CHLORINATION

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THE MULTIPLE BARRIER CONCEPT

- Source water protection
- Treatment
- Distribution system integrity and
- Disinfection

DISINFECTION

- Goal is to inactivate pathogenic organisms
  - Contact Time in Treatment Facility
  - Maintain Residual in Distribution
- Waterborne diseases may be life-threatening to some

CHLORINE COMPOUNDS

- Chlorine gas (Cl_2)
- Sodium Hypochlorite (liquid bleach)
- Calcium Hypochlorite (HTH)

TOTAL CHLORINE RESIDUAL is the sum of

FREE CHLORINE RESIDUAL + COMBINED CHLORINE RESIDUAL = TOTAL CHLORINE RESIDUAL

TOTAL = FREE + COMBINED

- Residuals can exist in water in several different forms:

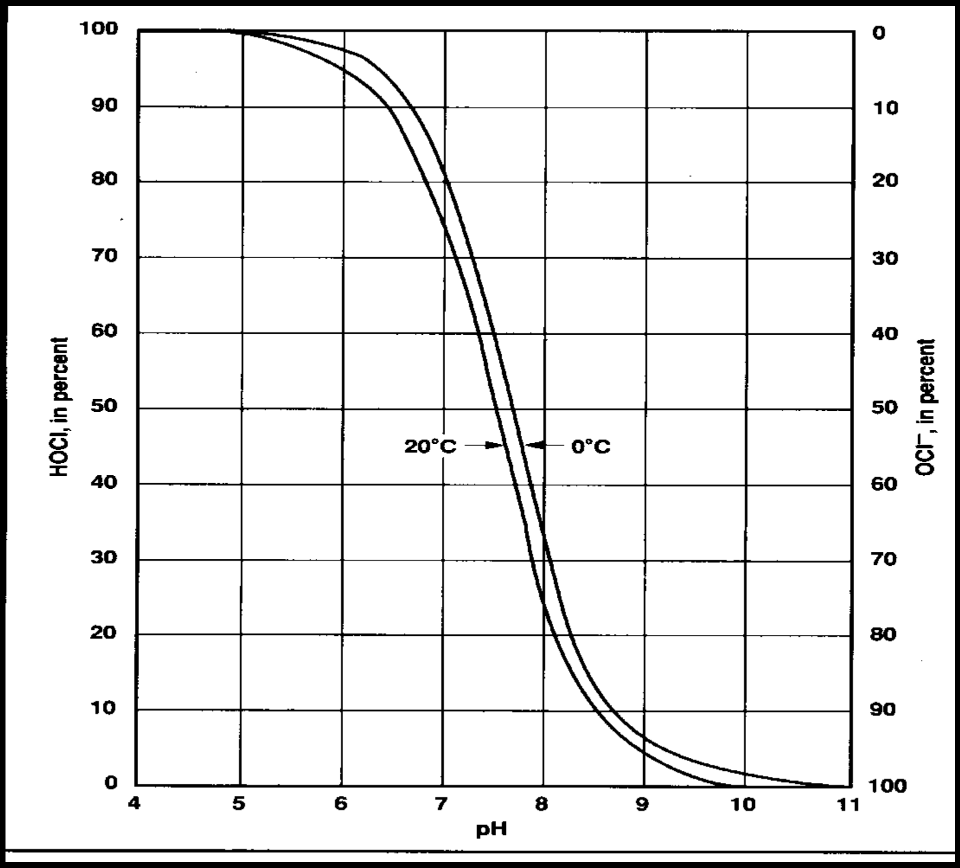
Free – 2 forms which are pH dependant

Hypochlorous acid or hypochlorite ion

Combined – 3 forms of chlorine combined with ammonia called chloramines

Mono-, di-, and trichloramine

FREE CHLORINE AND PH

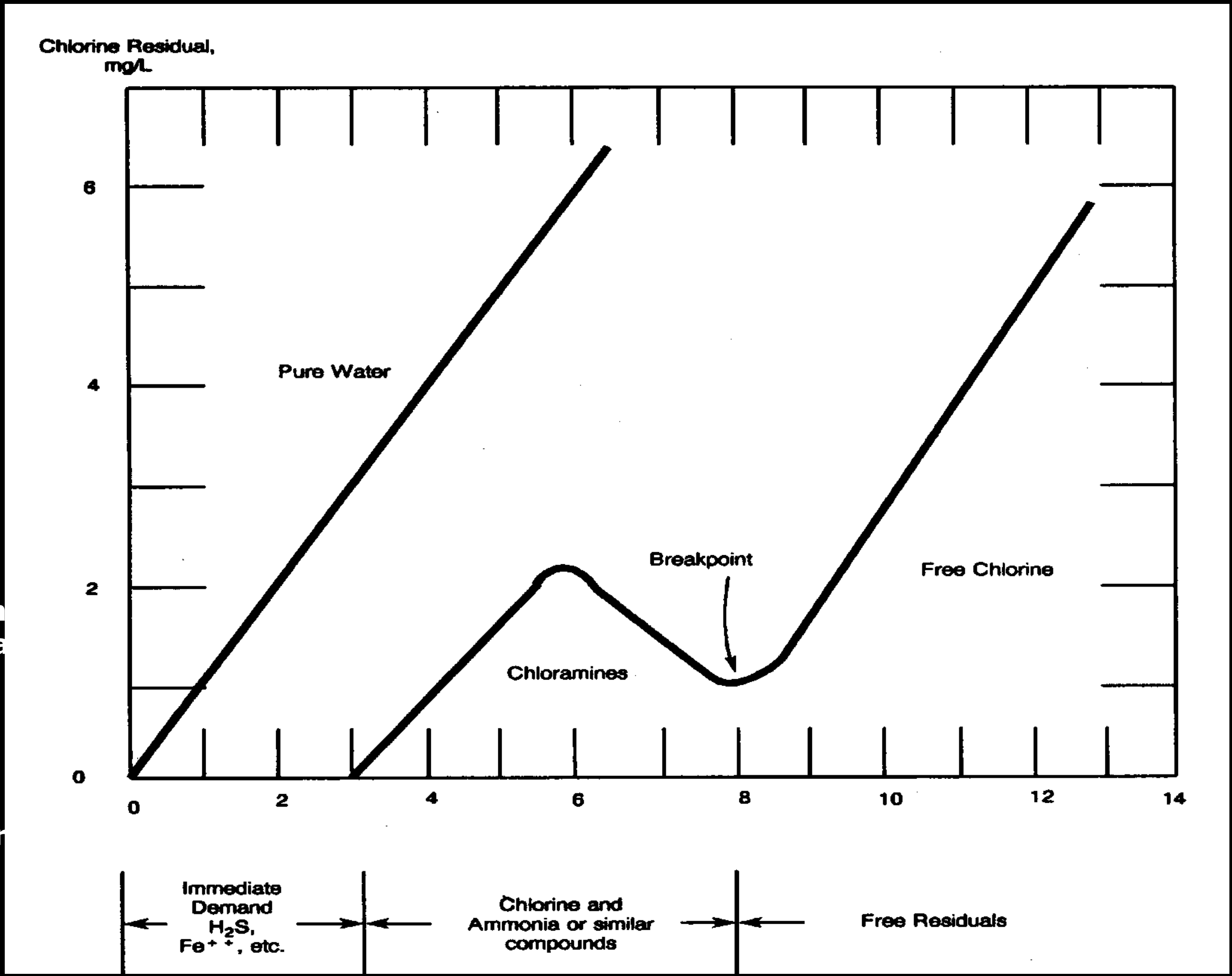


GENERAL ADVANTAGES AND DISADVANTAGES OF CHLORINATION AND CHLORAMINATION

	Free Chlorine	Combined Chlorine
More effective	x	
More stable or persistant residual		x
THM formation	x	
Taste & Odors	x*	x (di, tri-chloramines)

* free chlorine will combine with phenols to produce a medicinal taste.

