Disinfection Methods for Combined Sewer Overflow (CSO) Treatment

An Online Continuing Education Course for Engineers

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Credit: 1 Hour / 1 PDH / 1 CPD

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DESCRIPTION

Combined sewer overflows (CSOs) occur when flows exceed the hydraulic capacity of either the wastewater treatment plant (WWTP) or the collection system that transports the combined flow of storm water and sanitary sewage to the WWTP. When an overflow occurs, the excess flows tend to be discharged into a receiving body of water. CSOs typically discharge a variable mixture of raw sewage, industrial/commercial wastewater, polluted runoff, and scoured materials that build up in the collection system during dry weather periods. These discharges contain a variety of pollutants that may adversely impact the receiving water body, including pathogenic microorganisms, viruses, cysts, and chemical and floatable materials. Health risks associated with bacteria-laden water may result through dermal contact with the discharge, or through ingestion of contaminated water or shellfish.

Preliminary reduction of microorganisms and bacteria may be accomplished through physical reduction of solids in the wastewater, primarily through sedimentation, flotation, and filtration. Following solids reduction, most systems further reduce bacterial concentrations through disinfection. Disinfection occurs as the wastewater is brought into contact with oxidizing chemicals (such as chlorine, bromine, ozone, hydrogen peroxide, and related compounds).

Chlorine has long been the disinfectant of choice for most disinfection systems. It offers reliable reduction of pathogenic microorganisms at reasonable operating costs.

While chlorine disinfection is the most common method used to kill pathogenic microorganisms at wastewater treatment plants, this methodology may not be feasible at all CSOs for several reasons, including:

- CSOs occur intermittently and their flow rate is highly variable, thus making it difficult to regulate the addition of disinfectant.
- CSOs have high suspended solids concentrations.
- CSOs vary widely in temperature and bacterial composition.
- Residual disinfectants from chlorine disinfection may be prohibited from receiving waters.
- CSO outfalls are often located in remote areas and thus may require automated disinfection systems.

In addition to these problems, the increased health and safety concerns regarding the use of chlorine to disinfect CSOs has prompted the development of alternative disinfectants, which often pose fewer problems and hazards. Alternatives to chlorine have been developed and evaluated for continuous disinfection of wastewater discharges to small streams or sensitive water bodies, and are now being considered for treatment of CSOs and other episodic discharges.

This course addresses the use of chlorine dioxide, ozonation, ultraviolet radiation, peracetic acid and Electron Beam Irradiation (E-Beam) to treat CSOs.

Chlorine Dioxide

Studies have shown that chlorine dioxide is an effective wastewater disinfectant, although its use in the United States is limited. Chlorine dioxide is applied to wastewater as a gas that is generated on-site using excess chlorine. Although it is relatively easy and economical to produce chlorine dioxide is unstable and reactive and any transport is hazardous.

Chlorine dioxide is effective at oxidizing phenols, but does not react with aquatic humus to produce trihalomethanes (THMs). However, any excess chlorine remaining from the generation of chlorine dioxide would react with THM precursors and form THMs. Therefore, operators must be careful to use the correct amounts of chlorine when generating chlorine dioxide. And while chlorine dioxide will not react with wastewater to form chloramines, it can produce potentially toxic byproducts such as chlorite and chlorate.

Ozonation

Ozone is a strong oxidizer and is applied to wastewater as a gas. Its use in CSO treatment facilities for wastewater disinfection is relatively new in the United States, and there are few facilities currently using ozone for disinfection. This can be potentially attributed to high initial capital costs associated with ozone generation equipment. Ozone is equal or superior to chlorine in "killing" power, but it does not cause the formation of halogentated organics as does chlorination.

Ultraviolet (UV) Radiation

UV radiation is one example of electromagnetic radiation used for disinfection. UV disinfection incorporates the spectrum of light between 40 nanometers and 400 nanometers. Germicidal properties range between 200 and 300 nanometers, with 260 nanometers being the most lethal. The primary method for utilizing UV disinfection is to expose wastewater to a UV lamp. Historically, most UV disinfection facilities have been designed to utilize Low Pressure Low Intensity UV lamps for disinfection. For example, low-pressure mercury arc lamps emit approximately 90 percent of their light energy around 254 nanometers.

UV disinfection works by penetrating the cell walls of pathogenic organisms and structurally altering their DNA, thus preventing cell replication and function. No hazardous chemicals are produced or released while treating CSOs with UV.

Because UV is not a chemical disinfection method, it disinfects without altering the physical or chemical properties of water. However, UV efficiency is affected by suspended solids in the wastewater, which can scatter and absorb light. Thus, UV disinfection is not effective in wastewaters with a high TSS level.

Peracetic Acid

Peracetic acid (CH_3COOOH) (PAA), also known as ethaneperoxoic acid, peroxyacetic acid, or actyl hydroxide, is a very strong oxidant. Based on limited demonstration data for disinfection of secondary treatment plant effluent, peracetic acid appears to be an effective disinfectant and should be evaluated further for treating CSOs. The equilibrium mixture of hydrogen peroxide and acetic acid that produces PAA is too unstable and explosive to transport, and so PAA must be produced on site. The decomposition of PAA results in acetic acid, hydrogen peroxide and oxygen.

