher potential for forming DBP. (DBP concentrations tend to be higher in the third and fourth quarters of the year)

Production of Total Trihalomethanes (TTHMs)

TTHMs are produced by the reaction of chlorine with organic constituents found in natural waters.

The 4 Trihalomethane compounds of concern are:

- **Chloroform (typically >70% inland)**
- **Bromodichloromethane**
- **Bromoform (can be >70% coastal)**
- **Dibromochloromethane**

However, Chloroform or Bromoform will always constitute the higher portion of the TTHMs.

Bromoform is produced in coastal areas due to brackish intrusion and varies by well. Bromoform is formed by the reaction of Cl on Bromide.

Where TTHMs are Formed

- High Water Age (MRT)
- Storage Tanks with poor water turnover
- Low Demand Areas
- Stagnant & Slow-Moving Water Areas
- Dead Ends Pipelines (MRT)
- Note: Unlined CI Pipe (systems in existence before 1949) require higher residual chlorine levels

Unlined CI Pipe Tuberculation with Bacterial Growth producing <u>Organic Precursors</u>

Production of Haloacetic Acids

HAA5s are produced by the reaction of chlorine with organic constituents found in natural waters.

These 5 compounds are regulated as HAA5s.

Monochloroacetic Acid

Monobromoacetic Acid

Dichloroacetic Acid

Dibromoacetic Acid

Trichloroacetic Acid

These compounds begin to degrade a few days after formation.

Where HAA5 are Found

- Low demand areas
- Toward middle system areas w/ high chlorine concentration and low movement
- Near high chlorine dose and/or residual locations
- High bacterial growth internal to system
- HAA5 will degrade in systems with high water age

This presentation

Disinfection of drinking water is good

What are disinfection byproducts (DBP)?

Potential health impacts of DBP?

How monitor & regulate DBP?

What to do about DBP?

How are we exposed to DBP?

Drinking chlorinated or brominated water

Breathing in air containing DBP

Skin absorption while bathing & swimming

Duration DBP remain in body?

After exposure, DBP remain in the body for only a short period of time.”

US Centers for Disease Control & Prevention

Health effects

Chronic exposure to DBP may increase risk of cancer

- Liver, bladder, and anal cancer
- Lifetime risk of three cases per thousand
- Brominated HAA5 more carcinogenic

Exposure to unusually large amounts of DBP could result in liver damage

Endocrine system disruption

DBP Formation - Surface Source Water Chlorine Disinfectant

TTHMs & HAAs

+ enough time + enough exposure

- cancer
- endocrine system disruption
- reproductive harm

From IXOM Watercare

This presentation

Disinfection of drinking water is good

What are disinfection byproducts (DBP)?

Potential health impacts of DBP?

How monitor & regulate DBP?

What to do about DBP?

Development of DBP Regulations

Trihalomethane (THM) Rule

Effective in 1979

MCLs: TTHM = 0.100 mg/L (4 THMs)

Quarterly Samples (4 locations – one at max)

Running Annual Averages

Stage 1 D/DBP Rule

Promulgated in 1998; Effective in 2001

MCLs: TTHM = 0.080 mg/L; HAA5 = 0.060 mg/L

Must Demonstrate TOC Removal

Disinfectant Doses Limited

Maintain Specific residuals in Distribution System

Development of DBP regulations

Stage 2 D/DBP Rule

Promulgated in 2006; Effective in 2012-13

TTHM & HAA5 same as Stage 1 - 80/60 µg/L

Select IDSE Sites with highest levels

No system wide running annual averages

Use Location running annual average (LRAA)

Who is required to monitor for DBP?

Community and **Nontransient Noncommunity waterworks** that add:

chlorine, chloramines, chlorine dioxide must monitor for ***TTHM*** and ***HAA5***.

chlorine dioxide must monitor for ***chlorite***.

ozone must monitor for ***bromate***.

Transient Noncommunity waterworks adding chlorine dioxide to surface water or groundwater under the direct influence of surface must monitor for ***Chlorite***.

Monitoring requirements for DBP

Waterworks required to monitor for TTHM/HAA5 must collect distribution system samples from approved locations.

Approved monitoring locations selected from sites evaluated in the Initial Distribution System Evaluation (*IDSE*) or from hydraulic modeling (*to determine the average and maximum water age within a distribution system*)

Frequency and # of samples to be collected are based on source water type and population served.