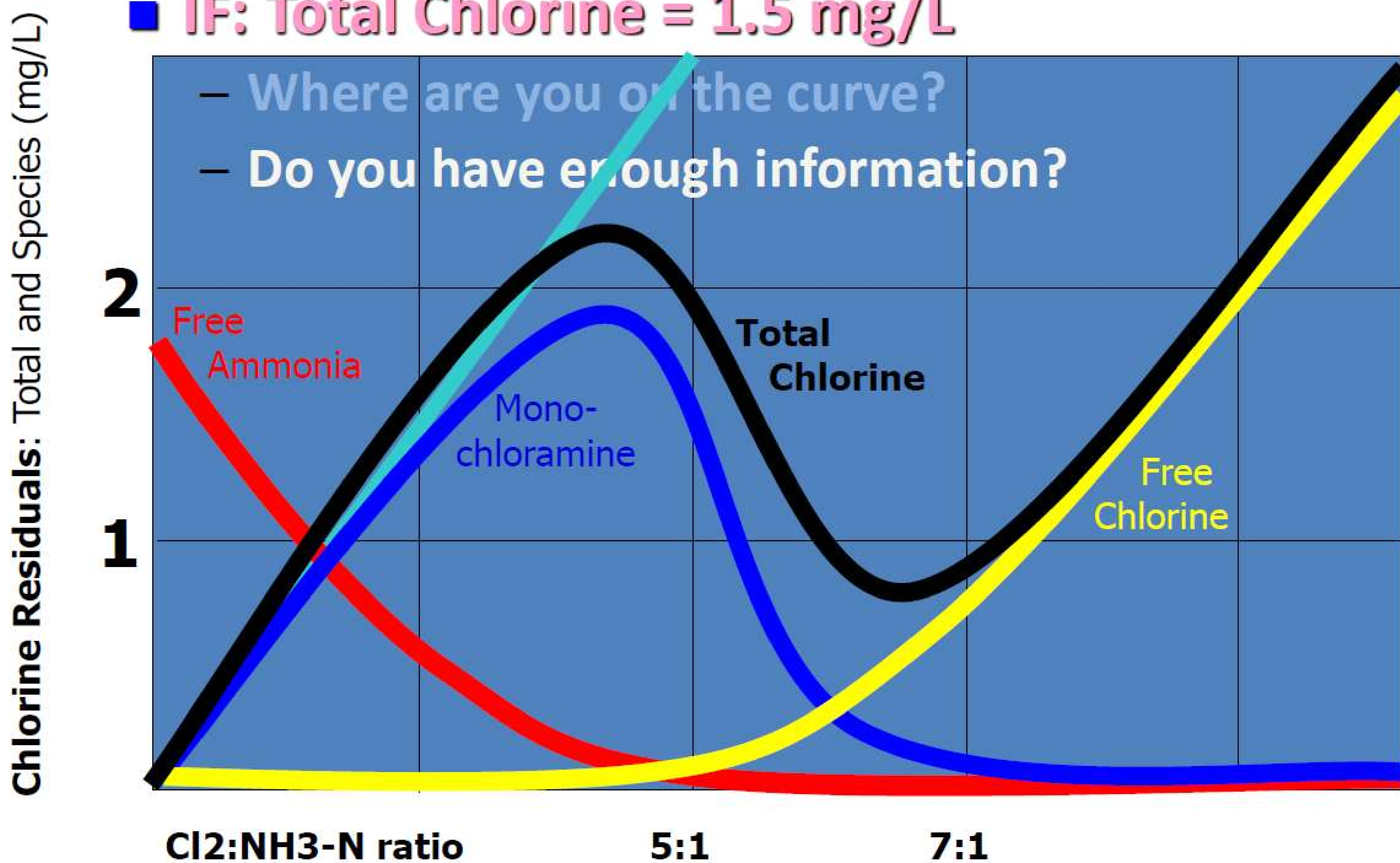
BREAKPOINT CHLORINATION CURVE



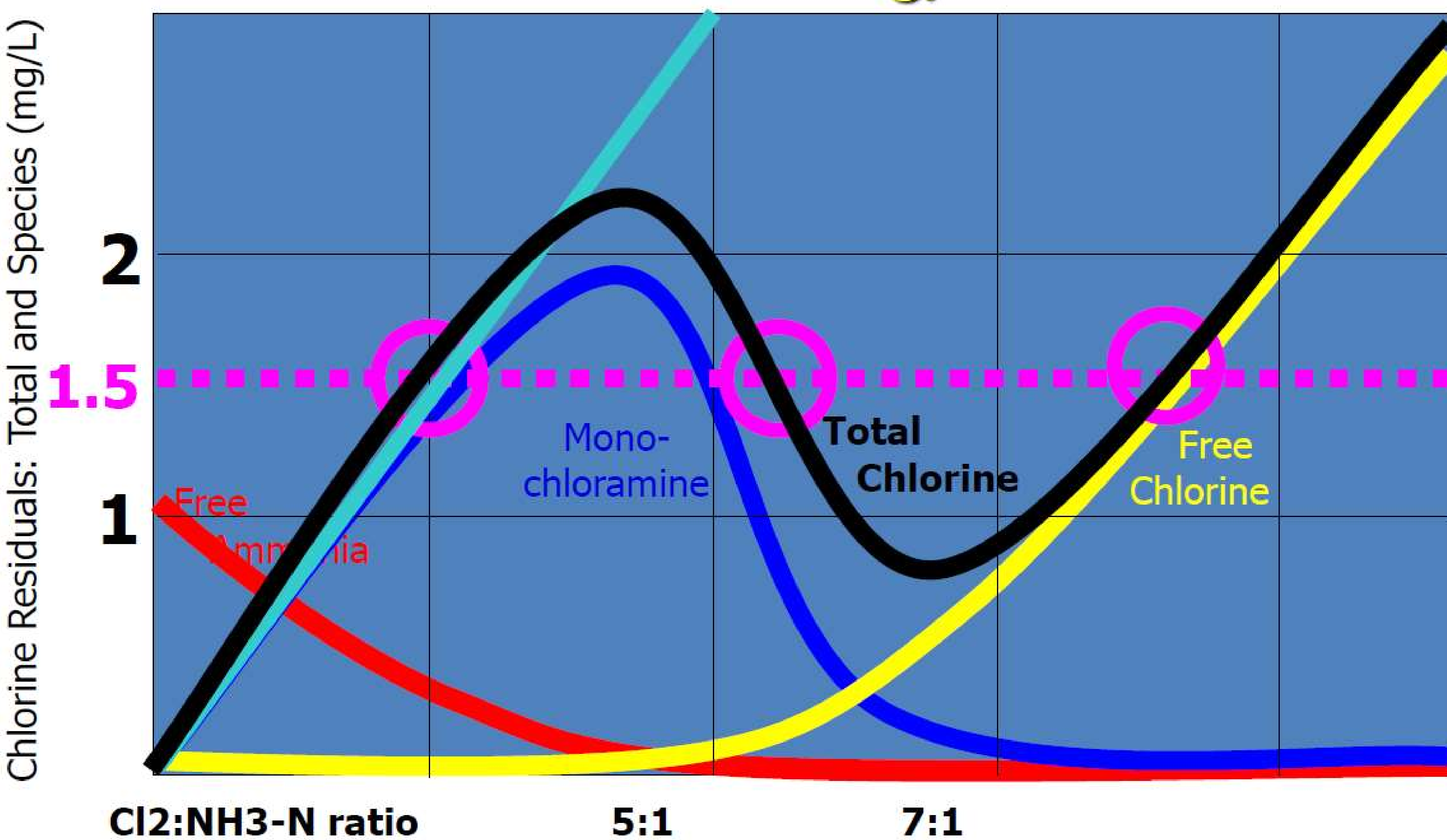
Chlorin
residua
mg/L

Chlor

- IF: Total Chlorine = 1.5 mg/L
  - Where are you on the curve?
  - Do you have enough information?

