The quality of a sodium hypochlorite solution is dependent upon the quality of the chlorine and caustic soda (sodium hydroxide) that are used in the manufacture of the sodium hypochlorite solution. In turn, the quality of the chlorine is impacted by the impurities in the brine or sodium chloride salt used to produce the chlorine. Poor control of the hypochlorite manufacturing process (temperature, etc.) can lead to additional impurities. Impurities in the sodium chloride will produce byproducts, such as bromates, in finished hypochlorite solutions. Chlorates will also be produced at elevated process temperatures or if the hypochlorite produced reacts with the chlorine being added. In addition, solutions of sodium hypochlorite decompose form chlorates. The presence of both bromates and chlorates in the hypochlorite solutions may make the hypochlorite solutions undesirable as a disinfectant in the treatment of drinking water. These impurities could impact other, non-drinking water uses for hypochlorite solutions.

**Bromine Salts**

There are compounds other than sodium chloride in mined salt or brine (sodium chloride solution). One of those more prevalent is sodium bromide. Varying amounts of bromide are found in brine depending upon the particular source of brine. In fact, those sources with the highest bromide content are used in the commercial production of bromine. Since chlorine is used in the manufacture of sodium hypochlorite, and bromide is an impurity in chlorine, (Equation 1), there have been limits imposed upon the impurities in and the quality of chlorine used in this process.

The presence of bromine is recognized by the specifications issued by the U.S. EPA for chlorine. The maximum amount of bromine allowed in chloride is 500 ppm when that chlorine is to be used in the manufacture of sodium hypochlorite solutions used for drinking water disinfection. These regulations fall under the Federal Insecticide, Fungicide, Rodenticide Act (F.I.F.R.A.) (Chlorine Institute, 1992). F.I.F.R.A. regulations cover drinking water additives. The bromide present in the brine will also react with chlorine to produce bromine (Equation 2) which in turn reacts with the caustic to produce sodium hypobromite (Equation 3).

Sodium hypobromite can act as an oxidant and disinfectant in water treatment just as sodium hypochlorite. In addition, any hypobromite produced can react with chlorine or hypochlorite to produce bromates. The presence of bromate compounds are recognized by the EPA as an important factor in contributing to the formation of Trihalomethanes (THMs). Current Maximum Contaminant Levels (MCLs) for bromates in drinking water are 0.01 mg/l or 10Fg/l with a Maximum Contaminant Level Goal (MCLG) of 0 (EPA, 1994). The bromate level in the drinking water should not exceed a maximum level of 10 Fg/l (EPA, 1994). A 14 to 15% hypochlorite solution (or 180 g/l of chlorine) when used in water treatment at a dosage of 5 mg/l, can have a maximum bromate concentration of 360 mg/l. The calculation to arrive at this value is shown below (Equation 4).

\[
180,000 \text{ mg/l} / 5 \text{ mg/l} = x \text{ mg/l} / 0.010 \text{ mg/l} \quad (\text{Eq. 4})
\]

or \( x = (180,000)(0.010) / 5 \)

\( x = 360 \text{ mg/l} \)

Bromate levels in hypochlorite solutions have been reported to vary from <2 mg/l to 51 mg/l. (Fair, 1992). Other unpublished information supports these values and, in fact, reaches values over 1000 mg/l. With these levels of bromate variation, it is important for the water plant operator to be cautious about the quality of hypochlorite solutions and the concentration of bromate.

**Chlorate Production**

The appearance of chlorate in the finished sodium hypochlorite solutions is to be expected due to the nature of the sodium hypochlorite solutions. The formation of sodium hypochlorite is identified in Equation 1. However, the sodium hypochlorite formed can decompose as it is formed (Gordon, 1993). The decomposition reaction is illustrated below in Equation 5.

\[
\text{Sodium hypochlorite} \rightarrow \text{Sodium chlorate} + \text{Sodium chloride} + \text{Water}
\]
This decomposition is hastened by any or all of the following reasons (Chlorine Institute, 1992):
1. Solution Strength - the higher the sodium hypochlorite strength the more rapid the decomposition to form chlorate.
2. Temperature - the higher the temperature the more rapid the decomposition to form chlorate.
3. pH - the lower the pH of the solution the more rapid the decomposition to form chlorate.
4. Metals - the presence of impurities (metals - iron, etc.) enhances the decomposition.
5. Light - the action of light enhances decomposition.

Chlorates have an impact on the blood and are generally recognized as affecting the hemoglobin and causing hemolytic anemia. The complete toxicological effects of chlorate are currently under investigation. Chlorates present in the treated drinking water must not exceed 10Fg/l (NSF, 1998). The NSF/ANSI Standard 60 has established a maximum of 10Fg/l value as a practical limit.

The chlorate level in the drinking water should not exceed a maximum level of 10 Fg/l (NSF 1998). Therefore, a 14 to 15% hypochlorite solution (or 180 g/l of chlorine) when used in water treatment at a dosage of 5 mg/l, can have a maximum chlorate concentration of 360 mg/l. The calculation to arrive at the 360 mg/l level is shown below (Equation 6).

\[
\frac{180,000 \text{ mg/l}}{5 \text{ mg/l}} = \frac{x \text{ mg/l}}{0.010 \text{ mg/l}} \quad \text{(Eq. 6)}
\]

where \( x \) is the concentration of chlorate in the hypochlorite solution

or \( x = \frac{(180,000)}{(0.010)} / 5 \)

\( x = 360 \text{ mg/l} \)

Summary
The quality of sodium hypochlorite is extremely important to the water treatment plant operator as it can impact the quality of the finished water. Since the sodium hypochlorite solution decomposes, the quality changes as the water treatment plant is using the solution.

Some operations using hypochlorite solutions have taken steps to minimize the formation of chlorates by installing chilling equipment to reduce the hypochlorite storage temperature. Alternately, solutions of hypochlorite are diluted in strength from the 12% to 14% commercially available levels to 5% on receipt. Specifications for the hypochlorite solutions to be purchased should include limits on bromate, chlorate and metals. Deliveries should be limited to those quantities that are freshly manufactured.

References
NSF, 1998, NSF/ANSI Standard 60, Drinking Water Additives

Design improvements may be made without notice.
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