SELECTING A DECHLORINATING CHEMICAL FOR A WASTEWATER TREATMENT PLANT IN GEORGIA

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REFERENCE: *Proceedings of the 1991 Georgia Water Resources Conference*, held March 19 and 20, 1991, at the University of Georgia, Kathryn J. Hatcher, Editor, Institute of Natural Resources, The University of Georgia, Athens, Georgia, 1991.

INTRODUCTION

Wastewater treatment plants (WWTPs) that employ chlorine or chlorine dioxide for disinfection maintain a small total residual chlorine (TRC) in the plant effluent prior to discharging into receiving bodies of water. A TRC as low as 0.02 milligram per liter (mg/L) is toxic to aquatic life. The NPDES permits for WWTPs in Georgia are now being issued with a very low TRC limit, making it necessary to add a dechlorination step in such plants.

The paper outlines an evaluation and comparison of available dechlorinating chemicals, demonstrates the cost analysis procedure and describes the influence of non-cost related aspects in the final selection of a chemical.

DECHLORINATION OPTIONS

Comparison of Dechlorination Techniques

The dechlorination techniques available are:

- Aeration
- Activated carbon treatment
- Chemical addition.

Of the above, the use of chemicals is generally preferred. Aeration can remove a small portion of combined chlorine residual (chloramines), but none of the free chlorine residual (hypochlorous acid and hypochlorite ion). Thus a zero chlorine residual cannot be achieved by aeration. Both free and combined chlorine residuals can be chemically removed by an activated carbon filter bed. But this technique has high equipment cost. Achieving consistent dechlorination is also difficult. The application of powdered activated carbon is not always practicable because the residual carbon has to be removed from the flow stream after the treatment. The activated carbon treatment technique cannot compete with the chemical addition method unless the reduction in soluble organics is also required.

Comparison of Chemical Additives

The following chemicals may be used for dechlorinating the WWTP effluent:

1. Sulfur dioxide
2. Sodium metabisulfite
3. Sodium sulfite
4. Sodium thiosulfate
5. Hydrogen peroxide

Of these chemicals one of the sulfur compounds is generally chosen. Hydrogen peroxide though easy to apply, does not remove chloramines at a useful rate. In addition it is highly unstable and subject to deterioration. For this reason hydrogen peroxide is excluded from further discussion. The sulfur compounds have significant use history in dechlorination. The sulfur compounds are compared in cost, storage and dosing equipment complexity, safety of handling and W.WTP operator preference for evaluating the options.

APPLICATION OF CHEMICALS

While liquid sulfur dioxide is available in pressurized containers the other sulfur compounds may be obtained dry or in solution.

The application of sulfur dioxide is similar to that of chlorine gas. Therefore no significant new techniques are to be learned for the safe handling and application of sulfur dioxide.

Since the dechlorinating chemical is dosed as a solution, the dry chemical is required to be dissolved. This not only adds an extra step in their use but also brings plant operators more into contact with the chemicals. A solution may be prepared in batches or continuously using dry chemical feeders and mixing equipment. By purchasing ready-made solutions in bulk the handling of dry chemicals is eliminated. There are also a few disadvantages of ready-made solutions. The solution may loose its strength upon prolonged storage. It is subject to freezing in cold weather. In addition sources of ready-made solutions are limited thus restricting competitive pricing. This situation may change in the future with more WWTPs starting to use ready-made solutions.

PROPERTIES OF DECHLORINATING CHEMICALS

Sulfur dioxide is a hazardous gas due to its toxic nature. It is suffocating and irritating if inhaled. A comparison of some safety aspects of chlorine and sulfur dioxide will indicate that the use of this gas will not be any more hazardous than the chlorine in use at many WWTPs. Sulfur dioxide is less toxic than chlorine.

Excepting sodium thiosulfate the remaining chemicals are all hazardous because they are corrosive and generate suffocating and irritating sulfur dioxide gas. Sodium sulfite is not as aggressive as sodium metabisulfite. However dry dust from both is irritating to the nose and throat, and may cause coughing or dyspnea. They are moderately toxic if injested. Repeated or prolonged exposure of skin to the chemicals may cause dermatitis. Respiratory, eye and skin protections are recommended while using the chemicals. Proper ventilation of the chemical handling area and solution tanks is also necessary.

