**CHLORINE REQUIREMENT WORKSHEET GUIDANCE**

The purpose of this worksheet is to provide a tool to aid in predicting the *approximate* concentration of chlorine (Cl2) that must be added to treated water to maintain 0.5 mg/l of free Cl2 in distributed water.

For review, the chlorine requirement of a particular water is defined as the Cl2 needed to meet regulatory requirements in all areas of a water supply distribution system. In Illinois, this requirement is either 0.5 mg/l of “free” chlorine **or** 1.0 mg/l of “total” chlorine. **Every treated water will be unique** and maintaining chlorine residuals that meet the requirement will be affected by contact time, temperature, and pH.

Chlorine demand is defined as the difference between the Cl2 remaining (after contact time) and the Cl2 added to the water. Again, the demand on the Cl2 added to a water supply will be dependent on contact time, temperature, and pH. When calculating demand, the reaction of Cl2 with dissolved/suspended organic matter and inorganic chemicals must be considered. The reaction with organic material forms disinfection biproducts (TTHMs and HAAs). The reactions inorganic chemicals form ferrous, manganous, nitrite, sulfide and sulfide ions. Additionally, the ammonia contained in the source water will react with Cl2 to form chloramines. Generally, overcoming these competing reactions requires the following:

* Iron will consume 0.64 times its concentration (mg/l) in Cl2.;
* Manganese will consume 1.3 times its concentration (mg/l) in Cl2 .;
* Hydrogen Sulfide will consume 2.2 times its concentration (mg/l) in Cl2 ; and
* Ammonia will consume 7.6 times its concentration (mg/l) in Cl2 .

There are several methodologies available to calculate chlorine demand. These methods are designed to conduct confirmatory monitoring to ensure the chlorine requirement is met (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) and water distributed remains safe and compliant. Unfortunately, these bench tests are only as good as the date/time they are conducted, and source water quality does not always remain stable. Therefore, obtaining and understanding the water quality parameters specific to the water system in question is of great import. Obviously, 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.

As a starting point, the Illinois EPA’s Drinking Water Watch Website should be accessed to 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, to to: <http://water.epa.state.il.us/dww/> .

For the purposes of this worksheet, we will make some general assumptions. First, in Illinois, most surface water systems are not using “free” residual in their distribution systems. Therefore, the remainder of this discussion will focus on groundwater sources. Second, groundwater sources in Illinois do not generally monitor TOC (unless DBP compliance is an issue) nor is hydrogen sulfide concentration readily available (you know it when you smell it). Therefore, our estimate of required chlorine will not include the demand created by these substances. Finally, the calculations below will not include the effects of treatment (e.g., aeration, filtration, ion exchange, etc.) commonly conducted at groundwater source systems in Illinois. To evaluate the effects of these treatment methods, process control monitoring will be necessary to measure the analytes of concern. However, the concepts remain the same and each source water must be evaluated.

To approximate chlorine demand from iron, manganese and free ammonia, complete the following table for your source water (note, the information contained in red is example water quality information) :

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Well # | Iron mg/l | IronDemand 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=Cl2 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:

$$lbs/Day=\frac{\left(MGD\right)\left(mg/l\right)\left(8.34\right)}{Purity (\% as a Decimal)}$$

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):

$$lbs/Day=\frac{\left(.5 MGD\right)\left(4.587mg/l\right)\left(8.34\right)}{1.00 Purity (\% as a Decimal)}$$

= 19.13 lbs/day

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.

Upon completing the iterative process of testing and increasing dosage to ensure that you have reached the target chlorine requirement, you can conduct an additional rule of thumb test to double check that you have reached a free residual. 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.

Finally, remember the limiting factor in achieving a free chlorine residual is the maximum NSF chlorine feed of 30 mg/l (as Cl2) for gas and 10 mg/l (as Cl2) for Sodium Hypochlorite (80 mg/l for 12.5% solution as product). For additional information on NAP please see the IRWA Website at: <http://www.ilrwa.org/Downloads.htm> .