

# **TCEQ Directed Assistance Module (DAM) No. 5: Understanding and Controlling the Chloramination Process**

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**Presented at the  
West Harris County Regional Water Authority  
*Chloramines 101* Workshop  
July 10, 2008**

by

Jack C. Schulze, P.E.  
Texas Commission on Environmental Quality  
Water Supply Division  
Public Drinking Water Section



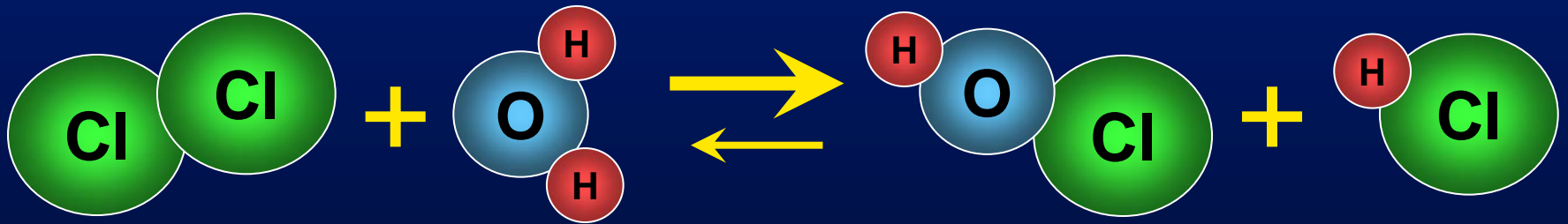
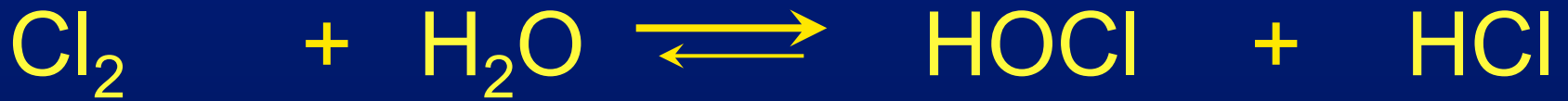
# What will we cover during this Seminar?

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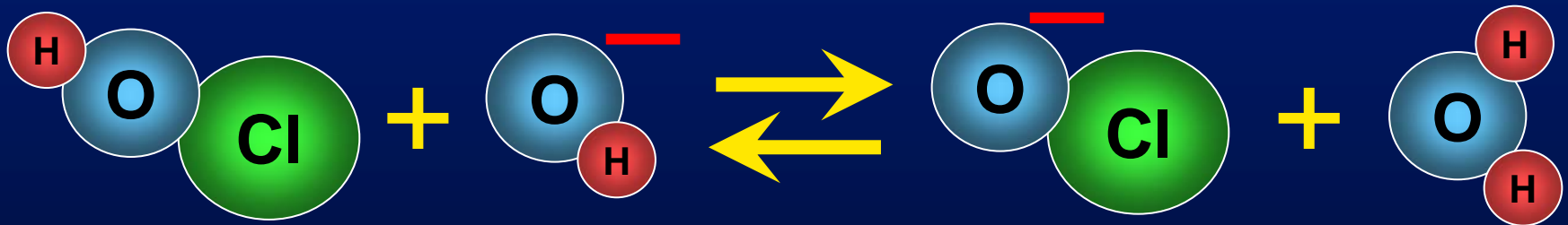
- ▶ Basic chloramination chemistry
- ▶ The chlorine breakpoint curve
- ▶ Weight-based doses and feed rates
- ▶ Process control and monitoring
- ▶ The TCEQ's regulatory approach
- ▶ DAM5 operator training

Basic  
Chloramination  
Chemistry

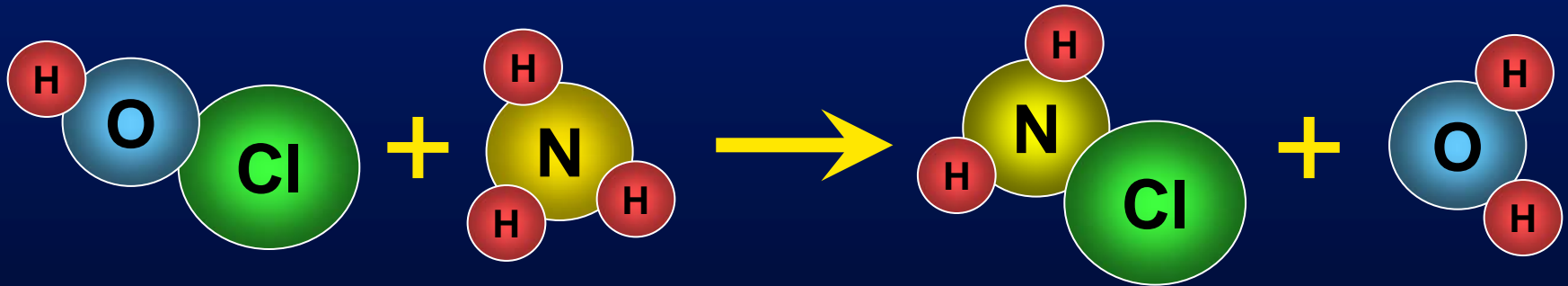
# Chlorine (gas) Hydrolysis



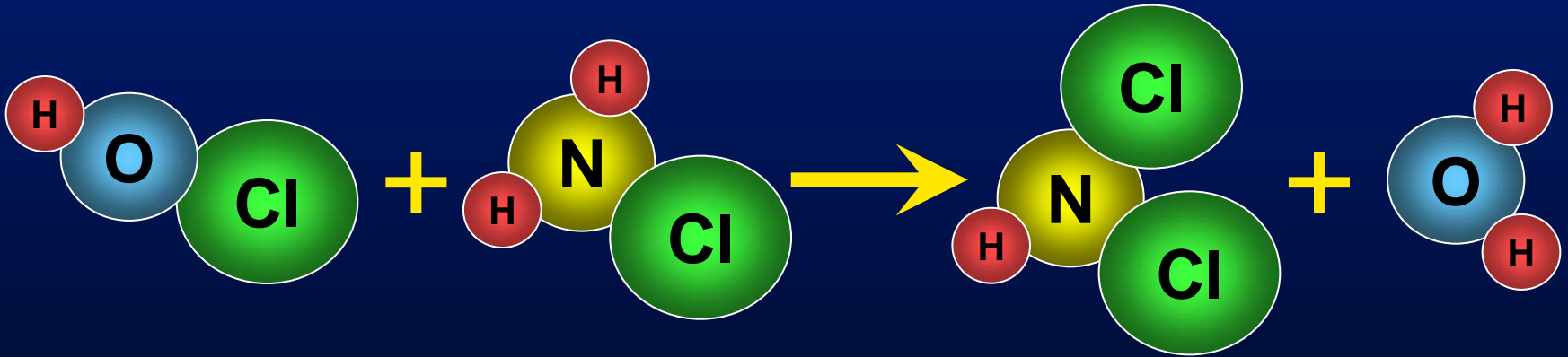
# Dissociation of Hypochlorous Acid



# Monochloramine Formation



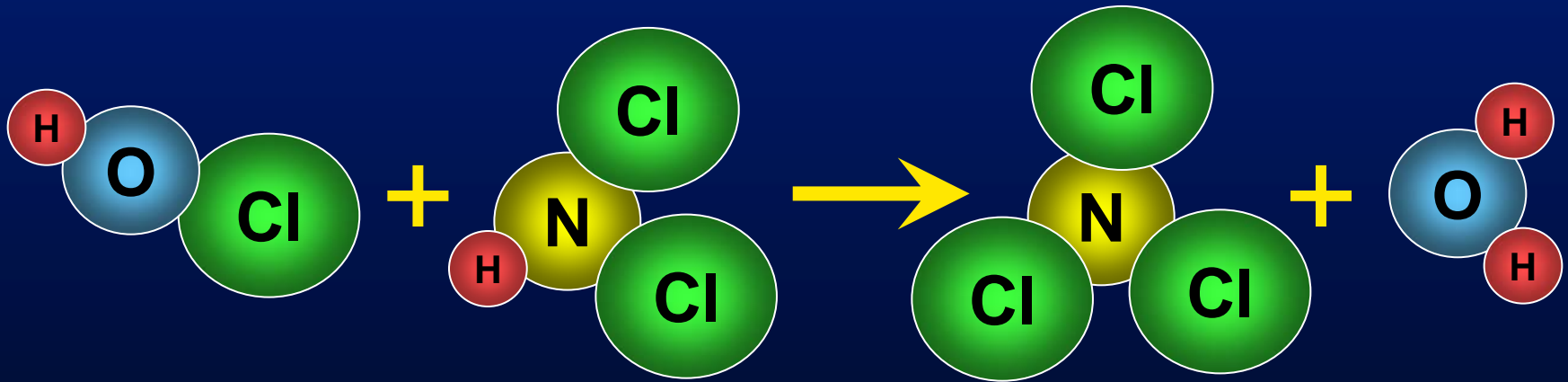
# Dichloramine Formation



Hypochlorous  
Acid

+ Monochloramine  $\longrightarrow$  Dichloramine + Water

# Trichloramine Formation



Hypochlorous  
Acid

+

Dichloramine

→

Trichloramine

+

Water

# Weight-Based Units of Measurement

Atom	Atomic Weight	Atom	Molecular Weight
Chlorine	35.5	Chlorine (Cl <sub>2</sub> )	71
Nitrogen	14	Ammonia (NH <sub>3</sub> )	17
Hydrogen	1	Monochloramine (NH <sub>2</sub> Cl)	51
		Dichloramine (NHCl <sub>2</sub> )	85
		Trichloramine (NHCl <sub>3</sub> )	129

# Weight-Based Ratios

(in the imaginary world)

$$\frac{\cancel{1 \text{ mol Cl}_2}}{\cancel{1 \text{ mol NH}_3}} \times \frac{71 \text{ lb Cl}_2}{\cancel{1 \text{ mol Cl}_2}} \times \frac{\cancel{1 \text{ mol NH}_3}}{17 \text{ lb NH}_3} = \frac{71 \text{ lb Cl}_2}{17 \text{ lb NH}_3}$$
$$= \frac{4.2 \text{ lb Cl}_2}{1 \text{ lb NH}_3}$$

$$\frac{\cancel{1 \text{ mol Cl}_2}}{\cancel{1 \text{ mol NH}_3}} \times \frac{71 \text{ lb Cl}_2}{\cancel{1 \text{ mol Cl}_2}} \times \frac{\cancel{1 \text{ mol NH}_3}}{\cancel{1 \text{ mol N}}} \times \frac{\cancel{1 \text{ mol N}}}{14 \text{ lb N}} = \frac{71 \text{ lb Cl}_2}{14 \text{ lb N}}$$
$$= \frac{5.06 \text{ lb Cl}_2}{1 \text{ lb N}}$$

# Impact of $\text{Cl}_2:\text{NH}_3$ ratio

(in the imaginary world)

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- ▶  $\text{Cl}_2:\text{NH}_3 < 4.2:1$ 
  - $\text{NH}_2\text{Cl}$  formed
  - Excess  $\text{NH}_3$  present after the reaction
- ▶  $\text{Cl}_2:\text{NH}_3 > 4.2:1$ 
  - Excess  $\text{Cl}_2$  was used and (therefore)
  - $\text{NHCl}_2$  and  $\text{NCl}_3$  are formed
- ▶  $\text{NH}_2\text{Cl}$  is dominant at  $4.2:1 \leq \text{Cl}_2:\text{NH}_3$
- ▶  $\text{NHCl}_2$  tends to form at  $4.2:1 < \text{Cl}_2:\text{NH}_3 \leq 7.6:1$
- ▶  $\text{NCl}_3$  tends to form at  $\text{Cl}_2:\text{NH}_3 > 7.6:1$

# Impact of $\text{Cl}_2:\text{NH}_3$ (as N) ratio

(in the imaginary world)

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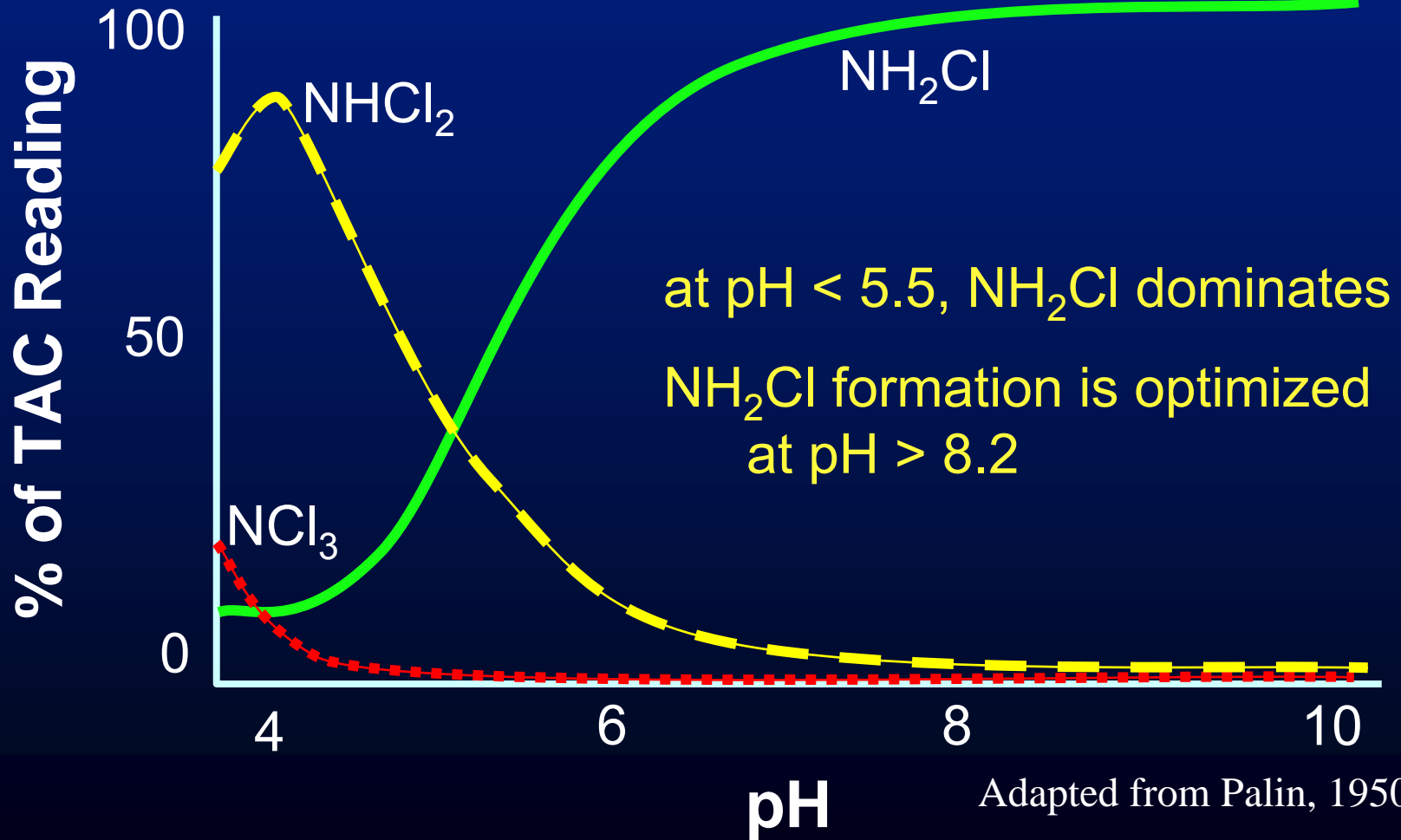
- ▶  $\text{Cl}_2:\text{N} < 5.1:1$ 
  - $\text{NH}_2\text{Cl}$  formed
  - Excess  $\text{NH}_3$  present after the reaction
- ▶  $\text{Cl}_2:\text{N} > 5.1:1$ 
  - Excess  $\text{Cl}_2$  was used and (therefore)
  - $\text{NHCl}_2$  and  $\text{NCl}_3$  are formed
- ▶  $\text{NH}_2\text{Cl}$  is dominant at  $5.1:1 \leq \text{Cl}_2:\text{N}$
- ▶  $\text{NHCl}_2$  tends to form at  $5.1:1 < \text{Cl}_2:\text{N} \leq 9.3:1$
- ▶  $\text{NCl}_3$  tends to form at  $\text{Cl}_2:\text{N} > 9.3:1$

