Concentration-Time (CT) Assessment

New Mexico Rural Water Association Annual Conference
Albuquerque, NM
April 2016

Peter Nathanson, PE
DWB SWIG Tech Services Manager
505.222.9509
peter.nathanson@state.nm.us

Chlorine Demand

The consumption of the chlorine used for disinfection

What is added		What is used		What remains
Dosage	–	**Demand**	=	**Residual**

Organics
Microorganisms
Ammonia-Nitrogen
Nitrate
Iron
Silt

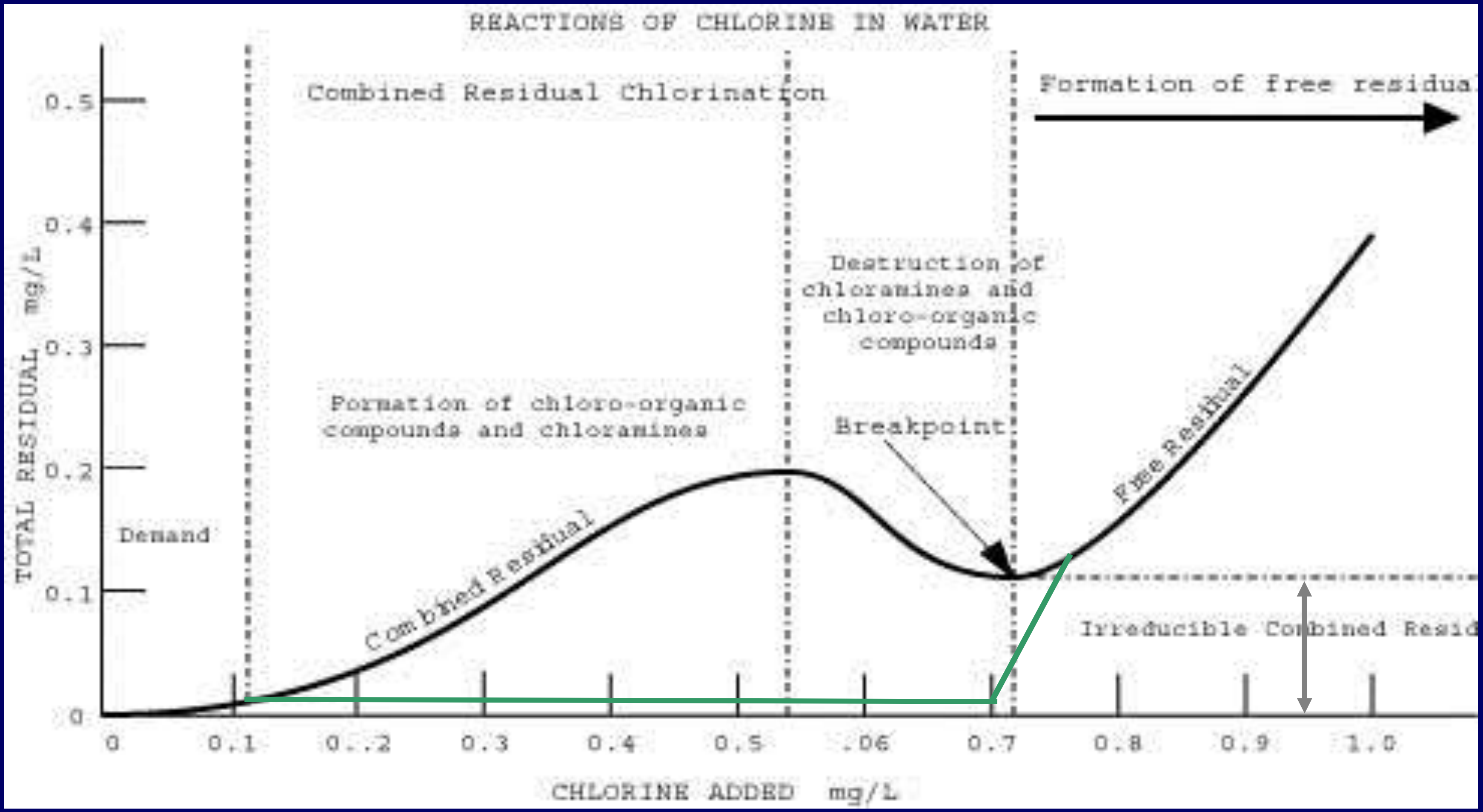
Chlorine Residuals

- **Free Chlorine Residual**
  - Uncombined chlorine in the form of HOCl, hypochlorous acid or OCl, hypochlorite ion
- **Combined Chlorine Residual**
  - Chlorine that is combined with ammonia-nitrogen to form chloramines: NH_2Cl, $NHCl_2$, NCl_3
- **Total Chlorine Residual**
  - Free Residual + Combined Residual = Total Residual