Electron Beam Irradiation

Electron Beam Irradiation (E-Beam) uses a stream of high energy electrons that are directed into a thin film of water or sludge. The electrons break apart water molecules and produce a large number of highly reactive chemical species. There are a few reactive species formed during this process and include oxidizing hydroxyl radicals, reducing aqueous electrons and hydrogen atoms.

APPLICABILITY

A brief summary illustrating the general applicability of chlorine dioxide, peracetic acid and UV radiation as alternative CSO disinfectants is provided in Table 1. While ozonation and the E-Beam process are discussed in this course as potential alternative disinfectants for CSOs, they are not currently considered practical for CSO disinfection and thus they are not included in Table 1. Because ozone must be generated on-site and the amount generated is dependent on the demand, ozone is not currently considered practical for intermittent use in situations where the system would be frequently turned on and off or where there are wide fluctuations in flow rate and disinfection demand, such as in CSO treatment applications. The E-Beam system was initially developed for the disinfection of municipal wastewater treatment plant sludge and the destruction of hazardous organic compounds, and it has not been evaluated for CSO disinfection. EPA will continue to evaluate the E- Beam system as a promising innovative technology for wastewater technology.

ADVANTAGES AND DISADVANTAGES

As discussed above, one of the primary reasons for seeking alternatives to chlorine disinfection of CSOs is the growing concern over safety in handling gaseous chlorine and the possible toxic side effects of treatment with chlorine. Studies on alternative disinfectants such as peracetic acid, ozone, E-Beam, and UV, have shown that these alternatives serve as good substitutes for chlorine because they produce no toxic byproducts. Although chlorine dioxide does produce byproducts and residuals, the limited use of chlorine dioxide in this country has made it difficult to assess these byproducts for toxicity.

The alternatives to chlorine for CSO disinfection are not problem-free, however, and their effectiveness depends on the physical and chemical characteristics of the wastewater (e.g., the presence of large particles may hinder disinfection). They require certain storage and use precautions, and disinfection residuals and byproducts may be a concern in receiving waters. As discussed above, Table 1 provides comparative data for chlorine dioxide, peracetic acid, and UV radiation to help in determining which compounds may be most advantageous for specific applications. The following sections summarize the advantages and disadvantages of using ozonation and E-Beam as alternative CSO disinfectants.

Ozonation: Advantages

- More powerful disinfectant than most chlorine compounds.
- Inactivates most strains of bacteria and viruses and is noted for destroying chlorine-resistant strains of both. Ozonation is highly effective for Cryptospiridium eradication.
- Will oxidize phenols with no negative residuals such as trihalomethane production.
- Does not produce a disinfection residual that would prevent bacterial growth.
- Degenerates into oxygen, which can elevate oxygen levels in treated water. It does not alter pH of water.
- Increases coagulation.
- Helps remove iron and manganese.
- Has taste and odor control properties.
- Requires short contact time

Ozonation: Disadvantages

- More costly than traditional chlorinated disinfection techniques.
- Forms nitric oxides and nitric acid which can lead to corrosion.
- Ozone is chemically unstable as a gas, and hazardous to transport. It must be generated on site and used immediately.

TABLE 1 SUMMARY OF GENERAL ATTRIBUTES OF CHLORINE DIOXIDE, PAA AND UV RADIATION

	ClO_2	PAA	UV RADIATION
Stability	Moderate	Low	High
Persistent Residual	Moderate	None	None
Potential Byproduct Formation	Yes	No	No
Reacts with Ammonia	No	No	No
pH Dependent	Moderate	No	No
Ease of Operation	[illegible]	[illegible]	Simple to Complex
Temperature Depende[illegible]	[illegible]	[illegible]	Simple to Complex
Contact Time	[illegible]	[illegible]	Low
Safety Concerns	[illegible]	[illegible]	Low
Effectiveness as Bacteri[illegible]	[illegible]	[illegible]	High
Effectiveness as Viricide	[illegible]	[illegible]	High
Likelihood of Regrowth	[illegible]	[illegible]	High

Source: Compiled from vari[illegible]

E-Beam: Advantages

Currently, there is insuff[illegible] a full determination of its usefulness for CSO d[illegible] York City Department of Environ[illegible] dvantages of the E-Beam system:

- No disinfectant ch[illegible]
- No toxic byproduc[illegible]sed.
- Short contact time re[illegible]
- Potential to deactivate a wide range of pathogens.
- Potential to penetrate waste streams with high solids concentrations.

E-Beam: Disadvantages

- Increased safety considerations due to use of high- voltage technology and the generation of X-ray radiation.
- No full scale application experience for CSOs.
- High capital costs.
- High O&M costs.
- Thin process flow stream.
- Abundant pretreatment straining of influent is required for this delivery system.