Monitoring

TABLE 374.1 Monitoring Frequency by Source Water Type for TTHM and HAA5			
SOURCE WATER TYPE	POPULATION SIZECATEGORY	MONITORING FREQUENCY[a]	DISTRIBUTIONSYSTEM MONITORING LOCATION TOTAL PER MONITORING PERIOD[b]
Surface water or GUDI Source	Less than 500	per year	2
	500 - 3,300	per quarter	2
	3,301 - 9,999	per quarter	2
	10,000 - 49,999	per quarter	4
	50,000 - 249,999	per quarter	8
	250,000 - 999,999	per quarter	12
	1,000,000 - 4,999,999	per quarter	16
	Equal to or greater than 5,000,000	per quarter	20
Groundwater	Less than 500	per year	2
	500 - 9,999	per year	2
	10,000 - 99,999	per quarter	4
	100,000 - 499,999	per quarter	6
	Equal to or greater than 500,000	per quarter	8

[a]The owner shall monitor during the month of highest DBP concentrations.

VIRGINIA DEPARTMENT OF HEALTH

To determine DBP compliance

Calculate the Locational Running Annual Average (LRAA) concentration of TTHM and HAA5 at each sample site. TTHM PMCL is 0.080 mg/L. HAA5 PMCL is 0.060 mg/L. If either TTHM or HAA5 LRAA exceeds the PMCL Levels, the entire waterworks is considered to be in violation.

Compliance for Chlorite is determined by calculating the average of the 3 distribution system samples collected each month. The PMCL for Chlorite is 1.0 mg/L.

Compliance for Bromate is determined by the running annual average, calculated quarterly, of monthly sample results. The PMCL for Bromate is 0.010 mg/L.

LRAA

LRAA – Locational Running Annual Average – the average of sample analytical results for samples taken at a particular monitoring location during the previous four calendar quarters.

LRAA = {current qtr + previous qtr + qtr before + qtr before} / 4 (for same location

Example LRAA Calc

TTHM results for Q1 = 99.5 ug/L, Q4 = 87 ug/L, Q3 = 116 ug/L, Q2 = 135 ug/L

LRAA TTHM = {99.5 + 87 + 116 + 135} / 4

LRAA TTHM = 109.4 ug/L = 0.11mg/L

1 mg = 1,000 ug

Example LRAA Calc

TTHM results for Q4 = 37 ug/L, Q3 = 62 ug/L, Q2 = 57 ug/L, Q1 = 32 ug/L

LRAA TTHM = {37 + 62 + 57 + 32} / 4

LRAA TTHM = 47 ug/L = 0.047mg/L

1 mg = 1,000 ug

Example LRAA Calc

HAA5 results for Q4 = 30 ug/L, Q3 = 8 ug/L, Q2 = 35 ug/L, Q1 = 24 ug/L

LRAA TTHM = {30 + 8 + 35 + 24} / 4

LRAA TTHM = 24 ug/L = 0.024mg/L

1 mg = 1,000 ug

VIRGINIA DEPARTMENT OF HEALTH

Example LRAA Calc

HAA5 results for Q2 = 48 ug/L, Q1 = 31 ug/L, Q4 = 27 ug/L, Q3 = 30 ug/L

LRAA TTHM = {48 + 31 + 27 + 30} / 4

LRAA TTHM = 34 ug/L = 0.034mg/L

1 mg = 1,000 ug

Operational Evaluation Level (*OEL*)

OEL: a level used to alert a waterworks it may need to act to avoid exceeding the PMCL for TTHM and/or HAA5.

TTHM OEL is calculated by summing the two previous quarters' TTHM results plus twice the current quarter's TTHM result, divided by four.

If the calculated OEL > 0.080 mg/L, the waterworks must develop and submit to the ODW an OEL Report within 90 days.

The HAA5 OEL is calculated the same way.

Example OEL Calc

TTHM results for Q1 = 99.5 ug/L, Q4 = 87 ug/L, Q3 = 116 ug/L, Q2 = 135 ug/L

OEL = [116 + 87 + (2 x 99.5)] / 4

OEL = 100.5 ug/L = 0.101 mg/l

1 mg = 1,000 ug

Example OEL Calc

TTHM results for Q4 = 37 ug/L, Q3 = 62 ug/L, Q2 = 57 ug/L, Q1 = 32 ug/L

OEL = [57 + 62 + (2 x 37)] / 4

OEL = 48 ug/L = 0.048 mg/l

1 mg = 1,000 ug

VIRGINIA DEPARTMENT OF HEALTH

Example OEL Calc

HAA5 results for Q4 = 30 ug/L, Q3 = 8 ug/L, Q2 = 35 ug/L, Q1 = 24 ug/L

OEL = [35 + 8 + (2 x 30)] / 4

OEL = 26 ug/L = 0.026 mg/l

1 mg = 1,000 ug

Example OEL Calc

HAA5 results for Q2 = 48 ug/L, Q1 = 31 ug/L, Q4 = 27 ug/L, Q3 = 30 ug/L

OEL = [27 + 31 + (2 x 48)] / 4

OEL = 39 ug/L = 0.039 mg/l

1 mg = 1,000 ug

VIRGINIA DEPARTMENT OF HEALTH

This presentation

Disinfection of drinking water is good

What are disinfection byproducts (DBP)?