SELECTION OF DECHLORINATION CHEMICAL

Consideration should be given to several factors such as chemical properties, safety and ease of handling, and the cost of owning and operating the dechlorination system before the selection of the chemical is finalized. The last factor is best evaluated by performing a cost effectiveness analysis.

For a cost effectiveness analysis the installed system cost should be determined first for systems with equivalent capabilities and redundancies.

The annual cost of each chemical should be determined next. Several factors are considered such as (1) the Application Factor (pound of chemical required per pound of TRC to be neutralized), (2) the purity of the commercial grade chemical as delivered to site, and (3) the unit price of the delivered chemical. The last item depends on the amount of chemical to be shipped at a time and the mode of delivery. Thus, the annual chemical cost should be determined for all possible alternatives.

Example

To illustrate the economics of the various chemicals a procedure of evaluating chemical costs for neutralizing 1.5 mg/L of TRC from the effluent of a 10 million gallon per day (mgd) wastewater treatment plant for the City of Gainesville, Georgia is presented.

Step 1: Determine the chemical dosage in pounds per day per mgd (lb/d/mgd) using Equation 1.

Chemical dosage =
834 x 1.5 x Application Factor/ % Purity (1)

Step 2: Calculate the pounds per day (lb/d) of chemical required for the plant capacity (mgd) by using Equation 2.

Daily chemical required =
Chemical dosage x Plant capacity (2)

Step 3: Calculate the pounds (lb) of chemicals needed in storage (a minimum 20 days supply at the plant's flow rate of 10 mgd) by using Equation 3 and select the shipping mode and quantities.

Storage needed =
Daily chemical required x 20 (3)

Step 4: Calculate the annual chemical consumption in pounds per year per mgd (lb/yr/mgd) for treating a plant effluent containing 1.5 mg/L of chlorine residual using Equation 4.

Annual chemical consumption =
365 x Chemical dosage (4)

Step 5: Calculate the annual chemical cost per mgd of plant flow in dollars per year per mgd ($/yr/mgd) by multiplying the annual chemical consumption by the unit price of the chemical.

The prices of the chemicals per pound ($/lb) used in this example are based on the lowest quoted price for chemicals delivered to the plant site as obtained from several local suppliers. The unit prices of the chemicals varied depending on the form in which the chemicals are delivered and the minimum quantity of each shipment. Table 1 summarizes the results of steps 1 and 2 for each dechlorinating chemical in the various forms available. Table 2 summarizes the calculations related to the selection of the shipping quantities of the chemicals in various forms. The results of calculations in steps 4 and 5 are shown in Table 3.

A review of Table 3 indicates that the sulfur dioxide gas is the least expensive chemical based on annual chemical cost. Sodium metabisulfite is both second in the anhydrous form supplied in bags and third as a 38 percent solution if delivered as full tank truck loads. The above data was utilized in accomplishing a life cycle cost comparison of these three chemicals.

A life cycle cost comparison is presented in Table 4. In this evaluation sulfur dioxide is more cost effective than sodium metabisulfite in either form. Sodium metabisulfite in dry form is the least cost effective of the three.

Sulfur dioxide was found to be the most cost effective chemical for the plant in the example. However discussions with plant operators identified significant operating advantages of ready-made 38 percent solution of sodium metabisulfite over the use of sulfur dioxide gas. This aspect was seen to override the optimum selection on an economic basis.

SUMMARY

1. Dechlorination of a WWTP effluent lessens the detrimental effect of TRC on aquatic life in the receiving body of water.
2. Out of the alternative dechlorination methods available the use of sulfur compounds though mostly hazardous is more common.
3. For a cost effectiveness analysis the installed system cost was determined for systems with equivalent capabilities and redundancies. The annual cost of each chemical was determined for all available physical forms of the sulfur compounds and practicable modes of delivery to site.
4. The selection of the 38 percent solution of sodium metabisulfite as the optimum chemical is finalized after giving due consideration to several factors such as chemical properties, safety and ease in handling and the cost of owning and operating the dechlorination system. The last factor is evaluated by performing a cost effectiveness analysis.

