Disinfectant #2: Chlorine: Is Chlorine Still at the Head of the Class??

Similar to quaternary ammonium solutions, most people are very familiar with the antimicrobial qualities of chlorine based solutions. Chlorine compounds were recognized for their deodorizing and disinfecting properties in 19th century and their wide use began soon thereafter. Today, chlorine's antimicrobial capabilities are most commonly harnessed for use in water treatment or surface disinfection.

This is how we would rate Chlorine disinfectants based on the key decision making criteria: (see below)

Chlorine Acid Disinfectant Report Card

Subject	Grade	Comments
Speed of Disinfection	**A** to **C**	*Most best practice guidelines recommend 10 minute contact times be utilized with bleach based solutions.* *Higher concentrations (>1000ppm) can elicit more rapid kill against bacteria and viruses*
Spectrum of Kill	**A** to **C**	*Similar to the speed of disinfection, performance in this criteria is tied to the in-use concentration.* *5000ppm is recognized as sporicidal; 1000ppm as effective against non-enveloped viruses; <1000ppm solely for use as a low level disinfectant*
Cleaning Effectiveness	**D**	*Chlorine solutions have no inherent detergency capabilities; best practice guidelines unanimously support the practice of cleaning surfaces with a detergent prior to using bleach as a disinfectant*
Safety Profile	**B** to **D**	*This is another parameter largely affected by the in-use concentration of the solution.* *>1000ppm solutions are generally irritating to eyes and skin (respiratory irritation also becomes a greater concern at higher concentrations); <1000ppm solutions require less precaution*
Environmental Profile	**A** to **B**	*Although chlorine compounds are not persistent in the environment upon disposal, because they tend to be so highly reactive the risk lies more in the potential cross-reactions with other chemicals that may be present in waste-water*
Cost Effectiveness	**A**	*Bleach is a commodity that is readily available in concentrated formats, however the diluted solutions must be replaced regularly which may result in wasted product*

Chlorine solutions, even in very low levels, can show high antimicrobial activity. The microbicidal action is attributed to hypochlorous acid, often referred to more generally as "free available chlorine". The antimicrobial activity of chlorine is very dependent on the pH of the solution as this determines the concentration of dissociated (available) hypochlorous acid in solution. An example of the "pH effect" can be illustrated by a study that found 25 PPM chlorine to kill 99% of bacterial spores within 2.5 minutes when the solution is at a pH of 6, however, the contact time required to achieve the same level

of kill with a 25 PPM solution at a pH of 12.86 was 465 minutes. One caveat that I must make is to note that **a product requires a 99.9999% kill in order to achieve EPA or Health Canada sporicidal claims so don't be fooled into thinking a 25ppm concentration of chlorine is sporicidal!**

A significant disadvantage of chlorine solutions, particularly hypochlorites (bleach) is that their overall performance is tied so closely to the stability of the hypochlorous acid. The stability of hypochlorous acid in the solution significantly depends on chlorine concentration (the lower the concentration, the lower the efficacy, but the higher the stability), presence of catalysts or reducing agents (catalysts reduce the stability), pH of the solution (higher alkalinity increases stability, but decreases efficacy), temperature of the solution (lower temperature increases stability), presence of organic material (organic material reduces both stability and efficacy). In short, there is a multitude of factors that need to be taken into account to ensure the effectiveness of a chlorine solution for use as a disinfectant.

For those of you with keen eyes, you will have identified the competing interests inversely affected by pH. On one hand, **the disinfectant capabilities of hypochlorite solutions are much better at lower pH values, however at these lower values the solutions are also very unstable**. Therefore, most commercially available products are only available as higher pH solutions to ensure stability but compromise with either **contact times that are too long (10 minutes)** to be realistically achieved or **concentrations at 5000ppm or higher that while improving upon speed also increase occupational health and safety risks**.

As we have dwelled upon in previous blogs, another very important consideration is a product's ability to clean and aid in the ability to lift and removal soils from a surface. Chlorine is a bleaching agent and while excellent at helping to whiten and brighten, Chlorine does not have any detergency properties. It is unable to reduce the surface tension between soils and a surface and **as a result chlorine's cleaning ability or efficiency is equivalent to water**. Certainly, there are some ready-to-use formulations that incorporate both chlorine and surfactants which will improve cleaning performance, but **in concentrated formulations of chlorine the addition of surfactants will degrade both the chlorine and the surfactant resulting in a product that can neither kill nor clean.**

Similar to efficacy, the concentration of chlorine is directly related to the chemical's toxicity. Chlorine is a strong oxidizing agent that is highly reactive not only with other chemicals, but with cell components such as DNA, proteins, lipids and carbohydrates. **While ingestion of chlorine solutions can be lethal, the extent of toxicity is directly related to the concentration.** Toxicity studies of exposure of chlorine to skin and eyes exposure have found that concentrations <1000ppm to be non skin sensitizing and cause only slight irritation to skin and eyes, at concentrations >1000ppm the irritation increases significantly as the concentration increases.

Both the concentration pH chlorine has a direct affect on respiratory irritation and toxicity. Studies on the rates of asthma in children and competitive swimmers have found a link between the exposures to chlorine from indoor swimming pools to increased rates in asthma. Concentrations of bleach >5000ppm especially if used in enclosed spaces with little ventilation have been found to be irritating to the user.

At pH of 5 or higher, the development of chlorine gas is negligible; **however acidified solutions with a pH less than 5 will release chlorine gas and can be toxic if inhaled**.

Lastly, one advantage to chlorine is that it readily degrades and is not persistent in the environment as it degrades to oxygen and chloride. This limits the chance pathogens will develop chemical resistance, however does not in any way make it environmentally benign. Chlorine as we have stated is highly reactive. **It can create toxic bi-products when mixed with chemicals and if released directly into water is very lethal to aquatic life.**

With these key points fresh in your mind, how would you grade chlorine as a disinfectant chemistry?

Remember that chlorine, particularly hypochlorites, is utilized within a spectrum of various concentrations.