# Reality Strikes

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- ▶ In the real world, other conditions affect the optimum  $\text{Cl}_2:\text{NH}_3$  ratio and the chloramination process
  - pH
  - Temperature
  - Chlorine demand
  - Competing reactions
  - Reaction time
  - Chloramine decay

# Real World Impact of pH



Adapted from Palin, 1950

# What's the Bottom Line so far?

- ▶ There are at least five chemical species that could be present

- $\text{NH}_3$  (free available ammonia or FAA)

- $\text{HOCl}$  and  $\text{OCl}^-$  (free available chlorine, or FAC)

- $\text{NH}_2\text{Cl}$  (monochloramine)

- $\text{NHCl}_2$  (dichloramine)

- $\text{NCl}_3$  (trichloramine)

combined  
chlorine

total available chlorine, or TAC

# What's the Bottom Line so far?

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- 2) One molecule of FAC reacts with one molecule of FAA to form one molecule of monochloramine
- 3) FAC and FAA cannot coexist to any significant degree
- 4) FAC and monochloramine cannot coexist to any significant degree

# What's the Bottom Line so far?

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- 5) If we have the correct ratio, the TAC will neither increase nor decrease
- 6) An incorrect  $\text{Cl}_2:\text{NH}_3$  ratio will result in excess FAA or the destruction of our target disinfectant (monochloramine)
- 7) In the real world, we use weight-based units of measurement rather than molecular units

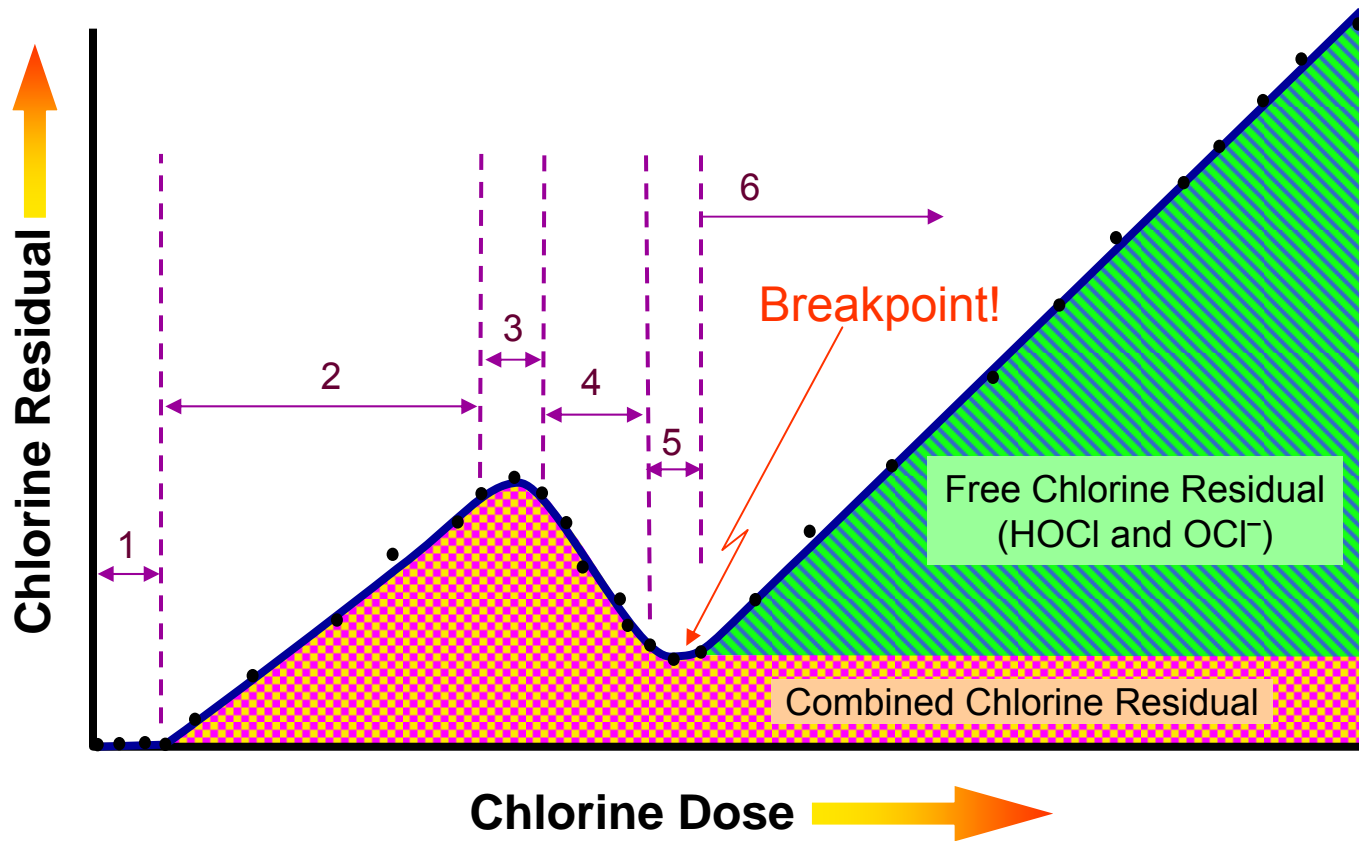
# What's the Bottom Line so far?

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- 8) In theory, the correct  $\text{Cl}_2:\text{NH}_3$  ratio is 4.2:1 and the correct  $\text{Cl}_2:\text{N}$  ratio is 5.1:1 (on a weight basis)
- 9) Real world operating conditions can influence the chloramination process.

# The Breakpoint Curve

# Understanding the Curve



# Two Disinfection Scenarios

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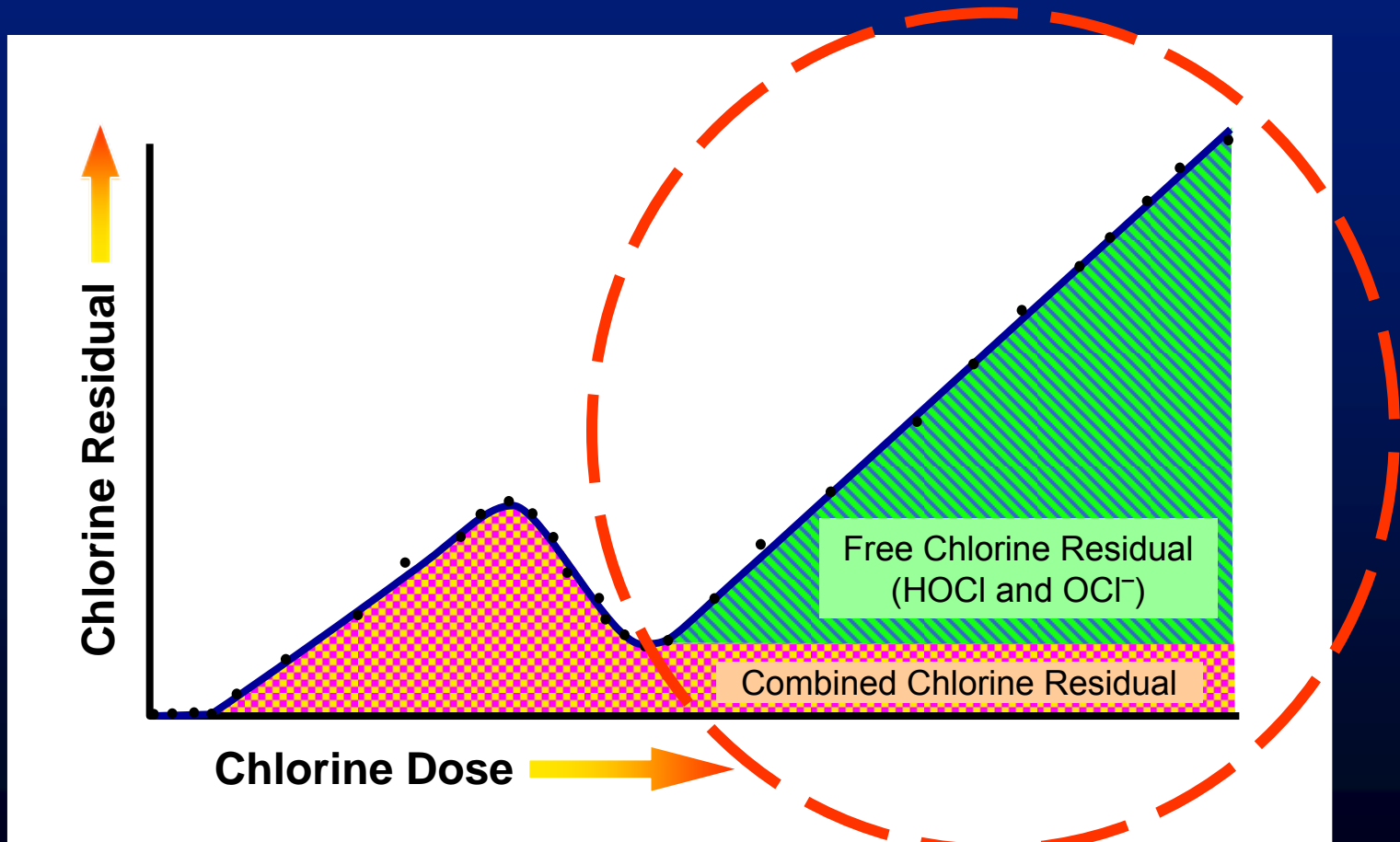
## ▶ Chlorine before Ammonia

- Primarily for initial disinfection
  - Provides safety factor for chloramine CT
  - Provides preoxidation

## ▶ Ammonia before chlorine

- Primarily for rechlorination
  - Reduces impact of competing reactions

# Scenario 1: Chlorine before Ammonia



# Scenario 1 Data

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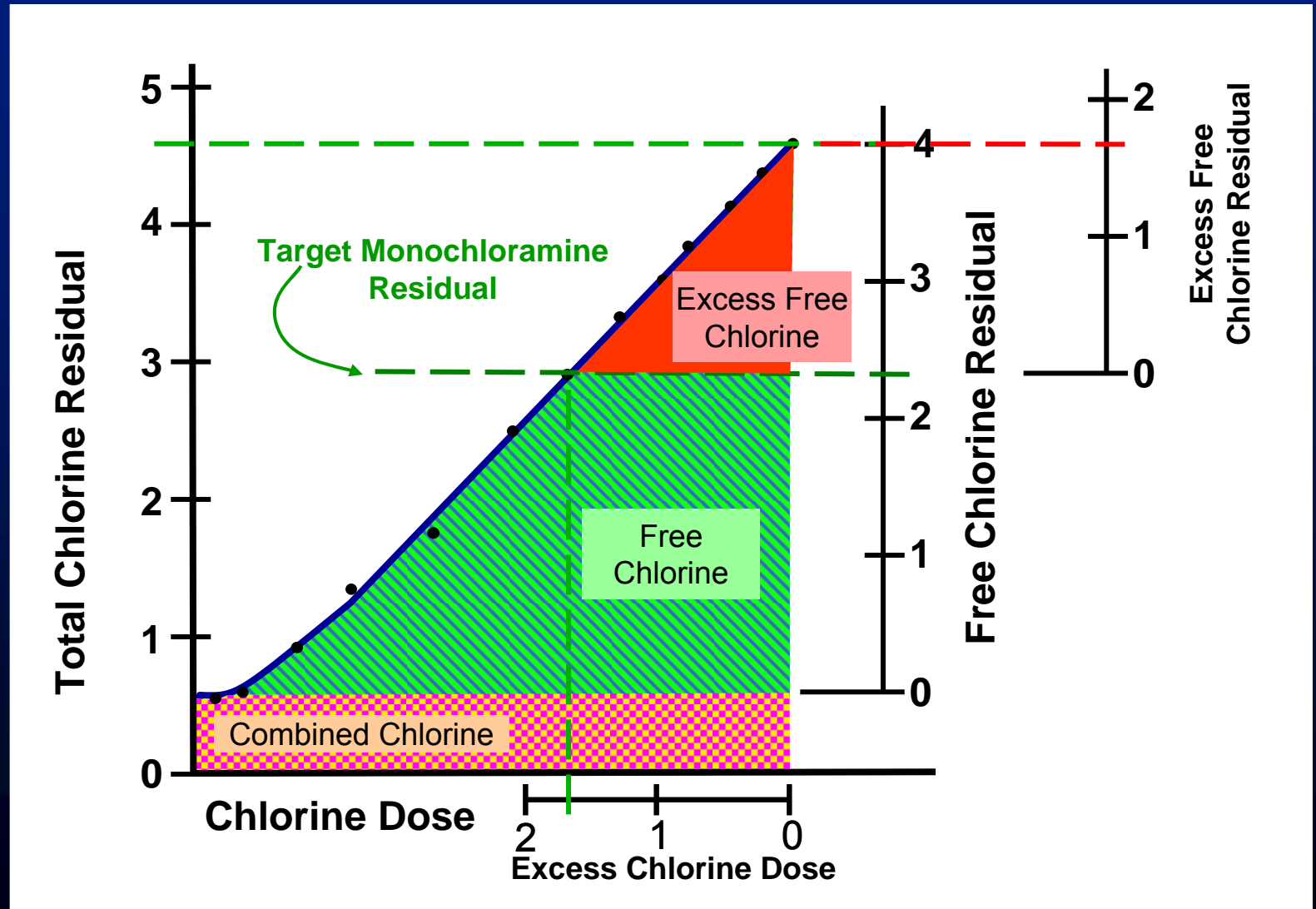
## ▶ Target

