



Residual Chlorine Reduction of Wastewater Using UV or Dechlorination

An Online Continuing Education Course for Engineers

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Introduction

Disinfection is considered to be the primary mechanism for the inactivation/destruction of pathogenic organisms to prevent the spread of waterborne diseases to downstream users and the environment. It is important that wastewater be adequately treated prior to disinfection in order for any disinfectant to be effective. Some common microorganisms found in domestic wastewater and the diseases associated with them are presented in Table 1.

Chlorination has been used widely to disinfect wastewater prior to discharge since passage of the 1972 Federal Water Pollution Control Act (WPCA). In the first years following the WPCA, disinfected wastewater with significant levels of residual chlorine was routinely discharged into the receiving waters. It became clear, however, that residual chlorine is toxic to many kinds of aquatic life. Moreover, the reaction of chlorine with organic materials in the water formed carcinogenic trihalomethanes and organochlorines.

In this course, we'll review Dechlorination and Ultraviolet (UV) disinfection of wastewater. While both technologies have advantages and disadvantages, what they share in common is the ability to achieve disinfection of wastewater without the negative impacts of discharging residual chlorine into receiving waters.

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**TABLE 1 INFECTIOUS AGENTS
POTENTIALLY PRESENT IN UNTREATED
DOMESTIC WASTEWATER**

Organism	Disease Caused
Bacteria	
<i>Escherichia coli</i> (enterotoxigenic)	Gastroenteritis
<i>Leptospira</i> (spp.)	Leptospirosis
<i>Salmonella typhi</i>	Typhoid fever
<i>Salmonella</i> (=2,100 serotypes)	Salmonellosis
<i>Shigella</i> (4 spp.)	Shigellosis (bacillary dysentery)
<i>Vibrio cholerae</i>	Cholera
Protozoa	
<i>Balantidium coli</i>	Balantidiasis
<i>Cryptosporidium parvum</i>	Cryptosporidiosis
<i>Entamoeba histolytica</i>	Amebiasis (amoebic dysentery)
<i>Giardia lamblia</i>	Giardiasis
Helminths	
<i>Ascaris lumbricoides</i>	Ascariasis
<i>T. solium</i>	Taeniasis
<i>Trichuris trichiura</i>	Trichuriasis
Viruses	
Enteroviruses (72 types, e.g., polio, echo, and coxsackie viruses)	Gastroenteritis, heart anomalies, meningitis
Hepatitis A virus	Infectious hepatitis
Norwalk agent	Gastroenteritis
Rotavirus	Gastroenteritis

Source: Adapted from Crites and Tchobanoglous, 1998.

Dechlorination

Description

Dechlorination is the process of removing residual chlorine from disinfected wastewater prior to discharge into the environment. Sulfur dioxide is most commonly used for dechlorination and is the major focus of this fact sheet. Some dechlorination alternatives include carbon adsorption, sodium metabisulfite, sodium bisulfite, and hydrogen peroxide. Sodium metabisulfite and sodium bisulfite are mainly used in small facilities because these materials are more difficult to control compared to sulfur dioxide. Hydrogen peroxide is not frequently used because it is dangerous to handle (WEF, 1996).

Applicability

Chlorination has been used widely to disinfect wastewater prior to discharge since passage of the 1972 Federal Water Pollution Control Act (WPCA), (Finger et al., 1985). In the first years following the WPCA, disinfected wastewater with significant levels of residual chlorine was routinely discharged into the receiving waters. It became clear, however, that residual chlorine is toxic to many kinds of aquatic life (see, for example, Mattice and Zittel, 1976, and Brungs, 1973). Moreover, the reaction of chlorine with organic materials in the water formed carcinogenic trihalomethanes and organochlorines (WEF and ASCE, 1991). As a result, dechlorination was instituted to remove residual chlorine from wastewater prior to discharge into sensitive aquatic waters.

Dechlorination minimizes the effect of potentially toxic disinfection byproducts by removing the free or total combined chlorine residual remaining after chlorination. Typically, dechlorination is accomplished by adding sulfur dioxide or sulfite salts (i.e., sodium sulfite, sodium bisulfite, or sodium metabisulfite). Carbon adsorption is also an effective dechlorination method, but is expensive compared to other methods. Carbon adsorption is usually implemented when total dechlorination is desired.

Specific design criteria and monitoring requirements for a particular region are determined by the state regulatory agency. Typically, the treatment plant's National Pollutant Discharge Elimination System (NPDES) permit limits effluent chlorine residual and toxicity. Currently, many permits require very low or "non-detect" chlorine residuals, making dechlorination critical.

One important alternative to dechlorination is to achieve disinfection without the use of chlorine. Other means of disinfection, such as ozone or ultraviolet disinfection, have also become increasingly prevalent (U.S. EPA, 1986; Blatchley, E.R. III, *et al.*, 1996).