TABLE 1. Chemical Required to Remove 1.5 mg/l Total Chlorine Residual in 10 mgd Flow

Chemical	Form	Purity %	Application Factor	Chemical Dosage lb/d/mgd	Chemical Required lb/d
Sulfur dioxide	gas/liquid	100.0	1.000	12.51	125.1
Sodium metabisulfite	anhydrous	95.0	1.340	17.65	176.5
Sodium sulfite	crystal	96.5	1.775	23.01	230.1
Sodium thiosulfate	pentahydrate	98.0	3.493	44.59	445.9
Sodium metabisulfite	38% solution	34.7	1.340	48.31	483.1
Sodium sulfite	15% solution	15.0	1.775	148.04	1,480.4
Sodium thiosulfate	30% solution	30.0	2.225	92.78	927.8

TABLE 2. Chemical Storage Quantities and Forms of Delivery

Chemical	Form	Chemical Required lb/d	Storage Needed lb	Shipping Quantity lb	Form of Delivery
Sulfur dioxide	gas/liquid	125.1	2,502	4,000	Ton cont. by truck
Sodium metabisulfite	anhydrous	176.5	3,503	4,000	Bags by truck
Sodium sulfite	crystal	230.1	4,602	5,000	Bags by truck
Sodium thiosulfate	pentahydrate	445.9	8,918	10,000	Bags by truck
Sodium metabisulfite	38% solution	483.1	9,662	44,000	Tank truck
Sodium metabisulfite	38% solution	483.1	9,662	10,000	Drums or tank truck
Sodium sulfite	15% solution	1,480.4	29,608	44,000	Tank truck
Sodium thiosulfate	30% solution	927.8	18,556	44,000	Tank truck
Sodium thiosulfate	30% solution	927.8	18,556	20,000	Drums or tank truck

TABLE 3. Estimate of Annual Chemical Costs

Chemical	Form of Chemical	Form of Delivery	Chemical Dosage lb/d/mgd	Chemical Consumption lb/yr/mgd	Price of Chemical $/lb	Annual Cost of Chemical $/yr/mgd
Sulfur dioxide	gas/liquid	Container	12.51	4,566	0.168	767
Sodium metabisulfite	anhydrous	Bags	17.65	6,442	0.213	1,372
Sodium sulfite	crystal	Bags	23.01	8,399	0.300	2,520
Sodium thiosulfate	pentahydrate	Bags	44.59	16,275	0.340	5,534
Sodium metabisulfite	38% Solution	Tank truck	48.31	17,633	0.107	1,887
Sodium metabisulfite	38% Solution	Tank truck	48.31	17,633	0.175*	3,086
Sodium metabisulfite	38% Solution	Drums	48.31	17,633	0.210	3,703
Sodium thiosulfate	30% solution	Tank truck	92.78	33,865	0.100	3,387
Sodium thiosulfate	30% solution	Tank truck	92.78	33,865	0.136+	4,606
Sodium thiosulfate	30% solution	Drums	92.78	33,865	0.160	5,418

* 10,000 lb delivery load

\+ 20,000 lb delivery load

TABLE 4. Life Cycle Cost Comparison of Sulfur Dioxide Versus Sodium Metabisulfite

Cost	Sulfur Dioxide	Sodium Metabisulfite Liquid	Sodium Metabisulfite Anhydrous
Annual Operation and Maintenance (O & M) Cost:			
(a) Variable Chemical Cost*	$ 767	$ 1,887	$ 1,372
(b) Uniform Costs:			
i. Labor	$ 7,000	$ 6,000	$ 12,000
ii. Power	$ 1,200	$ 1,500	$ 2,500
iii. Maintenance	$ 3,300	$ 2,400	$ 3,000
Total Uniform Annual O & M Costs	$ 11,500	$ 9,900	$ 17,500
Present Worth of Annual Chemical Cost**	$ 51,598	$ 126,943	$ 92,298
Present Worth of Annual Uniform Costs***	$ 112,909	$ 97,200	$ 171,818
Capital Cost	$ 99,000	$ 90,000	$ 119,600
Total Present Worth of Owning and Operating	$ 263,507	$ 314,143	$ 383,716

* Variable annual chemical cost in $/yr/mgd of plant flow from Table 3.

** Present worth of annual chemical cost is computed using a gradient series at an interest rate of 8 percent and 20 years assuming that the plant flow increases from 5 mgd in the initial year to 10 mgd in year 20.

*** Present worth of annual uniform cost is computed using a uniform series at an interest rate of 8 percent and 20 years.