- Mono = 2.3 mg/L

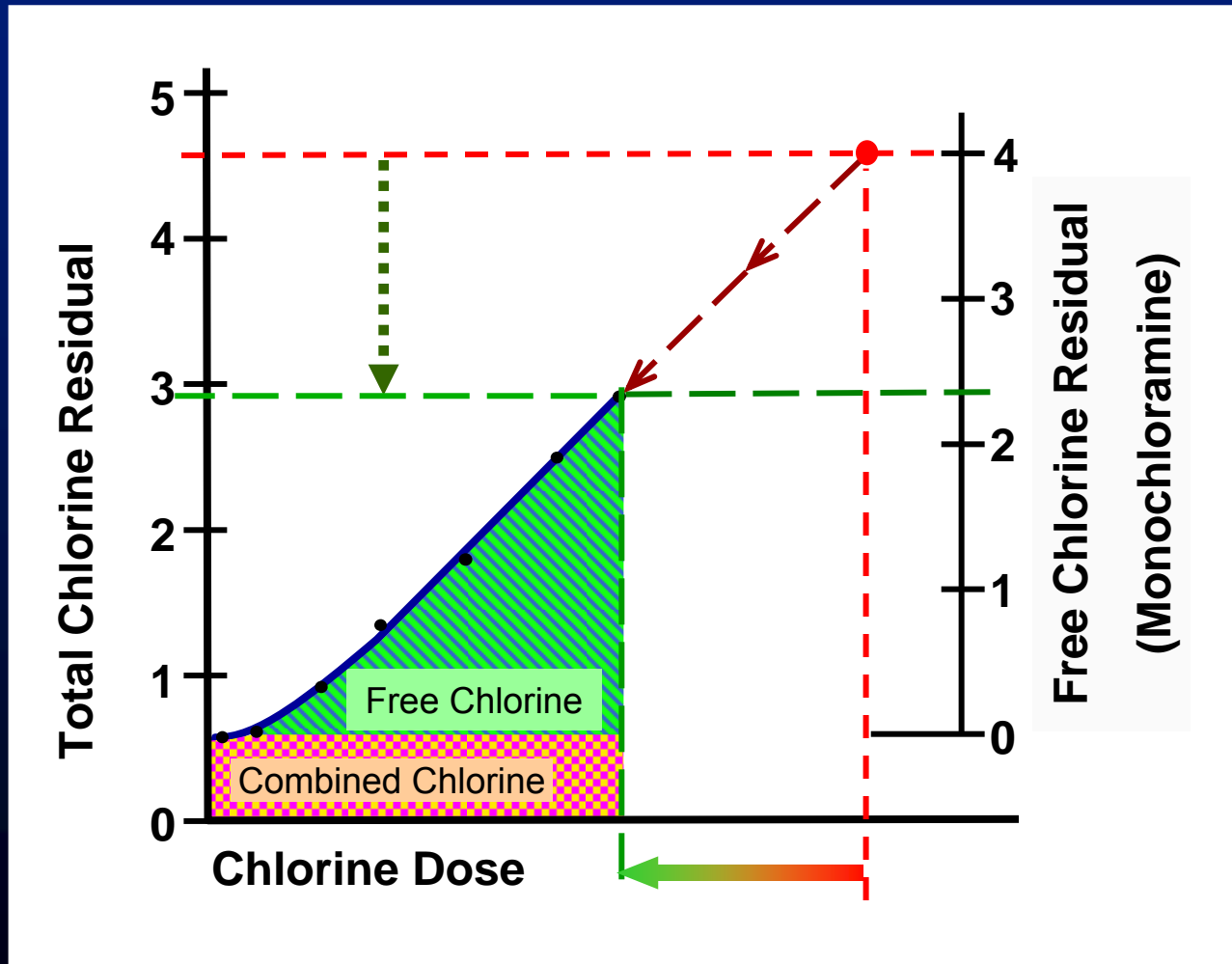
## ▶ Currently

- Mono = trace
- TAC = 4.6 mg/L
- FAC = 4.0 mg/L
- FAA = 0.0 mg/L

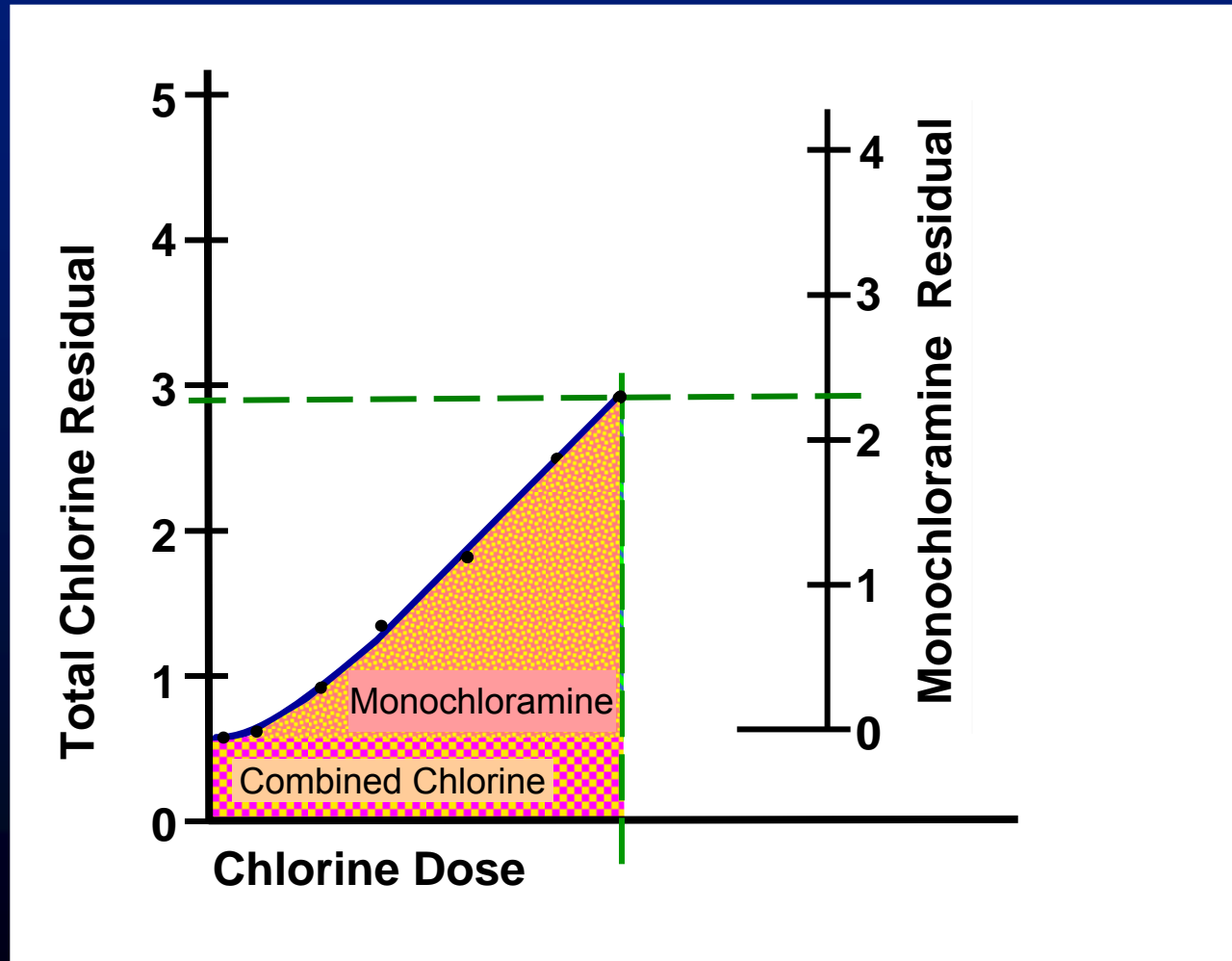
# Q1: What does our data tell us?



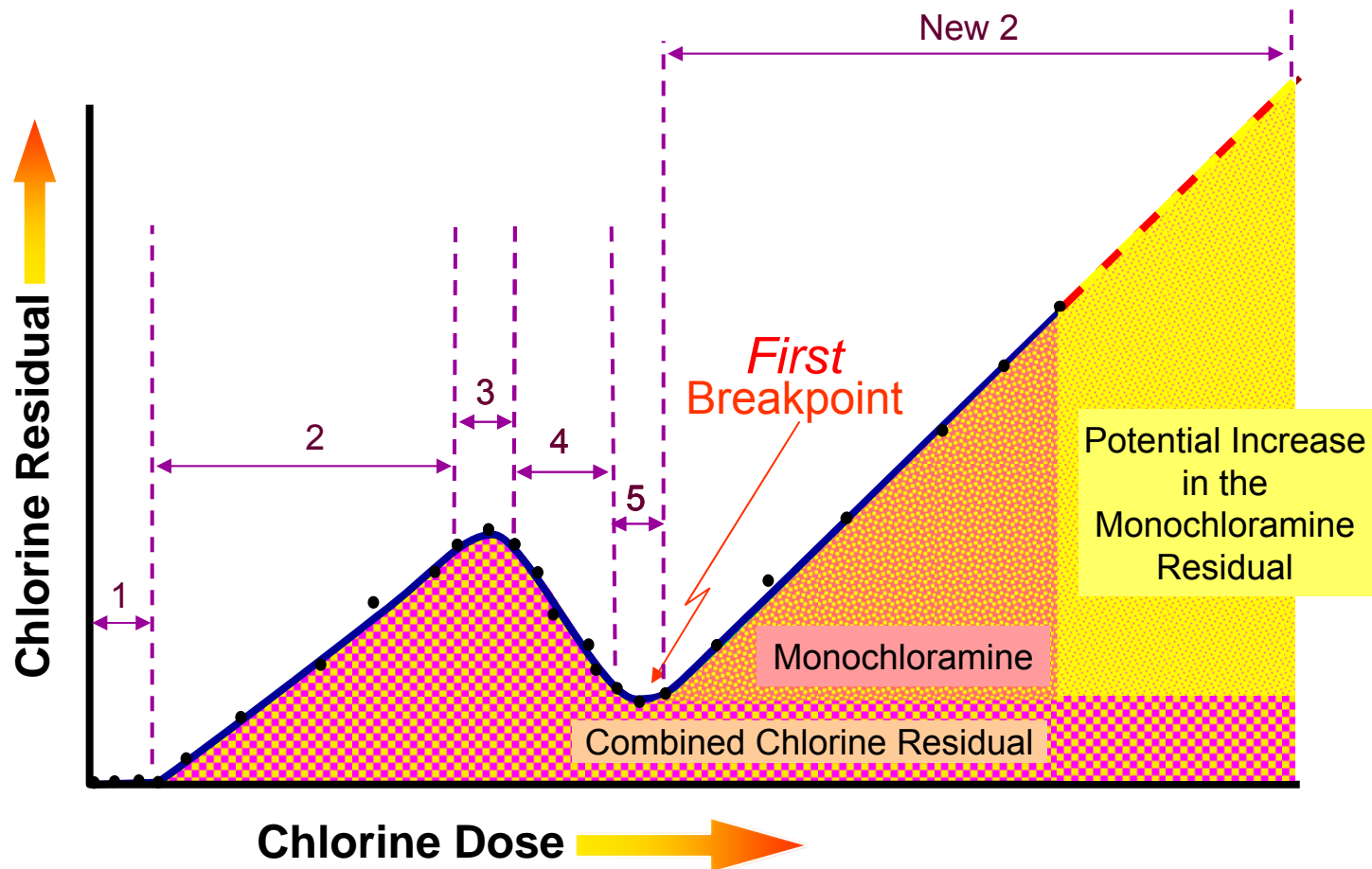
# Q2: What happens when we cut chlorine dose by 1.7 mg/L?



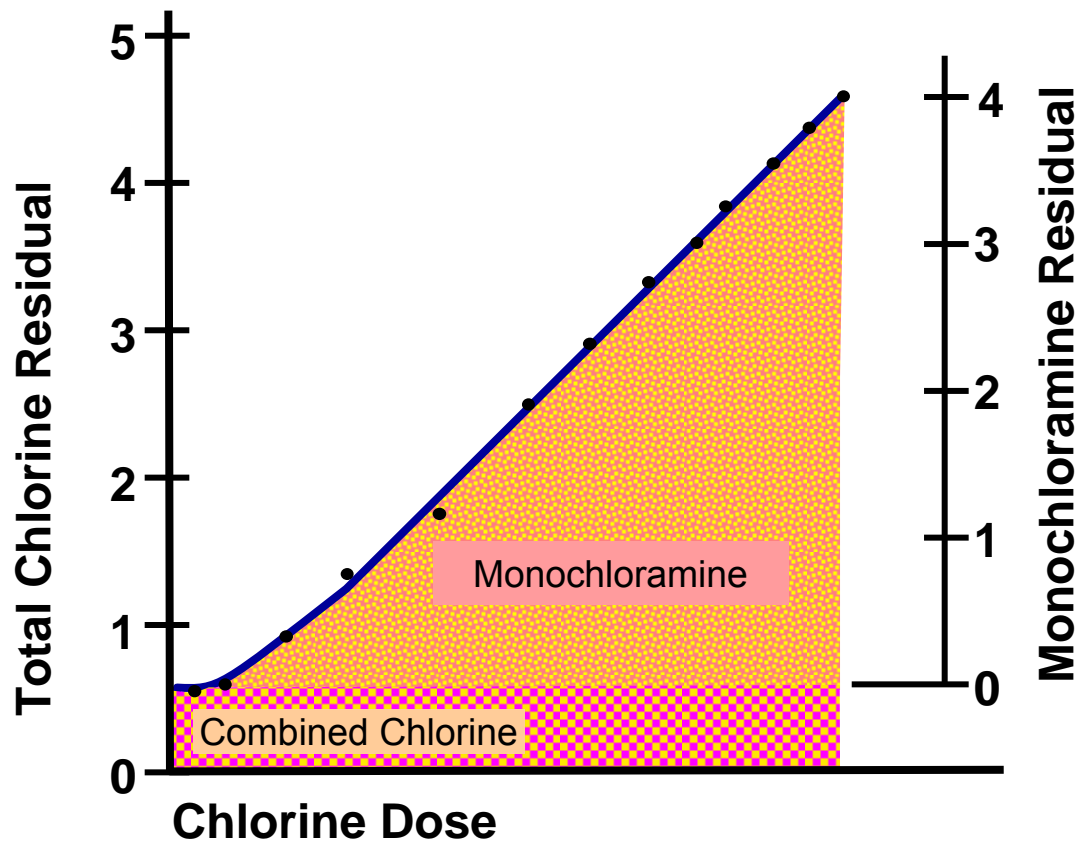
# Q3: What happens when we cut $\text{Cl}_2$ by 1.7 and then add $\text{NH}_3$ ?