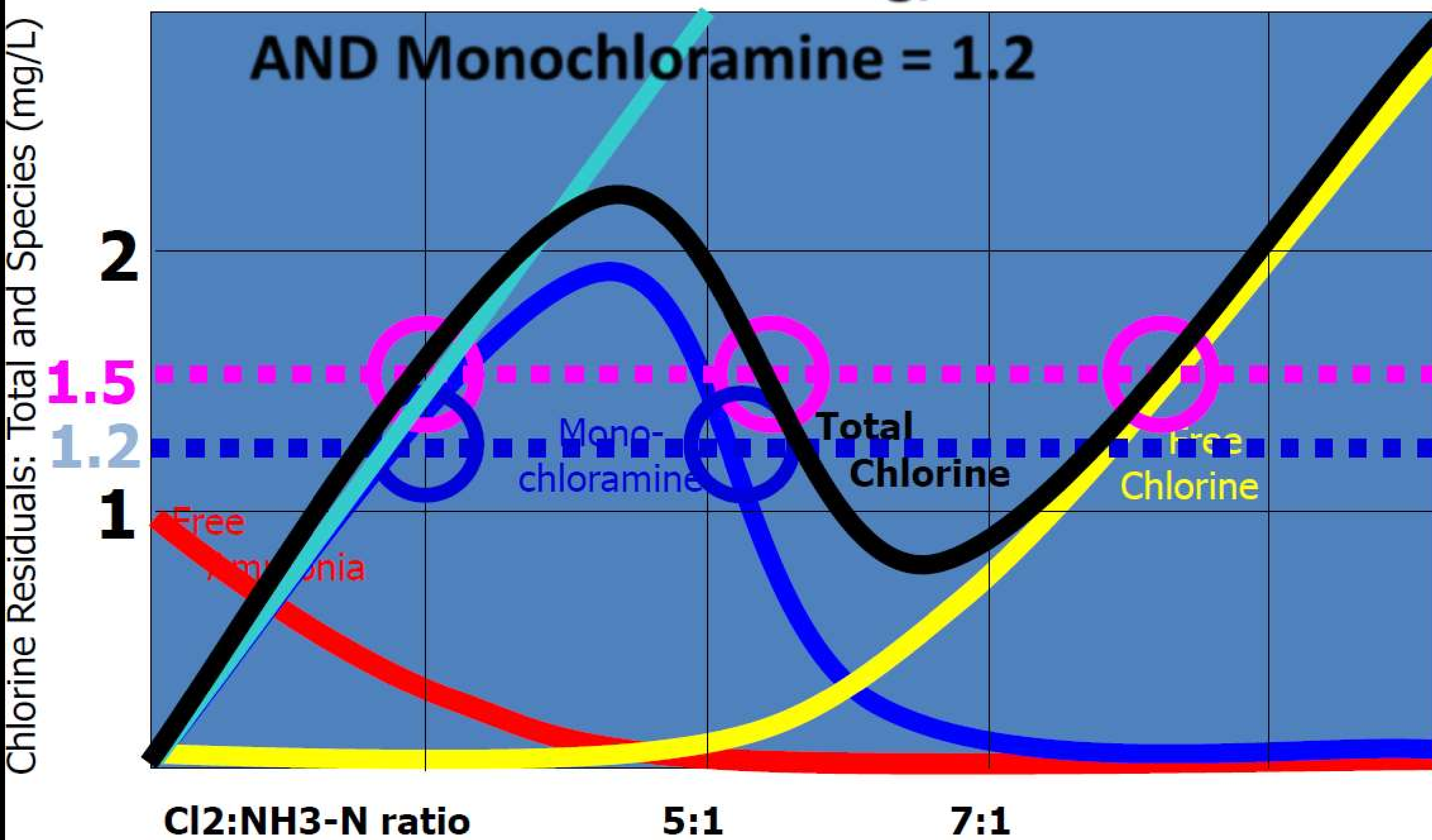


- IF: Total Chlorine = 1.5 mg/L



- **IF: Total Chlorine = 1.5 mg/L**

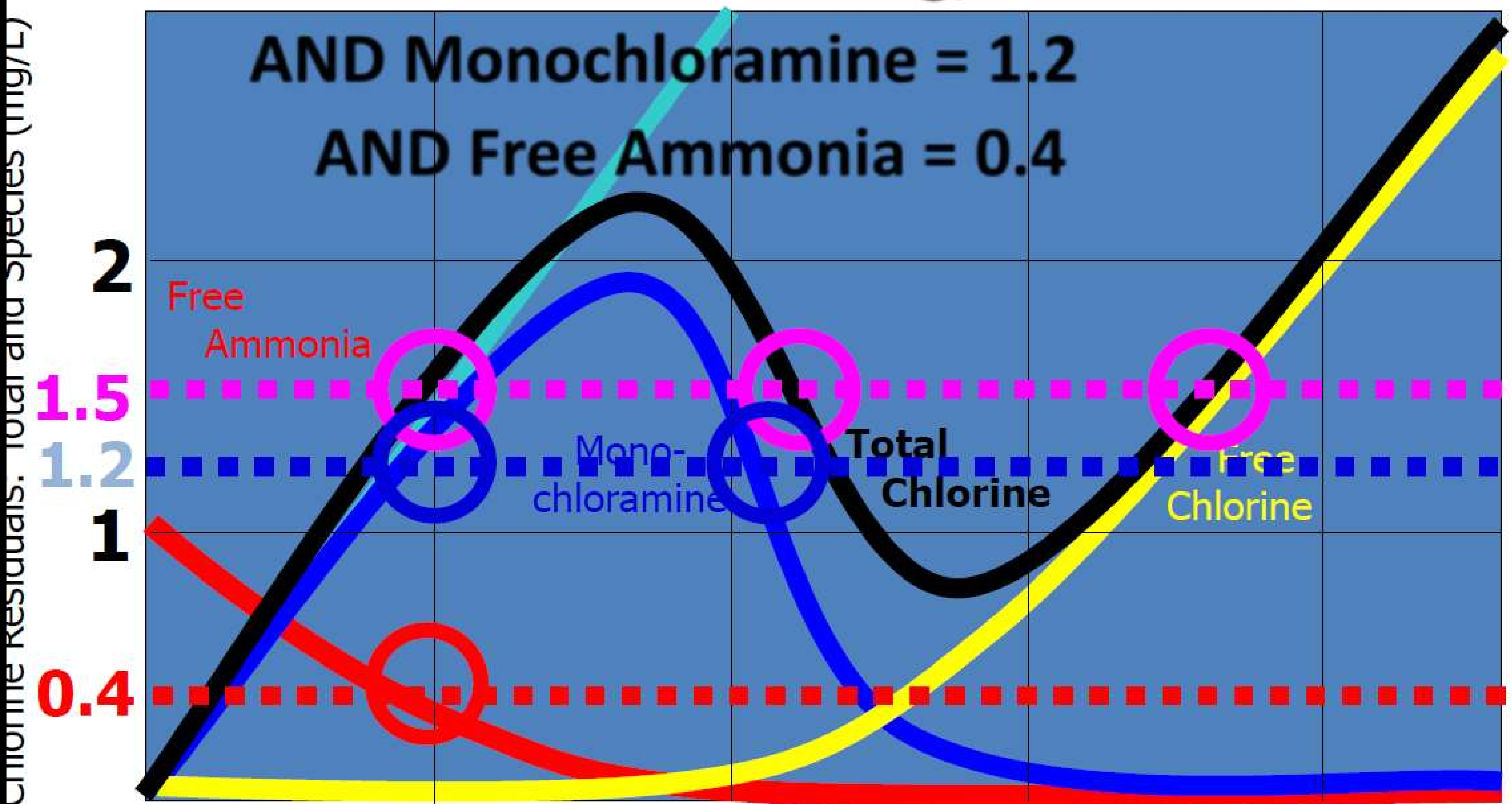
AND Monochloramine = 1.2



- **IF: Total Chlorine = 1.5 mg/L**

AND Monochloramine = 1.2

AND Free Ammonia = 0.4



DOSAGE = DEMAND + RESIDUAL

- **Demand** is the word used to refer to substances in the raw water which will consume chlorine.
- **Residual** is the measurable amount of available chlorine remaining in the water for disinfection purposes.
- **Dosage** then, is the amount of chlorine added to the water that will satisfy the chlorine demand and leave a satisfactory chlorine residual.

THEREFORE

- Residual = Dosage – Demand

and

- Demand = Dosage - Residual

EXAMPLES OF DEMAND

- Iron will consume 0.64 times its concentration (mg/l) in Cl_2.;
- Manganese will consume 1.3 times its concentration (mg/l) in Cl_2 .;
- Hydrogen Sulfide will consume 2.2 times its concentration (mg/l) in Cl_2 ; and
- Ammonia will consume 7.6 times its concentration (mg/l) in Cl_2 .
- (Don't forget total organic carbon (TOC))

ILLINOIS EPA’S DRINKING WATER WATCH WEBSITE

- Starting Point in Calculating Demand
  - Obtain data for all source waters.
    - Monitoring conducted in Illinois has demonstrated that each well or intake will need to be evaluated because water quality could vary greatly regardless of geographically or geologically similarity.

- For the Illinois EPA Drinking Water Watch Website: http://water.epa.state.il.us/dww/ .

Water System Details

water.epa.state.il.us/dww/JSP/WaterSystemDetail.jsp?tinwsys_is_number=716750&tinwsys_st_code=IL&wsnumber=IL0810450

Links

- Water System Facilities
- Sample Schedules
- Coliform/Microbial Sample Results
- Coliform Sample Summary Results
- Lead And Copper Sample Summary Results
- Chem/Rad Samples/Results
- Chem/Rad Samples/Results by Analyte
- Violations/Enforcement Actions
- Site Visits
- Milestones

Return Links

- Water Systems
- Water System Search
- County Map

Glossary

Drinking Water Branch

Water System Details

Water System No. :	IL0810450	**Federal Type :**	C
Water System Name :	WOODLAWN	**State Type :**	C
Principal County Served :	JEFFERSON	**Primary Source :**	SWP
Status :	A	**Activity Date :**	08-01-1967