ADVANTAGES AND DISADVANTAGES

Advantages

- Protects aquatic life from toxic effects of residual chlorine.
- Prevents formation of harmful chlorinated compounds in drinking water through reaction of residual chlorine with water-borne organic materials.

Disadvantages

- Chemical dechlorination can be difficult to control when near zero levels of residual chlorine are required.
- Significant overdosing of sulfite can lead to sulfate formation, suppressed dissolved oxygen content, and lower pH of the finished effluent.

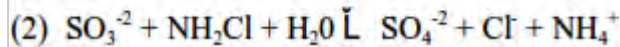
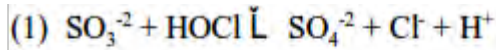
DESIGN CRITERIA

Chemistry of Dechlorination by Sulfonation

Sulfur dioxide (SO_2) is a corrosive, nonflammable gas with a characteristic pungent odor. At atmospheric temperature and pressure, it is a colorless vapor. When compressed and cooled, it forms a colorless liquid. Sulfur dioxide is supplied as liquefied gas under pressure in 100 or 150 pound containers and one-ton cylinders. As an alternative to sulfur dioxide gas, various dry chemicals are available which form sulfur dioxide in solution. These include sodium sulfite (Na_2SO_3), sodium metabisulfite ($\text{Na}_2\text{S}_2\text{O}_5$), sodium bisulfite (NaHSO_3), a 38 percent aqueous solution of sodium metabisulfite, and sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$), among others (Lind, 1995).

When dissolved in water, chlorine hydrolyzes to form hypochlorous acid (HOCl) and hypochlorite ions (OCl^-) which, taken together, are referred to as “free chlorine.” (Free, uncombined chlorine, Cl_2 , is rarely found in wastewater since the conditions of formation are relatively extreme [Lind, 1995]). Once formed, the free chlorine reacts with natural organic matter in water and wastewater to form chlorinated organic compounds. The free chlorine also combines with ammonia to form mono-, di-, and trichloramines in quantities dependent on the ratio of chlorine to ammonia nitrogen (Lind, 1995).

When either sulfur dioxide or sulfite salts are dissolved in water, aqueous sulfur compounds in the +4 oxidation state are produced, often notated S(IV) (Helz and Nweke, 1995). The S(IV) species, such as the sulfite ion (SO_3^{2-}), reacts with both free and combined forms of chlorine, as illustrated in equations (1) and (2) (WEF, 1996):



Since free chlorine and inorganic chloramines react rapidly with S(IV) (Helz, 1998), a short contact time of one to five minutes is considered to be sufficient; nevertheless, complete blending at the point of application is essential for effective dechlorination (WEF and ASCE, 1992).

Proper dosage is critical to produce a non-detectable chlorine residual. On a mass basis, 0.9 parts sulfur dioxide (or 1.46 parts NaHSO₃ or 1.34 parts Na₂S₂O₄) is required to dechlorinate 1.0 part residual chlorine. In practice, approximately 1.0 part sulfur dioxide is used (WEF, 1996). Dosing in excess must be avoided because it can lead to the formation of sulfite, which can react with dissolved oxygen (four parts sulfite to one part oxygen) in the water, leading to reduced dissolved oxygen concentrations. This is a concern for high levels of dosing (WEF, 1996).

Equipment for Gaseous Chlorination

Equipment required for gaseous chlorination, except that it must have a corrosion resistance (WEF, 1996). It should be equipped with automatic switch-off, a pressure regulator and a rotameter, and a residual analyzer to measure the chlorine residual in the sample stream.

In small concentrations, exposure to chlorine gas is not a health hazard. At high concentrations, exposure can irritate the eyes, nose, and throat, and cause respiratory tract. Therefore, the equipment should include features for safe storage, handling, and use of sulfur dioxide. The sulfite ion (SO₃²⁻) reacts with both free chlorine and combined chlorine, as illustrated in equations (1) and (2) (WEF, 1996): chlorine and sulfur dioxide cylinders should be located in separate rooms and stored in a well-ventilated, temperature-controlled area so that their temperature never drops below 18 or exceeds 70 degrees Celsius. Gas leak detectors are necessary in the storage area and the sulfonator area. An emergency eyewash shower and self-contained breathing apparatus should also be provided. All personnel should receive emergency response training. Facilities with more than 1,000 pounds of SO₂ stored on-site must abide by the Process Management Safety Standard in the OSHA regulations (OSHA, 1998).

Effect of Temperature on Gas Withdrawal Rate

The room temperature where the gas supply is located should be maintained around 70 degrees F to ensure optimal gas withdrawal rates (WEF, 1996). At this temperature, the maximum safe sulfur dioxide gas withdrawal rate is approximately 2 lb/hr for a 150 lb container,

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