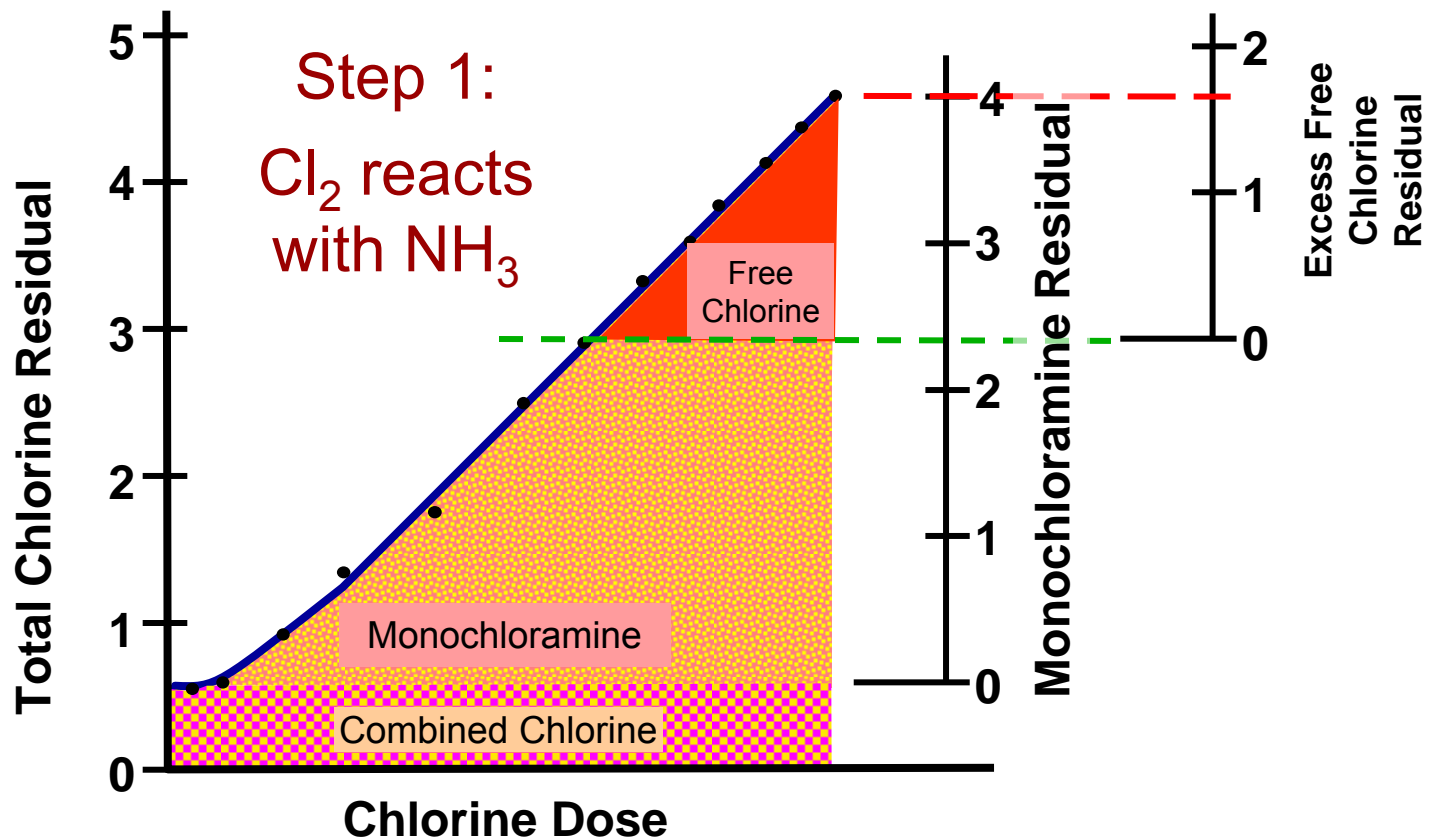
# Q4: What happens when we cut $\text{Cl}_2$ and then add excess $\text{NH}_3$ ?



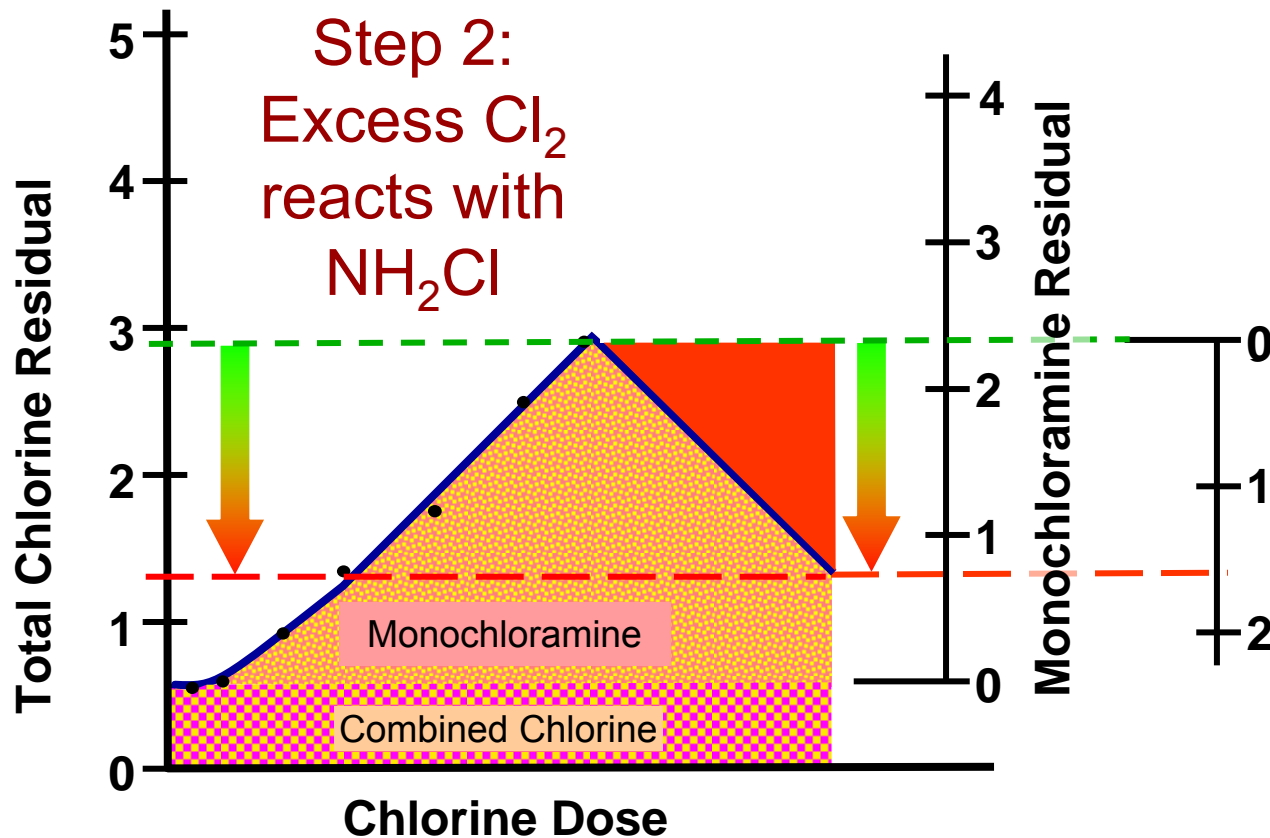
# Q5: What happens if we add too much $\text{NH}_3$ without cutting $\text{Cl}_2$ ?



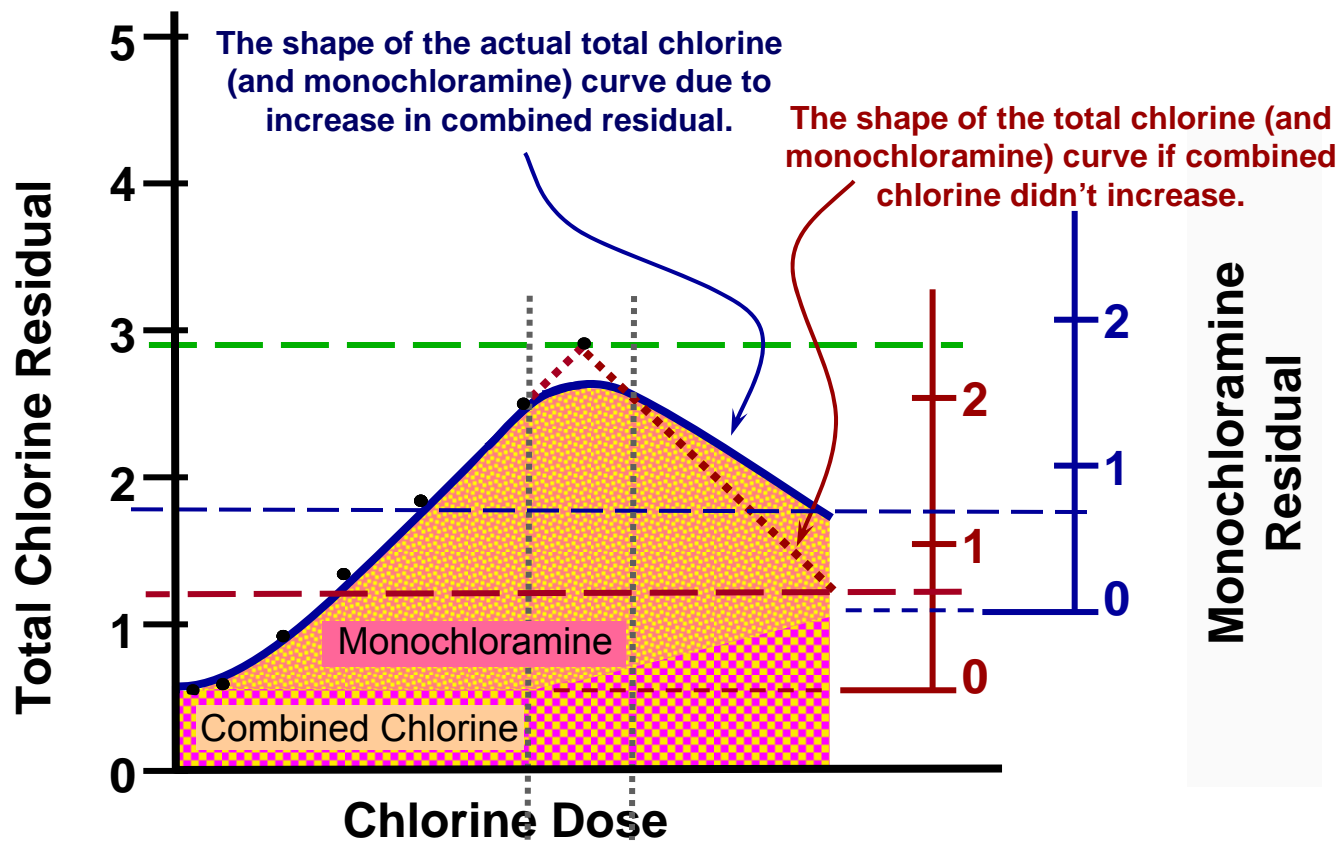
# Q6: What happens if we add the right $\text{NH}_3$ without cutting $\text{Cl}_2$ ?



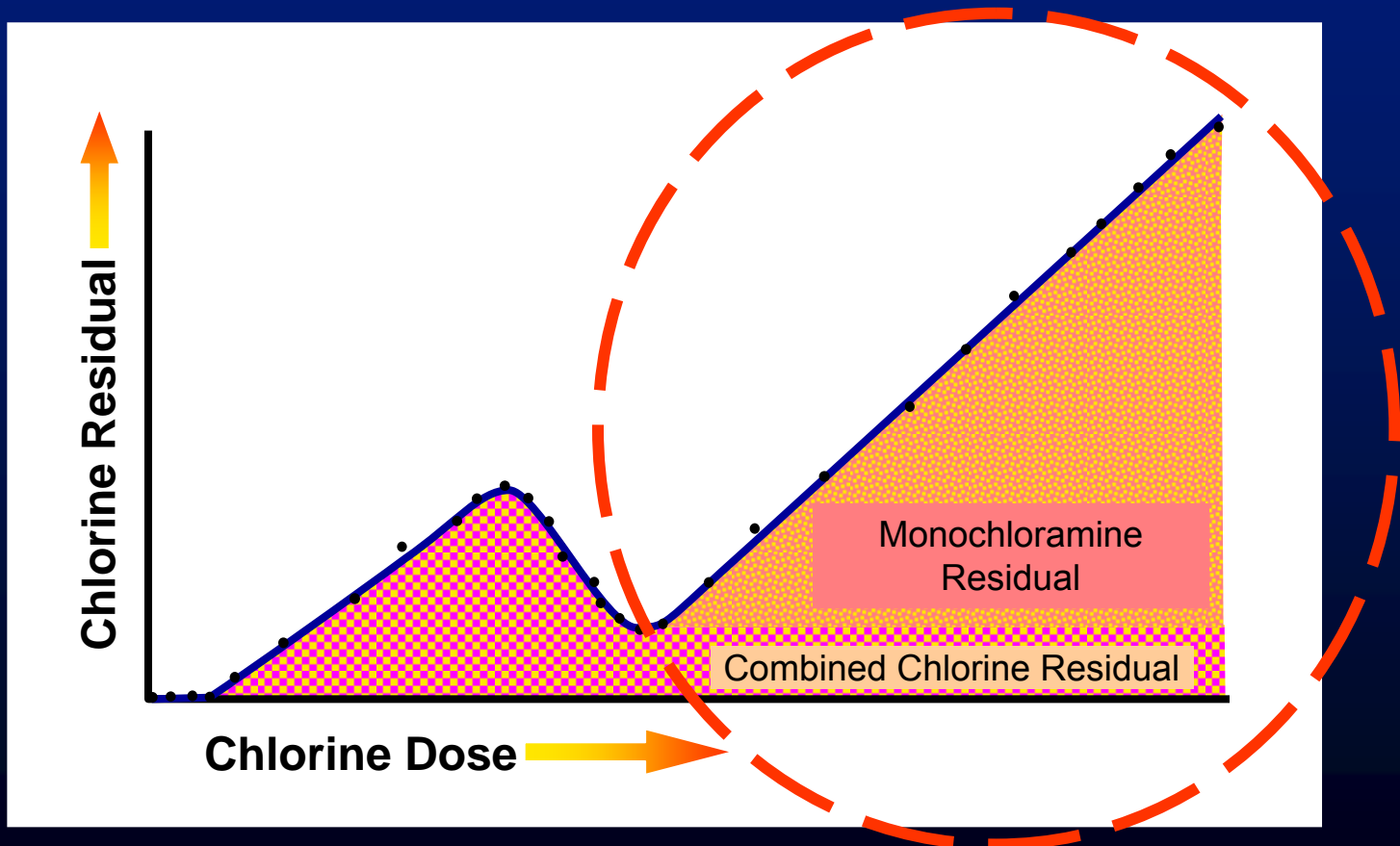
# Q6: What happens if we add the right $\text{NH}_3$ without cutting $\text{Cl}_2$ ?