Points of Contact

Name	Job Title	Type	Phone	Address	Email
WHEELER, AARON D.	OPERATOR	AC	618-231-3216	P.O. BOX 209, 202 SOUTH CENTRAL STREET, WOODLAWN, IL-62898	woodlawnvillage@hotmail.com
WHEELER, AARON D.	OPERATOR	SA	618-231-3216	P.O. BOX 209, 202 SOUTH CENTRAL STREET, WOODLAWN, IL-62898	woodlawnvillage@hotmail.com
AIRINGTON, RODNEY	MAYOR	OC	618-735-2110	PO BOX 209, WOODLAWN, IL-62898	WOODLAWNVILLAGE@HOTMAIL.COM

Annual Operating Periods & Population Served

Start Month	Start Day	End Month	End Day	Population Type	Population Served
1	1	12	31	R	3425

Service Connections

Type	Count	Meter Type	Meter Size Measure
RS	1418	ME	0

Sources of Water

Name	Type Code	Status
CC01 - WOODLAWN MASTER METER 1	CC	A
CC02 - WOODLAWN MASTER METER 2	CC	A
CC03 - WOODLAWN MASTER METER 3	CC	A

Service Areas

Code	Name
R	MUNICIPALITY

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Analyte Selection List

Not secure | water.epa.state.il.us/dww/JSP/AnalyteList.jsp?tinwsys_is_number=715970&tinwsys_st_code=IL

Drinking Water Branch

Analyte Selection List

Return Links

Water System Detail

Water Systems

Water System Search

County Map

Glossary

Water System No. :	IL0170250	**Federal Type :**	C
Water System Name :	VIRGINIA	**State Type :**	C
Principal County Served :	CASS	**Primary Source :**	GW
Status :	A	**Activity Date :**	12-01-1933

Analyte Code	Analyte Name	Type
2981	1,1,1-TRICHLOROETHANE	OC
2985	1,1,2-TRICHLOROETHANE	OC
2977	1,1-DICHLOROETHYLENE	OC
2378	1,2,4-TRICHLOROBENZENE	OC
2931	1,2-DIBROMO-3-CHLOROPROPANE	OC
2980	1,2-DICHLOROETHANE	OC
2983	1,2-DICHLOROPROPANE	OC
2110	2,4,5-TP	OC
2105	2,4-D	OC
2027	ACETOCHLOR	OC
2047	ALDICARB	OC
2044	ALDICARB SULFONE	OC
2043	ALDICARB SULFOXIDE	OC
2356	ALDRIN	OC
1927	ALKALINITY, TOTAL	WQ
1074	ANTIMONY, TOTAL	IOC
1005	ARSENIC	IOC
1094	ASBESTOS	IOC
2050	ATRAZINE	OC
1010	BARIUM	IOC
2990	BENZENE	OC
2306	BENZO(A)PYRENE	OC
1075	BERYLLIUM, TOTAL	IOC
2010	BHC-GAMMA	OC
2943	BROMODICHLOROMETHANE	OC
2942	BROMOFORM	OC

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TEST TO CONFIRM CHLORINE DEMAND

- Methods designed to conduct confirmatory monitoring to ensure the chlorine requirement is met (important if you have DBP/HAA or H_2S).
  - e.g., Hach provides Method 10223 utilizing DPD reagents is detailed on their website at: https://www.hach.com/asset-get.download.jsa?id=7639983911)
  - Bench tests are only as good as the date/time they are conducted, and source water quality does not always remain stable.
    - periodic testing (that includes evaluation of seasonal affects) is necessary to confirm that analytes remain in an acceptable range and that chlorine demand does not adversely affect chlorine requirement.

CONTACT TIME

- Disinfectant contact time" or "T" means the time in minutes that it takes for water to move from the point of disinfectant application or the previous point of RDC measurement to a point before or at the point where RDC is measured.

IN ILLINOIS TITLE 35 "MINIMUM CONTACT TIME" IS ALSO DEFINED AS:

- a) A minimum chlorine contact time of 60 minutes shall be provided for all surface water supplies and for ground water supplies using surface water - type treatment, springs, or infiltration lines, or water obtained from creviced rock aquifiers with less than 50 feet of cover.
- b) Contact time is measured as the time following filtration of surface or ground water, or chlorination of well water when there is no other treatment, and the time when the water reaches the first user.

ILLINOIS REQUIREMENTS FOR CHLORINE RESIDUALS

- Must maintain 0.5 mg/l in all areas of the distribution system.

<u>**OR**</u>

- Must maintain 1.0 mg/l of total chlorine in all areas of the distribution system

OTHER RULES AND REGS

- The MRDL (Maximum Residual Disinfectant Level):
  - Chlorine (as Cl_2) 4.0 mg/L
  - Chloramines (as Cl_2) 4.0 mg/L
  - Chlorine Dioxide (as ClO_2) 0.8 mg/L
- Maximum NSF chlorine feed = 30 mg/l for gas and 10 mg/l for Sodium Hypochlorite (80 mg/l for 12.5%).
  - This feed rate includes the sum of all points of application (pre, in process and post) and is based upon contaminants present when the gas or solution is made by the manufacturer.