Potential health impacts of DBP?

How monitor & regulate DBP?

What to do about DBP?

Reducing the production of DPB

1. Eliminate sources of surface water into production wells
2. Selecting well blends with lower DBP
3. Remove precursor material within treatment process
4. Change the point(s) of chlorine application
5. Lower the chlorine dose and/or residual
6. Use alternate disinfection strategies

Reducing the Production of DBP

7. WTP processes are absent of organic growth (*i.e.,* ion exchange and activated carbon systems)
8. Water Tank Turnover
9. Reduce Distribution System Water Age
10. Flush water in slow moving areas and at dead-ends
11. Remove sediment that creates chlorine demand
12. Remove biofilm that converts inorganic to organic materials

VDH VIRGINIA DEPARTMENT OF HEALTH

WTP applications

Disinfection strategies

Optimize WTP processes (coagulation)

Powered Activated Carbon (PAC)

UV

Ozone/Biofilters

Chloramines

Granular Activated Carbon (GAC)

WTP applications

Disinfection strategies

Optimize WTP processes (coagulation)

Powered Activated Carbon (PAC)

UV –Ryan Maslyn

Ozone/Biofilters

Chloramines

Granular Activated Carbon (GAC)

VDH VIRGINIA DEPARTMENT OF HEALTH

Distribution System applications

Reduce water age

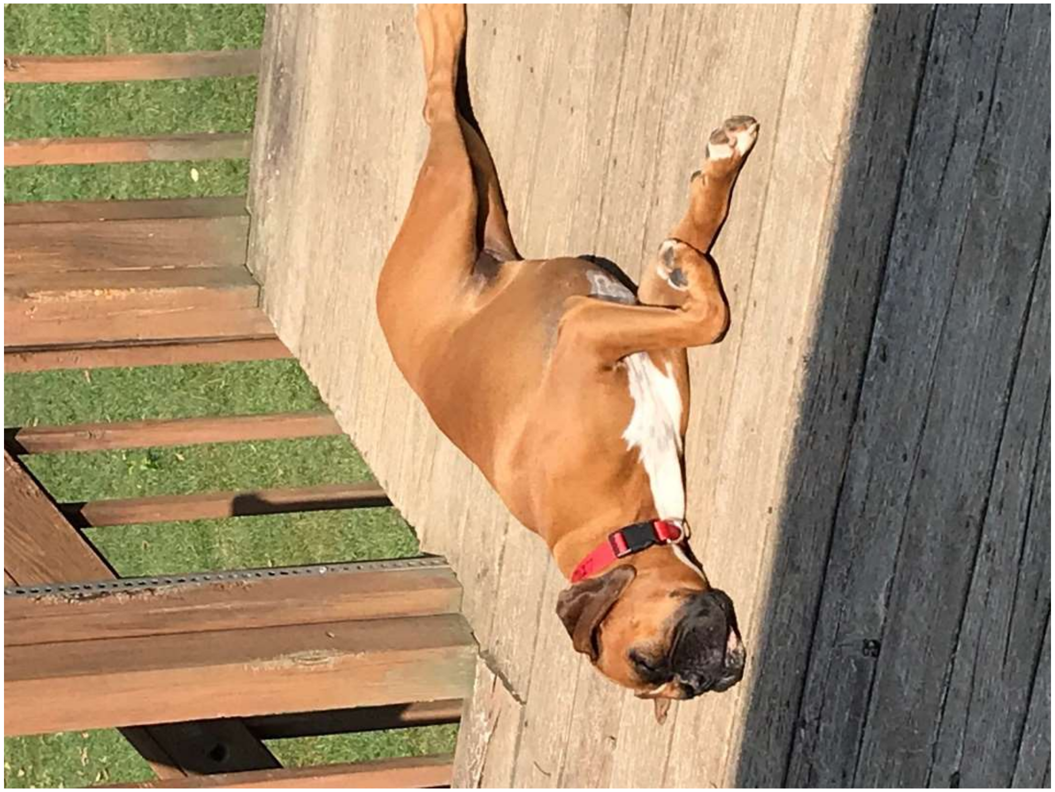
Storage tank mixing & aeration

Introduce chlorine throughout system

IF ALL ELSE FAILS…

Try the DBP mobile….

DBP Control II covers applications



Now that we're done

You should be able to:

1. Explain why DBP are undesirable
2. Describe TTHM and HAA5
3. Calculate LRAA & OEL
4. Name three ways to address DBP in a water system

For follow up

Please contact:

Lisa Crabtree

Abingdon Field Office Deputy Field Director

VDH Office of Drinking Water

(276) 525-6157

lisa.crabtree@vdh.virginia.gov