# Q6: What happens if we add the right $\text{NH}_3$ without cutting $\text{Cl}_2$ ?



# Scenario 2: Ammonia before Chlorine



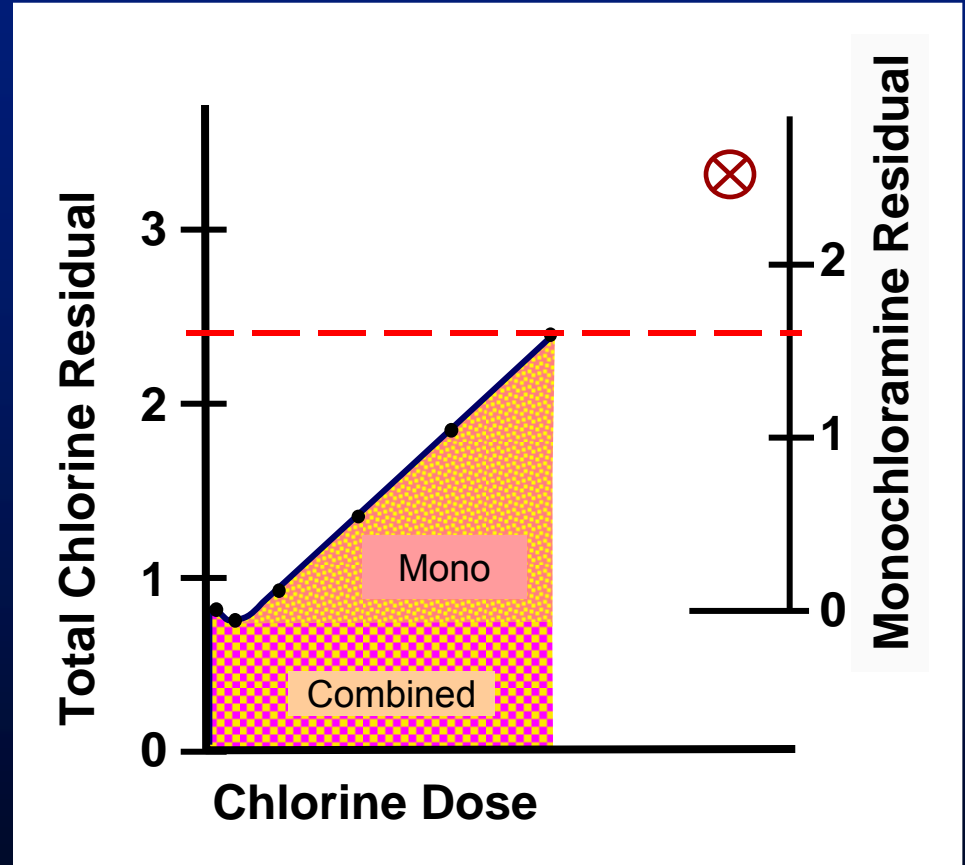
# Scenario 2 Data

## ▶ Target

- Mono = 2.3 mg/L

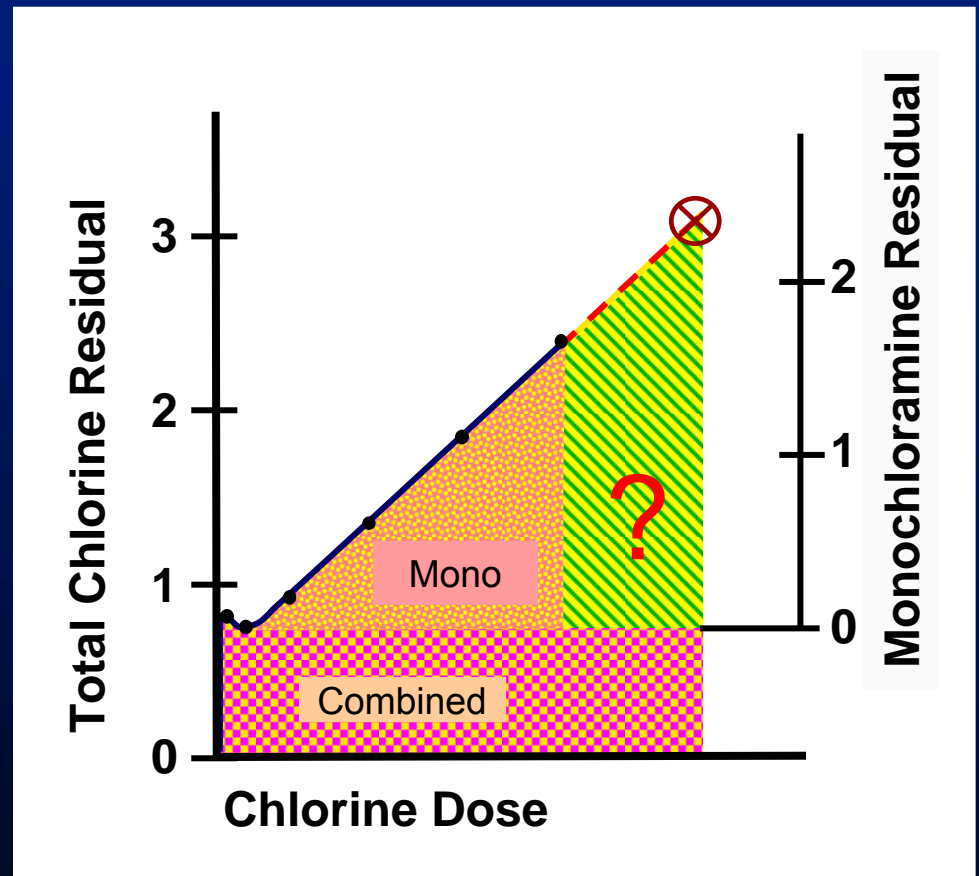
## ▶ Currently

- Mono = 1.6 mg/L
- TAC = 2.3 mg/L
- FAC = 0.0 mg/L
- FAA = 0.2 mg/L



# Scenario 2 Questions

- ▶ Q1: How much more (if any)  $\text{NH}_3$  is needed to reach our target?
- ▶ Q2: How much  $\text{Cl}_2$  is needed?



# What's the Bottom Line?

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- ▶ The Breakpoint Curve can help operators visualize what is happening during each step of the chloramination process.
- ▶ To evaluate the five chemical species that could be present, we need to be able to measure:
  - free available chlorine (FAC),
  - total available chlorine (TAC),
  - monochloramine (mono), and
  - free available ammonia (FAA)

# What's the Bottom Line?

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- 3) We can use FAC, TAC, mono, and FAA results to determine where we are on the curve and what general changes need to be made to get where we want to be.
- 4) If we add enough ammonia, the TAC residual will not change simply because we add ammonia. This is because:
  - One FAC molecule reacts with one FAA molecule to form one mono molecule, and
  - TAC includes FAC, mono, and combined.

# What's the Bottom Line?

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- 5) However, if we have too much FAC present after adding FAA:
- our mono will be lower than we expected,
  - our combined chlorine level will increase, and
  - our TAC level will drop (but not as much as our mono).

# What's the Bottom Line?

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- 6) Chlorine (or chlorine dioxide or ozone) needs to be added before ammonia when treating undisinfected water.
- 7) Ammonia should be added before chlorine if we are boosting the residual in water that has already been treated with chlorine, chlorine dioxide, or ozone.

# What's the Bottom Line?

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- 8) Competing reactions can affect the shape of the breakpoint curve. Consequently,
- It may take slightly more than 1.0 mg/L of chlorine to get 1.0 mg/L of mono, and
  - we may need to have a slight excess of ammonia present.
- 9) We have to be able to determine how much chlorine and ammonia we need to add to get what we want.

# Dosage and Feed Rate Calculations

# In Simple Terms

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- ▶ Chemical dose is the amount of chemical we add divided by the amount of water we put it in.
- ▶ Chemical feed rate is the amount of chemical we added divided by the amount of time it took us to add it.

# In the Real World

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- ▶ Dosage and feed rate calculations depend on the molecular formula and concentration of the chemicals used.
- ▶ The required dose and feed rates are affected by competing reactions.
- ▶ Our ability to control chloramination process is affected by our analytical methods.

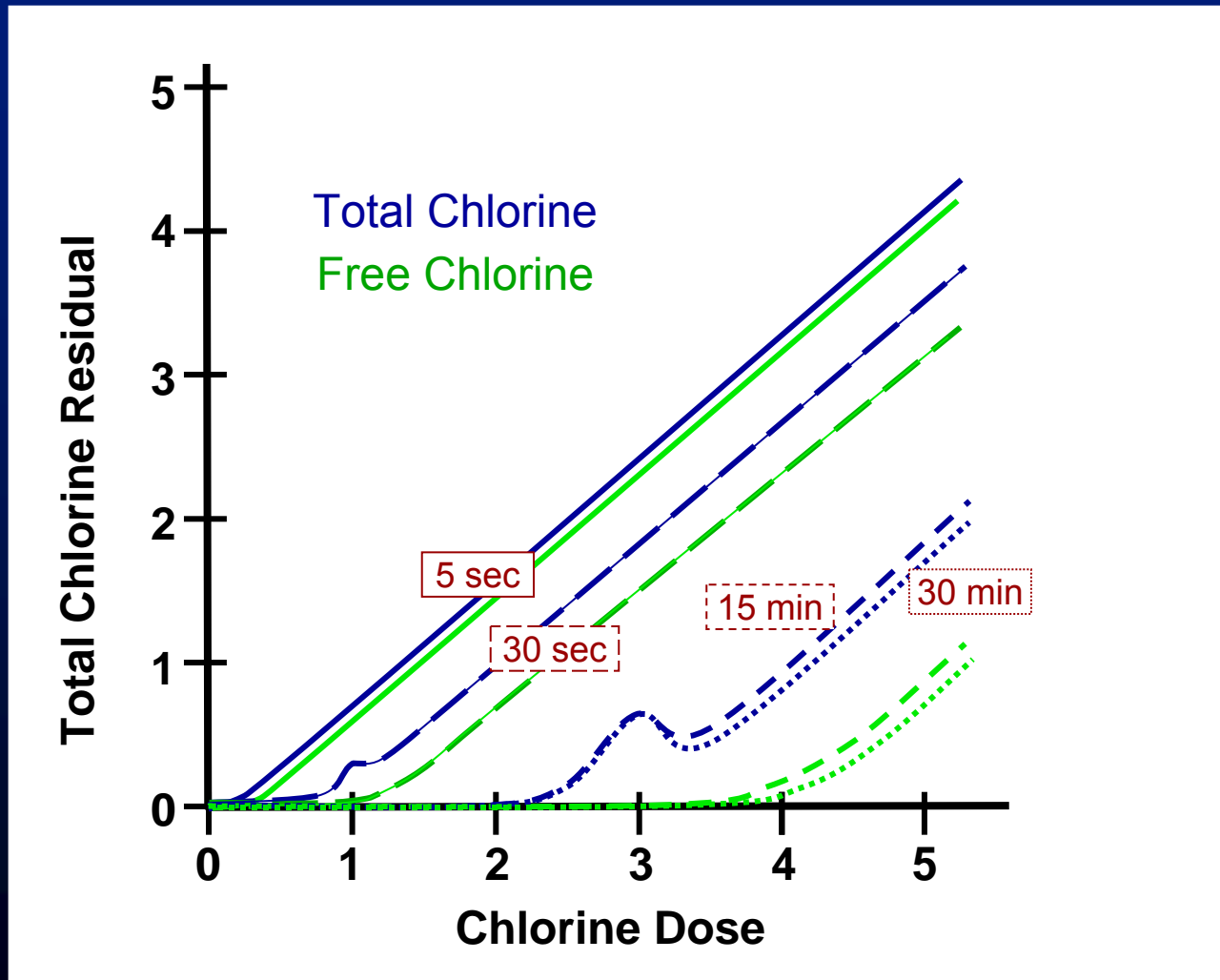
# Competing Reactions

# Reaction Conditions

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- ▶ Factors that affect reaction rates include:
  - the pH and temperature of the solution
  - the concentration of the reactants and products
- ▶ Chemical reactions can occur simultaneously but some are faster than others so time is important

# Reaction Time



# Analytical Methods

# Understand the Method Capabilities & Limitations

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- ▶ DPD powder pillows
  - Monochloramine interferes with the FAC test
- ▶ Amperometric titration (SM 4500Cl-D), DPD-FAS method (SM 4500Cl-F), and DPD colorimetric method (SM 4500Cl-G),
  - Can distinguish between FAC, Mono, and Combined (Di and Tri)

# Understand the Method Capabilities & Limitations

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## ▶ Hach Indophenol

- Monochloramine
- FAA

## ▶ Ion Specific Electrode

- FAA

## ▶ Hach Salicylate

- Low-level Monochloramine and FAA

# TCEQ Suggestions

## (for Field Investigators & Small Plants)

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### ▶ TAC and FAC

- DPD powder pillows and colorimeter

### ▶ Mono and FAA

- Hach Indophenol (Monochlor F)

# Understanding the Results

Compound & Concentration	Molecular Formula	Molecular Weight	Reported Result
0.1 millimoles of monochloramine (NH <sub>2</sub> Cl)	Cl <sub>2</sub>	71	7.1 mg/L as Cl <sub>2</sub>
	NH <sub>2</sub> Cl	51.5	5.15 mg/L as NH <sub>2</sub> Cl
	N	14	1.4 mg/L as N
0.01 millimoles of free available ammonia (NH <sub>3</sub> )	NH <sub>3</sub>	17	0.17 mg/L as NH <sub>3</sub>
	N	14	0.14 mg/L as NH <sub>3</sub> -N

# TCEQ Suggestions

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- ▶ Have the instrument report TAC, FAC, and Mono in units of mg/L as Cl<sub>2</sub>
- ▶ Have the instrument report FAA in units of mg/L as NH<sub>3</sub>
- ▶ If the instrument does not have the option, use conversion factors, e.g.
  - mg/L NH<sub>3</sub> = 1.21 times mg/L NH<sub>3</sub>-N
  - mg/L Cl<sub>2</sub> = 1.29 times mg/L NH<sub>2</sub>Cl

Applied Chemical Dose,  
Applied Reactant Dose,  
and  
Effective Reactant Dose

# Parts per Million

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- ▶ Chemical dose should be described on a weight-to-weight (w/w) basis whenever possible.
- ▶ Using a w/w basis compensates for molecular formula and chemical concentration
- ▶ On a weight-basis,  
 $1 \text{ ppm} = 1 \text{ lb per } 10^6 \text{ lbs} = 1 \text{ mg/L}$

# Molecular Formula and Chemical Concentration

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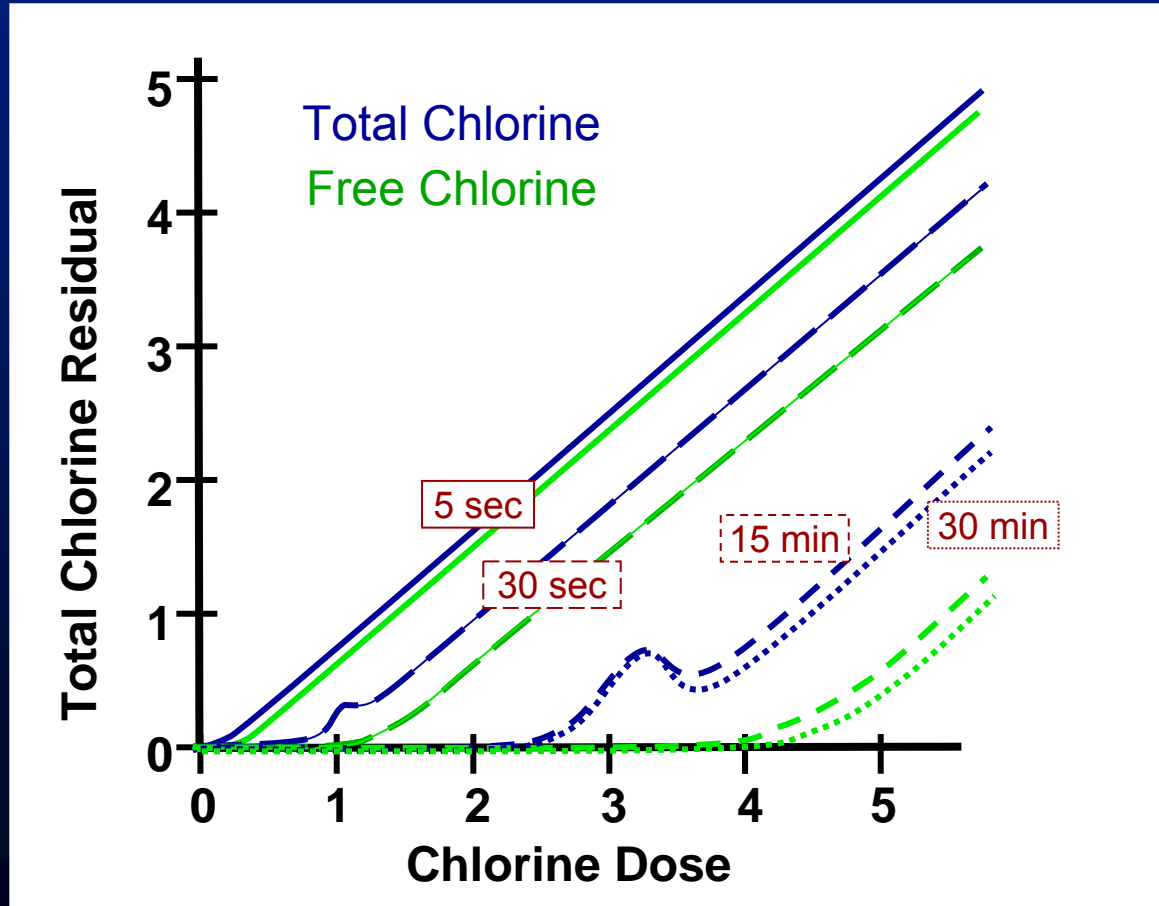
- ▶ Many of the chemicals that plants use are molecular compounds or solutions that contain materials other than the molecular group that participates in the chemical reaction.
- ▶ Dosage and feed rate calculations must compensate for the “purity” of the chemicals used.