Chlorination

- Breakpoint chlorination
  - addition of enough chlorine to destroy majority of nitrogen compounds
  - irreducible combined residual
- Total chlorine residual
  - free + combined residual
- Effectiveness
  - lower pH, higher temperature
  - free > combined residual
  - combined lasts longer
  - combined forms fewer TTHMs

The Breakpoint Curve



CT Worksheet

- DT
- Baffling factor
- DT_{actual}
- Correct table
  - extrapolation
  - worst case analysis
- Use tables to prove chlorine effectiveness
  - lower pH
  - higher temperature

Detention Time

- Theoretical detention time, TDT = volume ÷ flow
  - basin, pipe, process volume
  - peak instantaneous flow
  - amount of time water is in basin assuming perfect plug flow & no short-circuiting

- Actual detention time can be less than theoretical due to short-circuiting
  - baffling factor, BF
    - ✓ 0.1 = no baffling; agitated basin, hi velocities
    - ✓ 0.3 = poor; single or multiple inlets, outlets
    - ✓ 0.5 = average; baffled inlet, outlet, some intra-basin
    - ✓ 0.7 = superior; perf inlet, perf/serp intra-basin, outlet weir or perf launders
    - ✓ 1.0 = perfect plug flow; very hi L:W, perf inlet, outlet & intra-basin
  - ADT = TDT x BF, which also = disinfectant contact time

Calculating CT

- **C = disinfectant residual, milligrams/Liter**
  - **ideally, for each basin or process**
  - **worst-case based on highest pH, lowest temperature**
  - **measured at peak instantaneous flow**

- **T = time water in contact with disinfectant, minutes**
  - **based on actual detention time**

- **C x T = CT, (mg-min)/L**

Calculating Inactivation

- Need log inactivation for *Giardia* per regs
- Need log inactivation for viruses if using different primary disinfectant
  - O_3, chloramines, chlorine dioxide
  - not as effective for inactivating viruses as inactivating *Giardia*
- Compare calculated CT to required CT from tables
  - separate CT tables for different disinfectants due to varying effectiveness
  - separate CT tables for *Giardia* and viruses
  - CT req'd for desired log inactivation based on
    - ✓ residual & pH (for chlorine), temperature

Log Reduction

- Refers to logarithmic theory
- Relates to the percentage of microorganisms physically removed or inactivated by a given process
- Rule of "9's" – the log number coincides with the number of 9's in the percent reduction
  - 1-log reduction = 90% removed or inactivated
  - 2-log reduction = 99% removed or inactivated
  - 3-log reduction = 99.9% removed or inactivated
  - round up to next highest integer for 0.5-logs
    - ✓ 3.5-log → 4-log = 99.99%
- Regulations allow credit for some physical processes
  - total log reduction = physical log removal + log removal from disinfection

Determining Required CT

- Calculate CT based on system operating parameters & configuration
- Use CT tables to determine required CT
  - find appropriate table for disinfectant used
  - find appropriate table for target microorganism
  - for chlorine
    - ✓ find appropriate portion of table based on worst-case (lowest measured) temperature
    - ✓ find appropriate column based on worst-case (highest measured) pH
    - ✓ find appropriate row based on worst-case (lowest measured) residual
    - ✓ identify CT required from row/column convergence

Determining Actual Log Inactivation

- Actual log inactivation is based on ratio of calculated CT to required CT from table
- Depends on whether system is required to achieve 3-log *Giardia* or 4-log virus inactivation
  - actual *Giardia* log inactivation = 3 x (CT_{calc}/CT_{reqd})
    - regs require 3-log removal or inactivation for *Giardia*
  - actual virus log inactivation = 4 x (CT_{calc}/CT_{reqd})
    - regs require 4-log removal or inactivation for viruses
  - can modify either equation for multiple disinfection segments within treatment process
- www.epa.gov/safewater/mdbp/pdf/ profile/lt1profiling.pdf

Any Questions?