RULES AND REGS DISINFECTION BYPRODUCTS -DBPS

- Total Trihalomethanes (TTHMs)

  0.080 mg/L

- Haloacetic acids (HAA5)

  0.060 mg/L

SAMPLING AND TESTING

- All approved test procedures for residual chlorine can be found in the Standard Methods for the Examination of Water and Wastewater.
- Most testing done in the lab is by amperometric titration, which can differentiate between total, free, and the chloramine species.
- For many operators, the most common chlorine testing is done with portable instruments and test kits.
- In Illinois "*colorimetric determinations shall be made using the DPD methods.*"

FIELD TESTING WITH THE DPD PROCEDURE

- Use the correct reagent packet. It says "FREE" or "TOTAL" on the packet.
- Use the correct sample size. It says "5 ml" or "10 ml" on the reagent packet.
- Read at the appropriate time - immediately for free chlorine, after three minutes for total.
- Use a blank if called for.
- Use dedicated glassware for Free or Total tests.

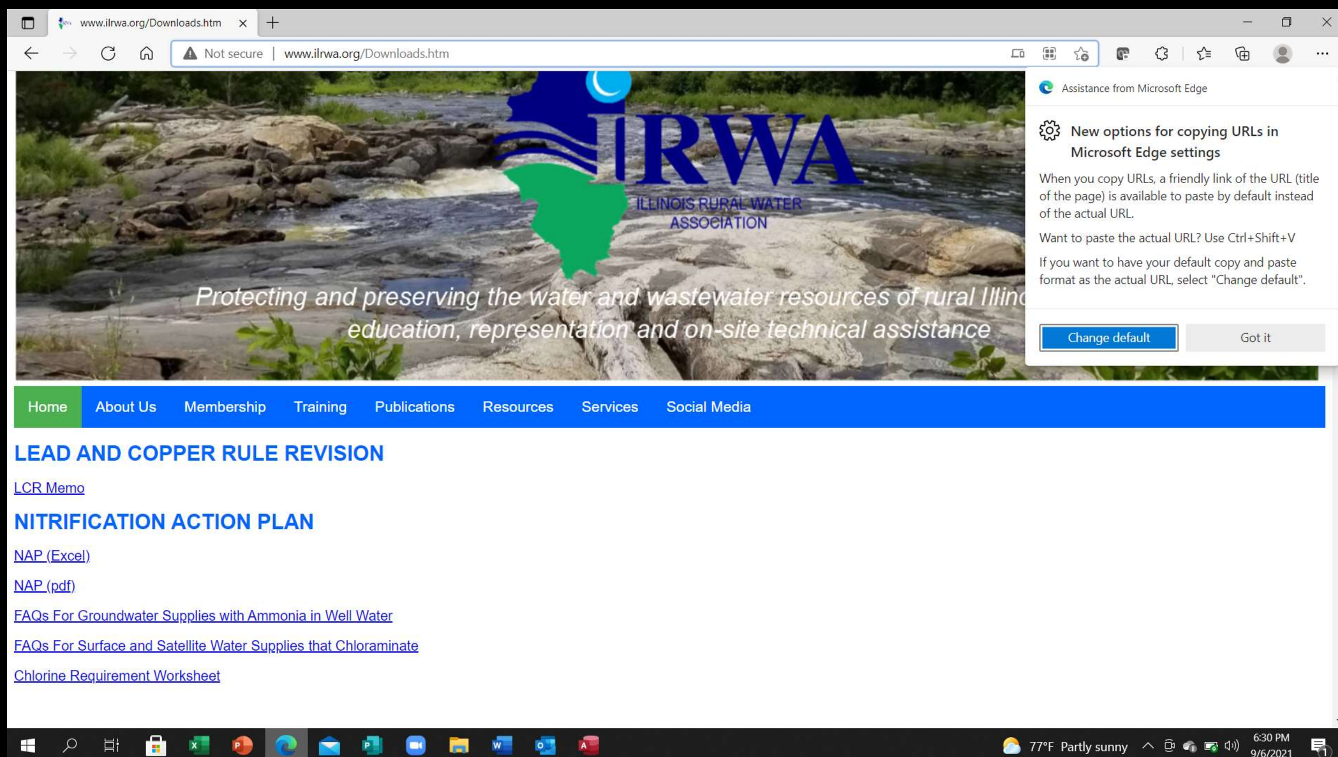
FIELD TESTING

- Chlorine COMPLIANCE testing tied to the **bacteriological sampling**.
  - The residual disinfectant level is measured at the **same points** in the distribution system and at the **same time** as total coliforms are sampled.
  - Total Chlorine measured at systems that chloraminate.
  - Free Chlorine measured at systems that achieve break point.