# Applied Chemical Dose vs. Applied Reactant Dose

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- ▶ Applied chemical dose is the amount of chemical that we add divided by the amount of water we add it to.
- ▶ Applied reactant dose is the amount of actual reactant (after we correct for “purity”) that we add divided by the amount of water we add it to.

# Remember competing reactions can consume some of our reactants



# Applied Reactant Dose vs. Effective Reactant Dose

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- ▶ Applied reactant dose is the amount of “pure” reactant we added divided by the amount of water we added it to.
- ▶ Effective reactant dose is the amount of reactant that remained (after competing reactions) divided by the amount of water we added it to.

# Chlorine Dose and Feed Rate

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- ▶ Chlorine is available in a variety of forms and concentrations
  - chlorine gas is 100% available chlorine
  - calcium hypochlorite is a solid that generally contains 60 – 75% available chlorine
  - sodium chlorite is a liquid that contains 5 – 12% available chlorine

# To feed 10 lbs per day of Cl<sub>2</sub> using gas chlorine:

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## ▶ Data:

- Chlorine gas is 100% available chlorine

## ▶ Calculations:

- Rotameter setting is 10 ppd . . . maybe

# Gases are Compressible Fluids

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- ▶ Each gas has a unique specific gravity (density) that changes with temperature and pressure.
- ▶ Rotameters are calibrated with a specific gas under specific pressure at a specific temperature using a specific float design and material.

# Typical Rotameter Design Data

Float Material	Specific Gravity	Gas	Specific Gravity <sup>(1)</sup>
Teflon	2.2	Air	1.0
Glass	2.53	Ammonia	0.593
Sapphire	3.99	Chlorine	2.45
Titanium	4.50	Nitrogen	0.967
316 SS	8.02	<sup>(1)</sup> At STP which is: T = 70°F P = 1 atm (14.7 psi)	
Carboloy	15.00		

# To feed 10 lbs per day of $\text{Cl}_2$ using calcium hypochlorite:

## ► Data:

- The  $\text{Ca}(\text{OCl})_2$  contains 65% available  $\text{Cl}_2$
- The feed solution contains 10 lbs of  $\text{Ca}(\text{OCl})_2$  in 10 gallons of water

## ► Calculations:

$$\frac{10 \text{ lbs } \cancel{\text{Cl}_2}}{\text{day}} \times \frac{1 \text{ lb } \text{Ca}(\text{OCl})_2}{0.65 \text{ lbs } \cancel{\text{Cl}_2}} = \frac{15.4 \text{ lbs } \text{Ca}(\text{OCl})_2}{\text{day}}$$

$$\frac{15.4 \text{ lb } \cancel{\text{Ca}(\text{OCl})_2}}{\text{day}} \times \frac{10 \text{ gal of solution}}{10 \text{ lb } \cancel{\text{Ca}(\text{OCl})_2}} = \frac{15.4 \text{ gal of solution}}{\text{day}}$$

# To feed 10 lbs per day of $\text{Cl}_2$ using sodium hypochlorite:

## ► Data:

- The NaOCl bleach contains 10% available  $\text{Cl}_2$
- The bleach has a specific gravity of 1.28

## ► Calculations:

$$\frac{10 \text{ lbs } \cancel{\text{Cl}_2}}{\text{day}} \times \frac{\text{lb bleach}}{0.10 \cancel{\text{ lbs } \text{Cl}_2}} = \frac{100 \text{ lbs bleach}}{\text{day}}$$

$$1 \text{ gallon of bleach} = 1.28 \times 8.34 = \frac{10.68 \text{ lbs of bleach}}{\text{gallon of bleach}}$$

$$\frac{100 \cancel{\text{ lb bleach}}}{\text{day}} \times \frac{\text{gal bleach}}{10.68 \cancel{\text{ lb bleach}}} = \frac{9.4 \text{ gal of bleach}}{\text{day}}$$

# Summary Example

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## ▶ Data:

- Water flow rate at the point of application is 167 gpm = 0.24 MGD = 2.0 million ppd
- Chemicals are applied at the rate calculated in each of the individual examples
- Chlorine demand at this application point = 2.0 mg/L

# Summary Example

	Chlorine Gas	Calcium Hypochlorite	Sodium Hypochlorite Bleach
Chemical Feed Rate (ppd) (from the example)	10	15.4	100
Water Flow Rate (million ppd)	2.00	2.00	2.00
Applied Chemical Dose (ppm)	5	7.7	50
Reactant feed rate (ppd of Cl <sub>2</sub> )	10	10	10
Applied Reactant Dose (ppm of Cl <sub>2</sub> )	5.0	5.0	5.0
Chlorine Demand (mg/L of Cl <sub>2</sub> )	2.0	2.0	2.0
Effective Reactant Dose (ppm of Cl <sub>2</sub> )	3.0	3.0	3.0

# Ammonia Dose and Feed Rate

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- ▶ Ammonia, like chlorine, is available in a variety of forms and concentrations
  - ammonia gas is 100% FAA
  - ammonium hydroxide and ammonium sulfate are available in both solid and liquid forms
- ▶ Unlike in the case of chlorine, the concentration of ammonia compounds can be described in a variety of ways

# Ammonia Compound Composition

Compound	Molecular Formula	Molecular Weight	Available Ammonia	
			As NH <sub>3</sub>	As N
anhydrous ammonia (gas)	NH <sub>3</sub>	17	100%	82.4%
ammonium hydroxide (dry)	NH <sub>4</sub> OH	35	48.6%	40.0%
ammonium sulfate (dry)	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	132	25.8%	21.2%

# Ammonia Solution Concentration

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It is extremely important to know exactly how the vendor specs his product.

- Chlorine concentration is almost always described in terms of “% available chlorine on a  $w/w$  basis”
- No such standard exists for ammonia solutions. Depending on the vendor, one pound of a 25% LAS product could contain:
  - 0.25 lb of dry ammonium sulfate, or
  - 0.25 lb of ammonia, or
  - 0.25 lb of nitrogen

# To feed 2 lbs per day of $\text{NH}_3$ using anhydrous ammonia:

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## ▶ Data:

- Anhydrous ammonia is 100% available  $\text{NH}_3$

## ▶ Calculations:

- Rotameter setting is 2 ppd . . . maybe

# To feed 2 lbs per day of $\text{NH}_3$ using liquid ammonium sulfate:

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## ► Data:

- Ammonium sulfate  $(\text{NH}_4)_2\text{SO}_4$  contains two ammonium  $(\text{NH}_4)$  groups and therefore two ammonia  $(\text{NH}_3)$  molecules
- 132 lbs of  $(\text{NH}_4)_2\text{SO}_4$  contains 34 lbs of  $\text{NH}_3$
- The LAS contains 38% ammonium sulfate ( $^w/w$ )
- The LAS has a specific gravity of 1.23

# To feed 2 lbs per day of $\text{NH}_3$ using liquid ammonium sulfate:

- Calculations:

$$\frac{2 \text{ lbs } \cancel{\text{NH}_3}}{\text{day}} \times \frac{132 \text{ lb } \cancel{(\text{NH}_4)_2 \text{SO}_4}}{34 \text{ lbs } \cancel{\text{NH}_3}} \times \frac{1 \text{ lb LAS}}{0.38 \text{ lbs } \cancel{(\text{NH}_4)_2 \text{SO}_4}} = \frac{20.4 \text{ lbs LAS}}{\text{day}}$$

$$1 \text{ gallon of LAS} = 1.23 \times 8.34 = \frac{10.26 \text{ lbs of LAS}}{\text{gallon of LAS}}$$

$$\frac{100 \text{ lb } \cancel{\text{LAS}}}{\text{day}} \times \frac{1 \text{ gal LAS}}{10.68 \text{ lb } \cancel{\text{LAS}}} = \frac{2.0 \text{ gal of LAS}}{\text{day}}$$

Notice: gpd of LAS = ppd of ammonia (as  $\text{NH}_3$ ) when the plant feeds this specific product

# What's the Bottom Line?

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- ▶ We always need to be aware of the potential impact of competing reactions and the time that is available for them to occur.
- ▶ We must be aware of and understand how our instruments are reporting our results before we can interpret the data

# What's the Bottom Line?

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- 3) If possible, analytical instruments should be set to:
  - a) report FAC, TAC, and mono levels as “mg/L as Cl<sub>2</sub>”
  - b) report FAA levels as “mg/L as NH<sub>3</sub>”
- 4) It is extremely important to understand the product specifications

# What's the Bottom Line?

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- 5) Chemical dosage should be calculated on a weight-to-weight ( $^w/w$ ) basis whenever possible
- 6) 1 ppm ( $^w/w$ ) = 1 lb/10<sup>6</sup> lbs = 1 mg/L
- 7) There is an important difference between:
  - a) Applied Chemical Dose
  - b) Applied Reactant Dose
  - c) Effective Reactant Dose

# What's the Bottom Line?

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## 7a) Applied Chemical Dose:

The amount of chemical we add divided by the amount of water we put it in

## 7b) Applied Reactant Dose:

The amount of reactant (contained in the chemical we added) divided by the amount of water we put it in

# What's the Bottom Line?

---

## 7c) Effective Chemical Dose:

The amount of reactant (contained in the chemical we added) that is actually available (after any competing reactions) to form our desired product divided by the amount of water we put it in

# What's the Bottom Line?

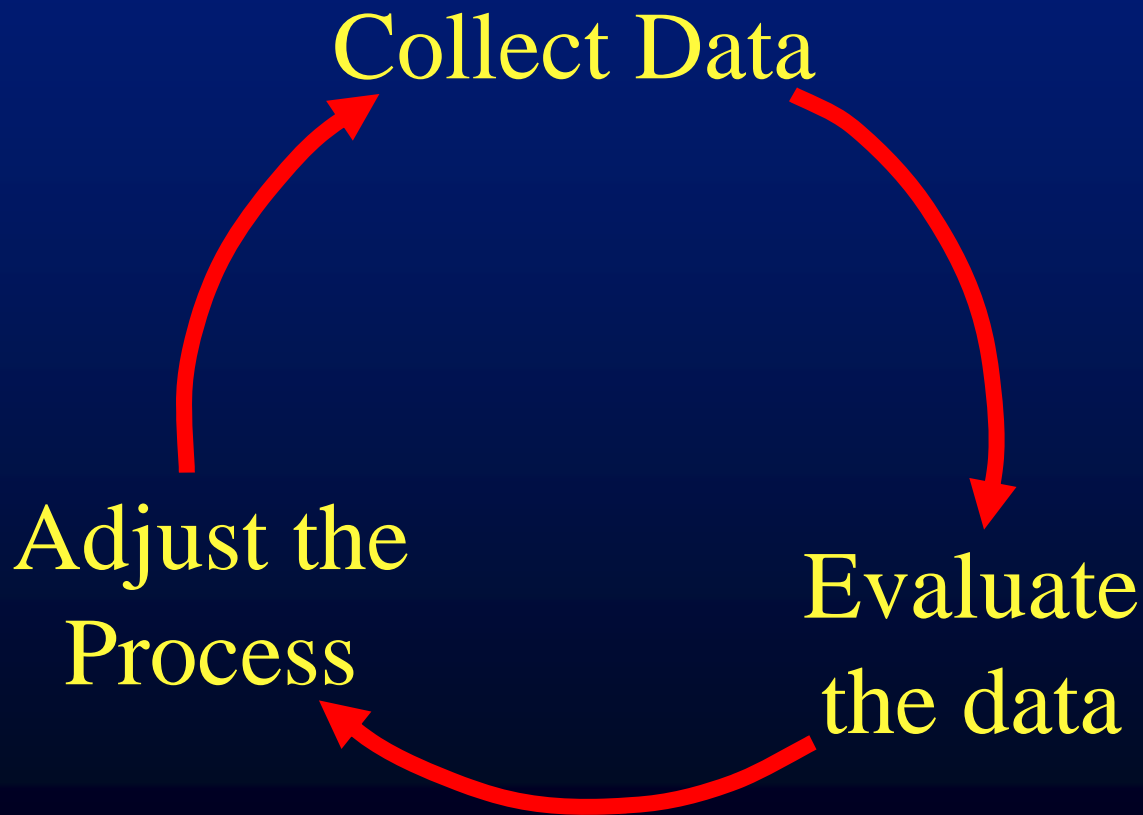
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- 8) It is important to understand how to set the chemical feed equipment
- 9) Plants that feed liquid chemicals need to have a hydrometer (or some other means) to check specific gravity
- 10) It is important to know the water flow rate at each point of chemical application

# Applying the Concepts

# Chuck Schwarz's Simplified Process Control Loop

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# Applying the Concepts . . . in a practical way

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- ▶ What do we need to measure to control the process?
- ▶ Where is the best spot to test for it?
- ▶ What results are we looking for?
- ▶ What do we do if we don't get them?

# Collecting the Data

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For each chemical application point, we need to know:

- 1) our current FAC, TAC, mono, and FAA levels
- 2) our target FAC, TAC, and mono residuals and our target FAA level
- 3) our current chemical feed rate and water flow rate
- 4) the molecular weight and formula for each chemical we are using
- 5) the concentration (on a  $^w/w$  basis) and specific gravity of each liquid chemical

# What do we need to measure and why?

---

1) FAC . . . to find out

- a) if we added the right amount of  $\text{Cl}_2$
- b) exactly how much  $\text{NH}_3$  is needed to form mono

2) FAA . . . to find out

- a) if we applied too much  $\text{NH}_3$
- b) exactly how much  $\text{Cl}_2$  is needed to reduce  $\text{NH}_3$  levels

# What do we need to measure and why?

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3) Monochloramine . . . to find out

- if we added the right amount of  $\text{Cl}_2$  and  $\text{NH}_3$

4) TAC . . . to find out

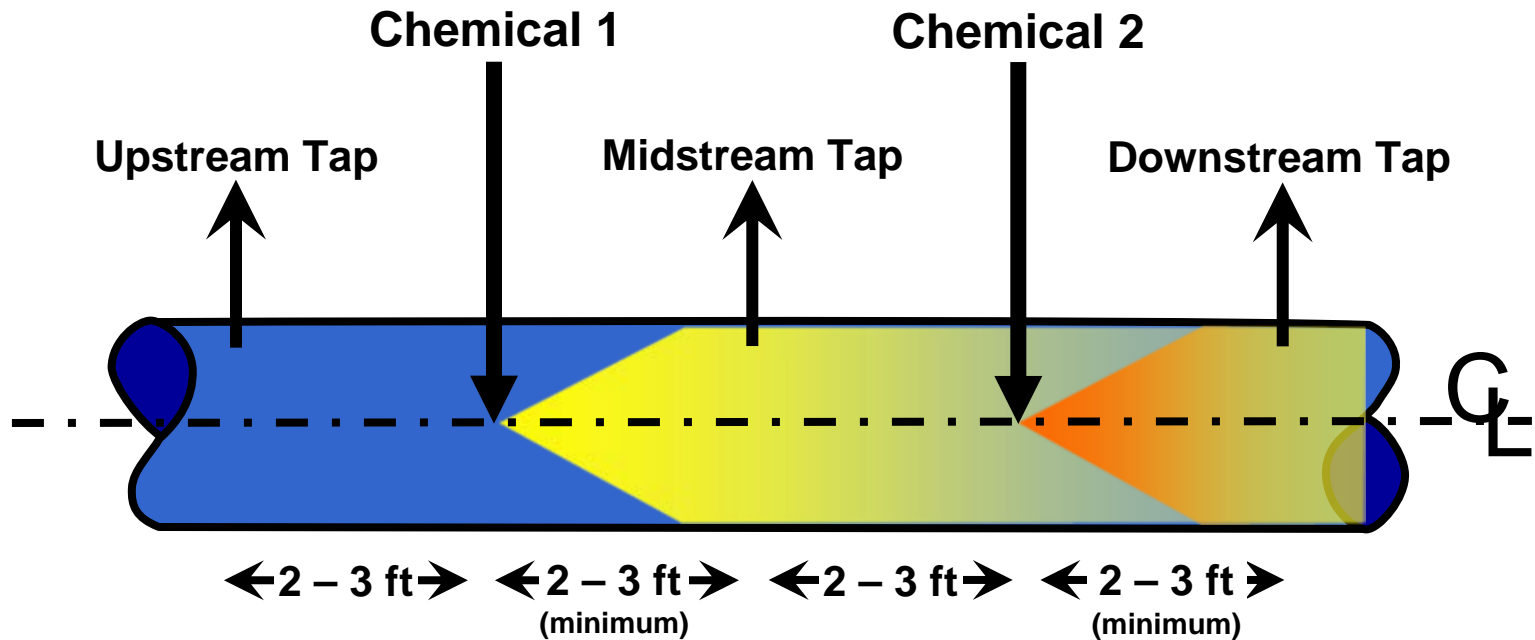
- if we made any di- or trichloramine
- how much difference we should expect between TAC and monochloramine levels after we add  $\text{NH}_3$

# Where should we test?

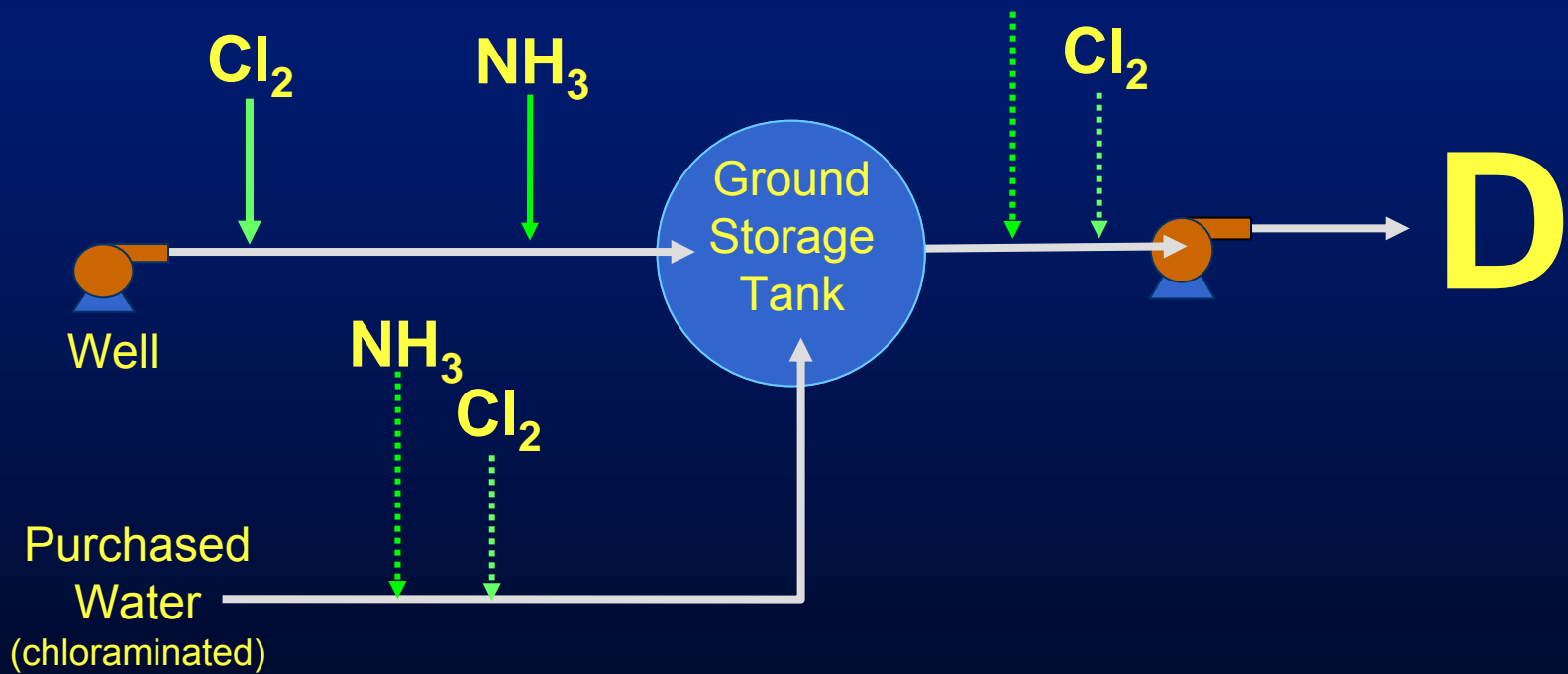
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- ▶ For regulated parameters . . .  
At every location required by regulations
  - At the end of the disinfection zone
  - At the point of entry to distribution
- ▶ For process control parameters . . .  
At every critical control point
  - Upstream of the chemical injection point
  - Downstream of the chemical injection point

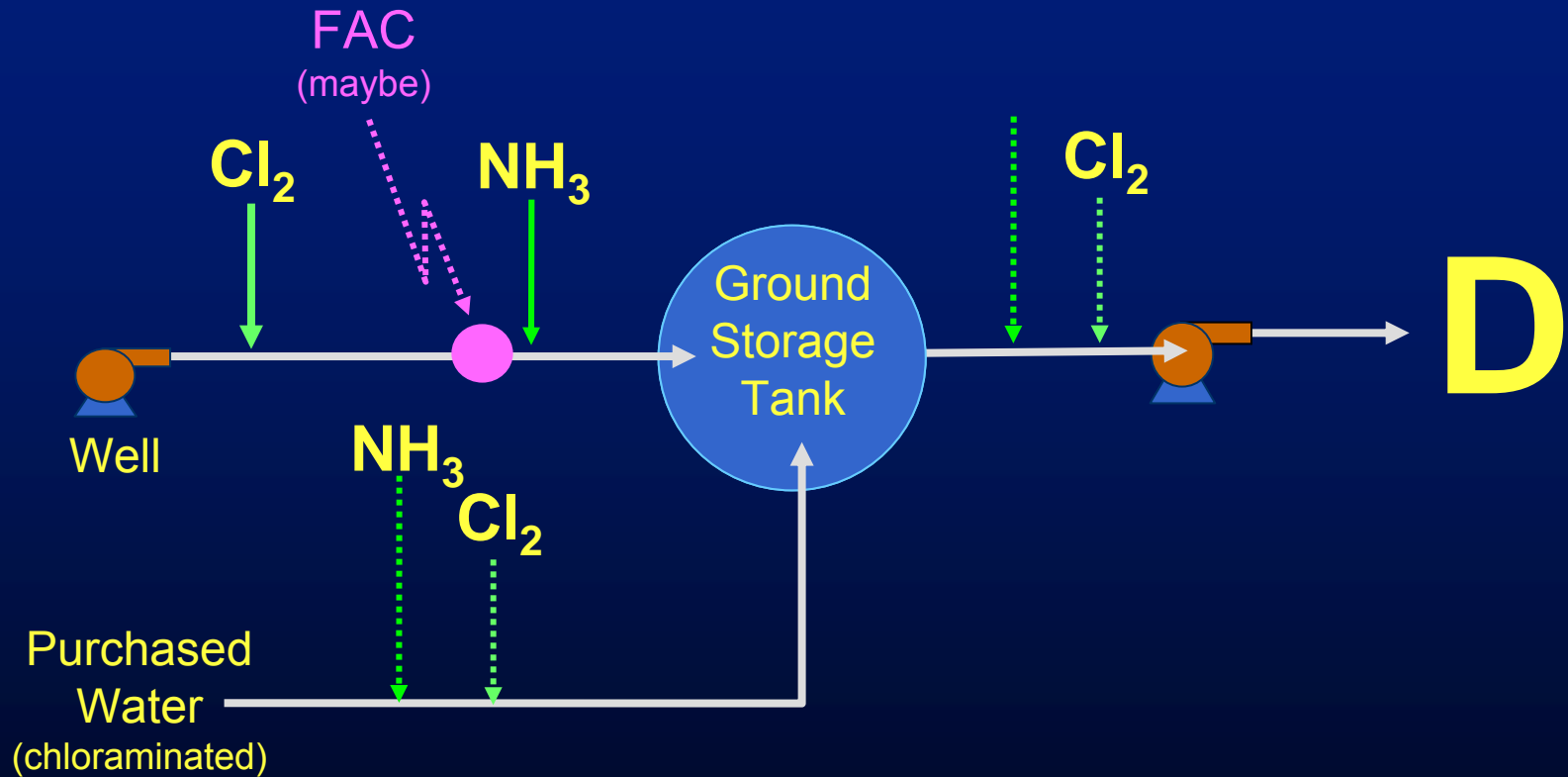
# Where should we test?