FIELD TESTING CONTINUED

- Process control monitoring
  - Daily monitoring at representative location
  - Check monitoring at locations with oldest water
- Nitrification Action Plan Testing
  - In addition to monitoring total chlorine, systems that have chloraminated water must conduct routine monitoring for:
    - Monochloramine
    - Nitrate
    - Nitrite
    - Total ammonia
    - Free ammonia

CHLORINATION MATH



- IRWA Home Page (Groundwater and Surface Water FAQs)
  - http://www.ilrwa.org/Downloads.htm

CALCULATE CHLORINE DEMAND

Well #	Iron mg/l	Iron Demand mg/l	Manganese mg/l	Manganese Demand mg/l	Ammonia mg/l	Ammonia Demand mg/l	Total Demand mg/l	Chlorine Requirement mg/l
?	*a*	*a* mg/l x .64 = *A*	*b*	*b* mg/l x 1.3 = *B*	*c*	*c* mg/l x 7.6 = *C*	*A* + *B* + *C* = *D*	*D* + Target mg/l = Cl_2 Requirement
Ex #6	.222	x .64 = .142	< .015	x 1.3 = .020	.290	x 7.6 = 2.204	.142+.020+2.204= 2.366	2.366+.5= **2.866**
Ex #10	**.299**	**x .64 = .191**	**< .015**	**x 1.3 = .020**	**.330**	**x 7.6 = 2.508**	**.191+.020+3.876= 4.087**	**4.087+.5= 4.587**
Ex #8	.230	x .64 = .147	< .015	x 1.3 = .020	.510	x 7.6 = 3.876	.147+.020+3.876= 4.043	4.043+.5= **4.543**
Ex #7	.057	x .64 = .036	.011	x 1.3 = .014	.290	x 7.6 = 2.204	.036+.014+2.204= 2.254	2.254+.5= **2.754**
Ex #1	1.422	x .64 = .910	.055	x 1.3 = .071	.290	x 7.6 = 2.204	.910+.071+2.204= 3.185	3.185+.5= **3.685**
Ex #5	.400	x .64 = .256	.005	x 1.3 = .007	.300	x 7.6 = 2.280	.256+.007+2.280= 2.543	2.543+.5= **3.043**

- Take the chlorine requirement for worst case well and solve the following equation to determine the amount of chemical that you need to feed as a starting point:

  lbs/Day=(MGD)(mg/l)(8.34)/(Purity (% as a Decimal))

- Using the "worst well" in our examples above and assuming that this well is pumping 500,000 gallons per day and the chlorine being fed is 100% purity gas (we already established our target concentration at .5 mg/l):

  lbs/Day=(.5 MGD)(4.587mg/l)(8.34)/(1.00 Purity (% as a Decimal))

  = 19.13 lbs/day

SIDE BAR COMMENT

- Following approximating the chlorine requirement of the source water and considering the specifics of your particular pumping scenario(s), you can begin the iterative process of testing your results.
- Make sure that your sampling point is far enough downstream of the chemical addition that complete mixing has occurred and slowing increasing dosage as needed.
- Do not expect to get your target value on your first try.
  - Recall there are many variables that can affect chlorine residual (including contact time, pH and temperature).
  - Also, remember that you have not allowed for reactions that will occur with TOC and hydrogen sulfide.

RULE OF THUMB TEST

- Using a DPD test method, conduct a free and total chlorine test according to the manufacturer's procedures.
- If your results indicate that the free chlorine value is greater than 80% of the total chlorine value, you have likely achieved a true free residual. If the free value is less than 80%, you are likely getting a false indication of free residual (caused by testing interference).

  - E.g., Tested free Cl2 value is 0.90 mg/l; Tested total Cl2 value is 1.00 mg/l. Likely, a free chlorine residual has been established which confirms calculations and iterative testing.

BREAKPOINT AND MONOCHLORAMINE

- Until you reach breakpoint (7.6 to 1), adding chlorine to water containing monochloramines with no free ammonia, will form dichloramine (moving to the right on the breakpoint curve). Once dichloramine is formed, the reaction cannot be reversed to form monochloramine.

- In this situation, increasing chlorine after monochloramine has been formed can adversely affect water stability, increase nitrification and decrease the ability to maintain residual disinfectant in distribution systems.

OPTIMIZE YOUR CHLORAMINATION PRACTICES - WHAT, WHERE AND WHY TO MEASURE

- Free Chlorine
  - Measure throughout your treatment process to ensure CT
  - Measure free chlorine (residual, not dose) prior to ammonia addition to determine how much ammonia to add.
  - Target will depend upon treatment process and necessary CT.
- Free Ammonia
  - Measure throughout your treatment process
  - Purpose to determine location on the curve.
  - Target 0.04 – 0.1 mg/L
    - Free Ammonia is too high • Reduce NH3 • Increase Cl_2

CHLORAMINATION OPTIMIZATION CONTINUED

- Monochloramine (and Total Chlorine)
  - This is the target disinfectant for chloraminating systems measure at the entry point to distribution system
  - Total residual = Monochloramine
  - Establish target to achieve 1.0 mg/l in all areas of distribution system
  - Before sending water to the distribution system if:
    - Monochloramine is too high • Reduce NH_3 • Reduce Cl_2
    - Total Chlorine dropped after Ammonia addition • Increase NH_3 • Reduce Cl_2
    - Total higher than mono and no free ammonia • decrease chlorine feed

CHLORAMINATION OPTIMIZATION CONTINUED

- pH
  - Measure at the entry point and designated points in the distribution system
  - Chloramines are more stable (long lasting) at higher pH.
  - Nitrifying bacteria growth rate declines as pH increases, and declines significantly at pH's approaches 9 and above.
- Nitrite and nitrate
  - Measure at the source, entry point and designated points in the distribution system
  - Important to determine if nitrification is occurring