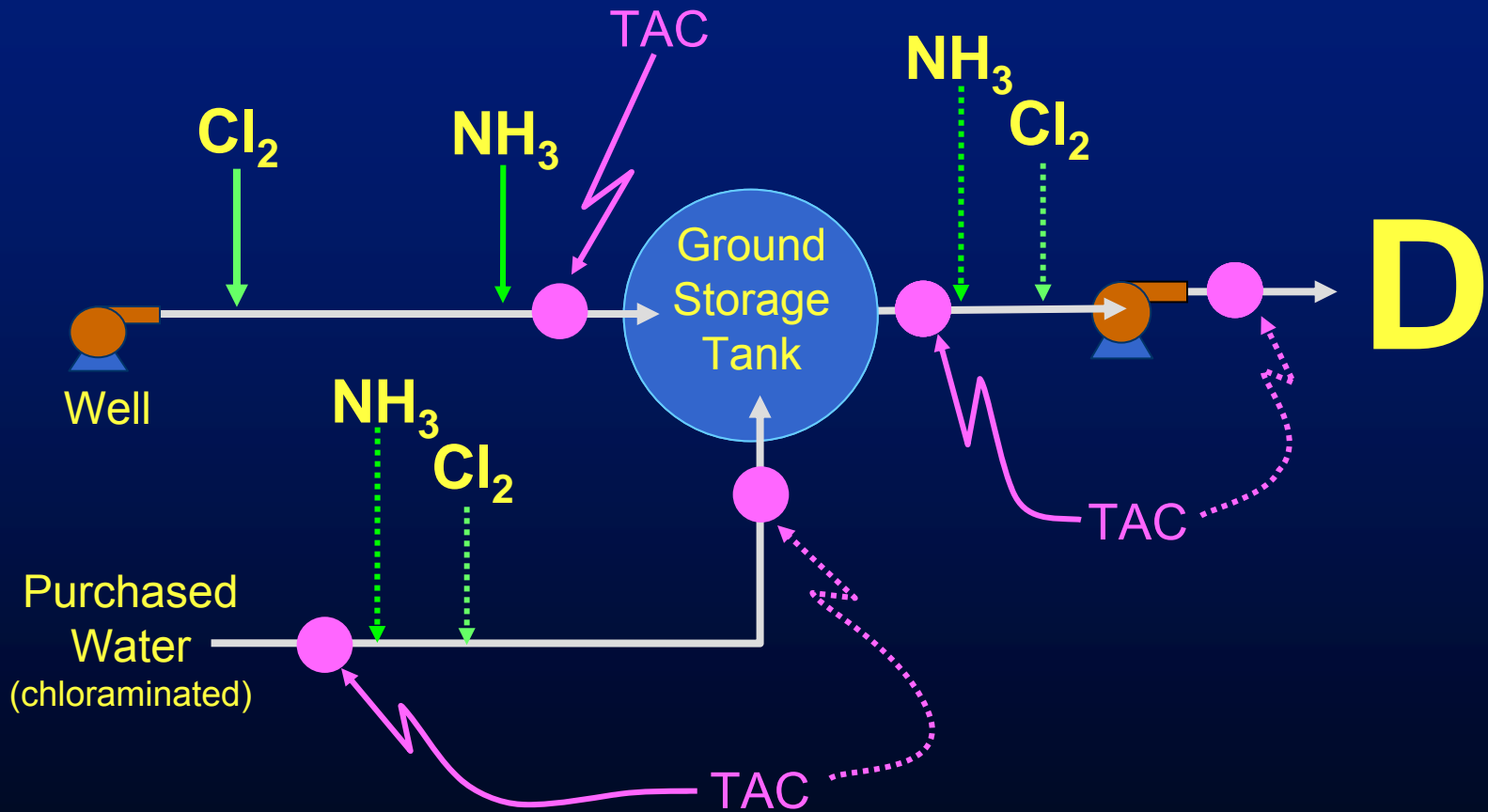
# Plant Schematic and Feed Points



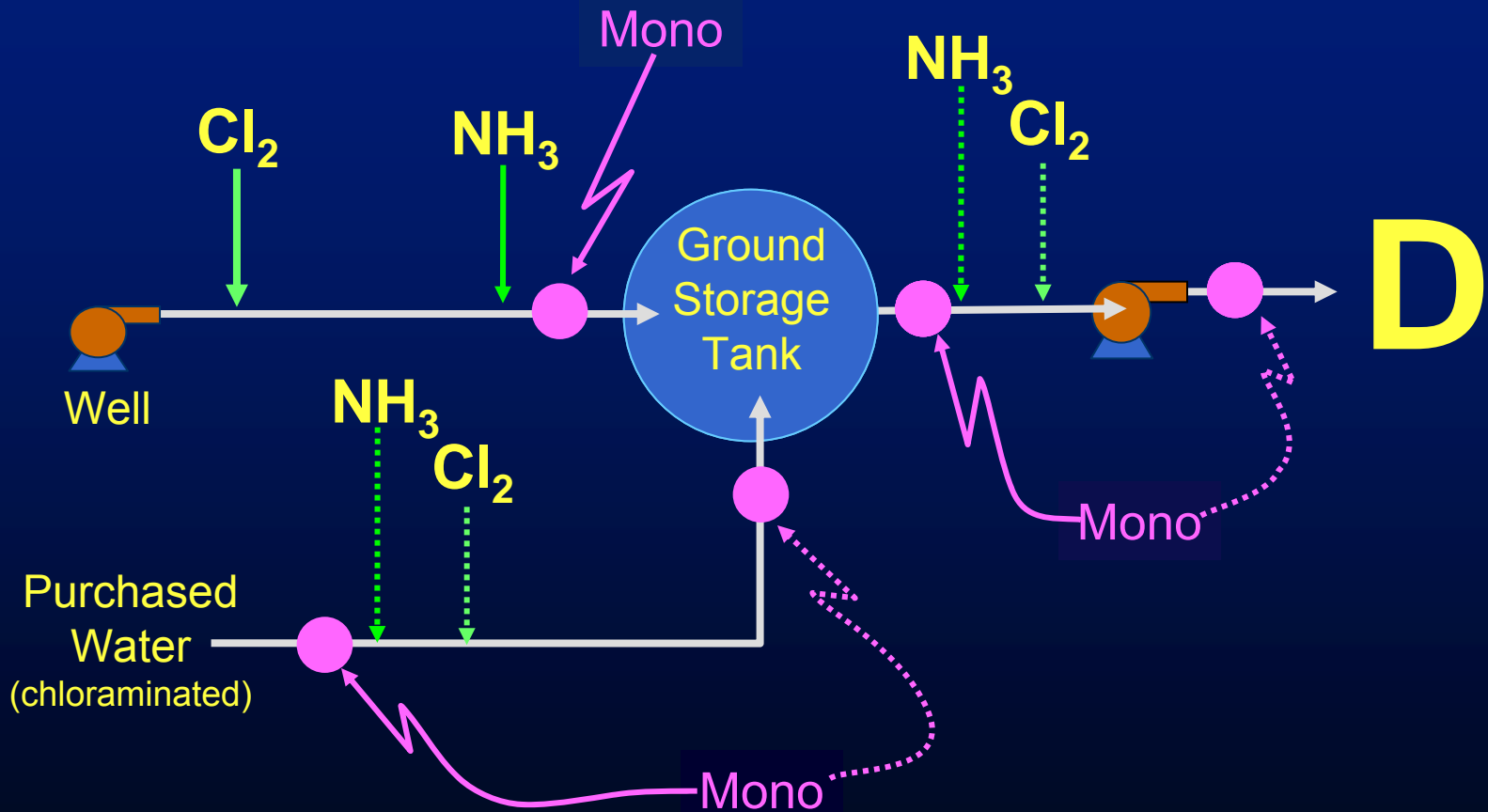
# Where to Measure FAC



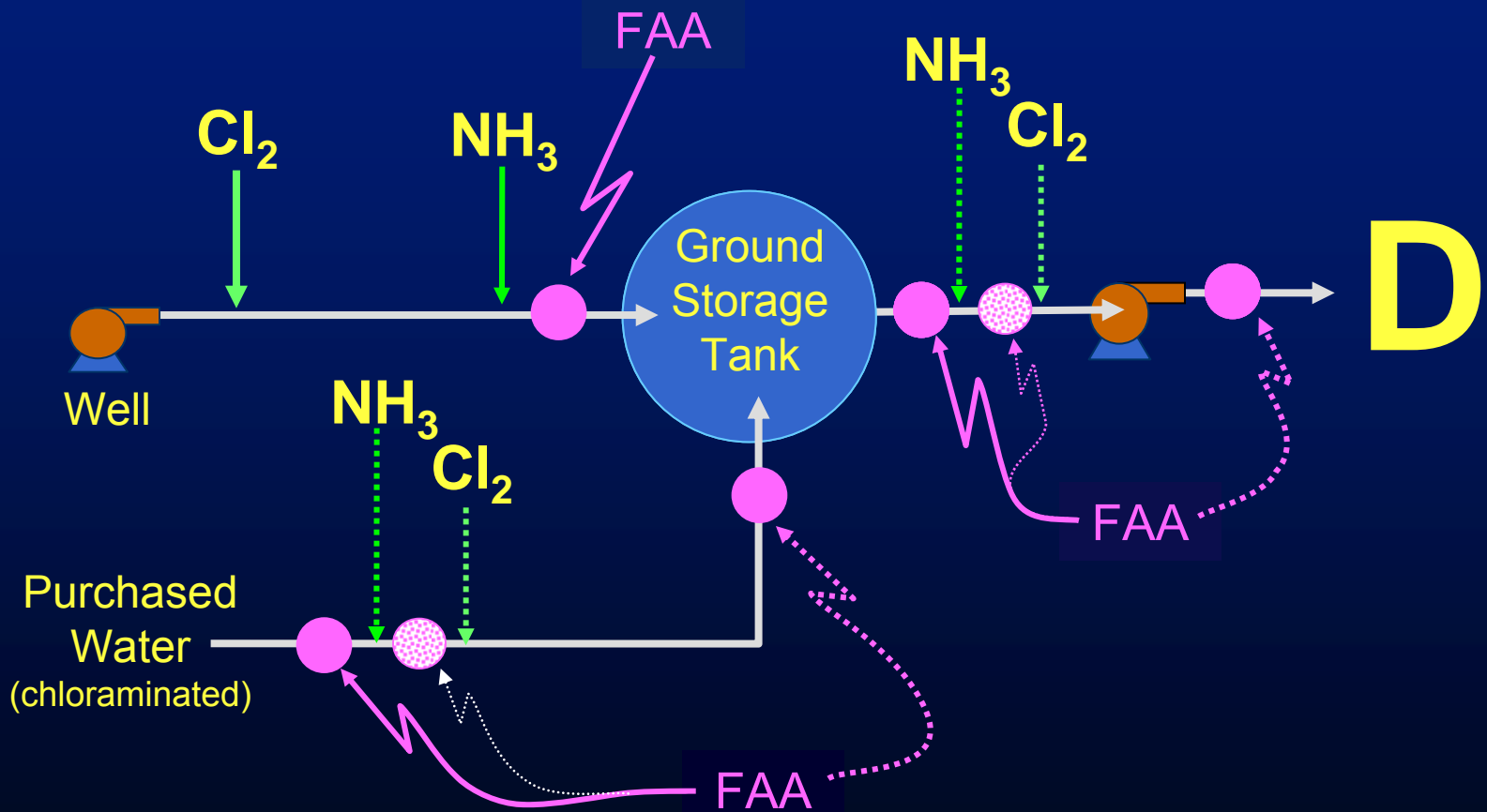
# Where to Measure TAC



# Where to Measure $\text{NH}_2\text{Cl}$



# Where to Measure FAA



# Evaluating the Data

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For each chemical application point,  
we need to determine:

- 1) our performance target(s) and
- 2) our acceptable range(s).

# What are our general objectives?

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- ▶ If  $\text{Cl}_2$  is added before  $\text{NH}_3$ 
  - $\text{FAC} = \text{Target NH}_2\text{Cl}$
- ▶ If  $\text{NH}_3$  is added before  $\text{Cl}_2$ 
  - $\text{FAA} = \text{Target NH}_2\text{Cl} \div \text{target Cl}_2:\text{NH}_3 \text{ ratio}$

# What are our general objectives? (cont)

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- ▶ After adding the  $\text{Cl}_2$  and  $\text{NH}_3$ 
  - $\text{NH}_2\text{Cl} = \text{Target NH}_2\text{Cl}$
  - Minimal change in the combine chlorine  
i.e.,  $\text{TAC} - \text{FAC} = \text{TAC} - \text{NH}_2\text{Cl}$
  - $\text{FAA}$  as  $\text{NH}_3$  is within acceptable range

# What should the targets be?

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## ▶ FAC, TAC, and mono

- Within the plant, targets will probably be based on CT requirements
- At the HSPS, targets will probably be based on distribution system needs

## ▶ FAA

- Within the plant, targets will probably be based on monochloramine targets
- At the HSPS, FAA as  $\text{NH}_3 = 0.05 - 0.10$  mg/L

# What's an acceptable upper limit?

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- ▶ For FAC, TAC, and Mono
  - probably no more than 1.0 – 1.5 mg/L higher than the target
- ▶ For combined chlorine
  - More than a 0.5 – 1.0 mg/L increase should be avoided if possible.
- ▶ For FAA
  - probably around 0.2 mg/L within the plant
  - no more than 0.15 mg/L at the HSPS.

# Adjusting the Process

## Where to START

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- ▶ If  $\text{FAC} > \text{NH}_2\text{Cl}$  target, then
  - Reduce the  $\text{Cl}_2$  dose
- ▶ If  $\text{NH}_2\text{Cl}$  is too high, then
  - Reduce the  $\text{NH}_3$  dose and
  - Reduce the  $\text{Cl}_2$  dose
- ▶ If  $\text{NH}_3$  is too high, either
  - Reduce the  $\text{NH}_3$  dose or
  - Increase the  $\text{Cl}_2$  dose

# Adjusting the Process

## Where to START (cont)

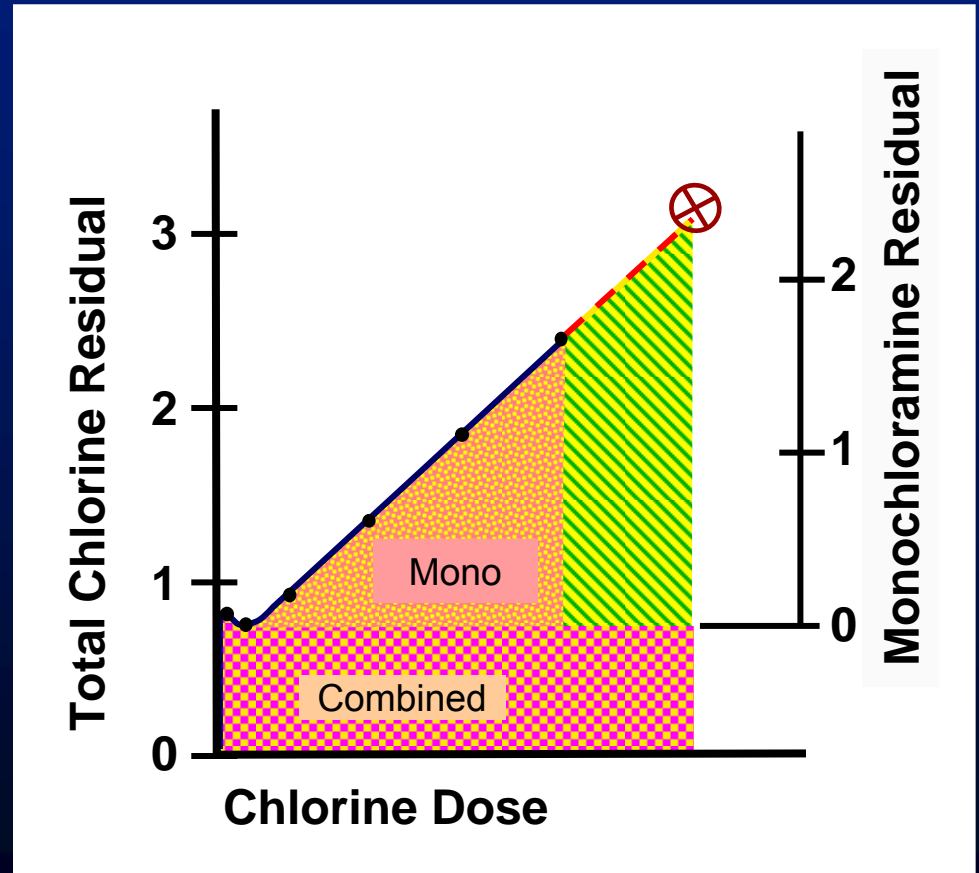
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- ▶ If TAC dropped after  $\text{Cl}_2$  addition, either
  - Increase the  $\text{NH}_3$  dose or
  - Reduce the  $\text{Cl}_2$  dose
- ▶ If combined chlorine increased, either
  - Increase the  $\text{NH}_3$  dose or
  - Reduce the  $\text{Cl}_2$  dose

IT'S A BALANCING ACT BASED ON WHERE  
THEY'RE AT ON THE BREAKPOINT CURVE

# Back to the Scenario 2 Questions

- ▶ Q1: How much (if any)  $\text{NH}_3$  is needed to reach our target?
- ▶ Q2: How much  $\text{Cl}_2$  is needed?



# The Situation:

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## ► Data:

- $\text{NH}_3$  was applied before  $\text{Cl}_2$
- $\text{NH}_2\text{Cl}$  target = 2.3 mg/L
- TAC = 2.3 mg/L
- FAC = 0.0 mg/L
- $\text{NH}_2\text{Cl}$  = 1.6 mg/L
- FAA = 0.2 mg/L as  $\text{NH}_3$
- 1.0 mg/L of FAC will produce 1.0 mg/L of mono (as  $\text{Cl}_2$ ) so we need to add 0.7 mg/L of  $\text{Cl}_2$
- Based on a 1:1 molecular  $\text{Cl}_2$ :  $\text{NH}_3$  ratio, the weight-based  $\text{Cl}_2$ :  $\text{NH}_3$  ratio = 4.2:1

# The Outcome:

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## ► Calculations:

$$\frac{0.7 \text{ mg } \cancel{\text{Cl}_2}}{\text{L}} \times \frac{\text{mg NH}_3}{4.2 \text{ mg } \cancel{\text{Cl}_2}} = \frac{0.17 \text{ mg NH}_3}{\text{L}}$$

- ## ► After the adding 0.7 mg/L of Cl<sub>2</sub>
- TAC does not change from 2.3 mg/L
  - FAC remains at 0.0 mg/L
  - NH<sub>2</sub>Cl increases (from 1.6) to 2.3 mg/L
  - FAA drops (from 0.20 mg/L) to 0.03 mg/L as NH<sub>3</sub>

# What's the Bottom Line?

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- 1) Effective Process Control is more than just complying with regulatory monitoring requirements
  
- 2) Effective Process Control is a continuous multi-step process that involves:
  - a) Collecting Data
  - b) Evaluating Data against performance targets
  - c) Making Appropriate Adjustments

For More Information, Contact Anyone But:

**Jack C. Schulze, P.E.**  
**TCEQ/WSD/PDWS (MC-155)**  
**P.O. Box 13087**  
**Austin, Texas 78711-3087**

**Phone: (512) 239-6046**

**Fax: (512) 239-0030**

**E-mail: [jschulze@tceq.state.tx.us](mailto:jschulze@tceq.state.tx.us)**

For example:

**Cindy Haynie**

**chaynie@tceq.state.tx.us (512) 239-3465**

**Teresa Rogers**

**trogers@tceq.state.tx.us (512) 239-1734**

**Noble Johnson, P.E.**

**njohnson@tceq.state.tx.us (903) 535-5143**

**Don Tharp, R.S.**

**dtharp@tceq.state.tx.us (325) 692-6075**