Regulatory Update

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Treatment alternatives for compliance with the Stage 2 D/DBPR: An economic update

TO HELP UTILITIES PREPARE FOR COMPLIANCE WITH STAGE 2 OF THE DISINFECTANTS/DISINFECTION BYPRODUCTS RULE, THIS ARTICLE UPDATES THE DECEMBER 2005 REPORT FROM THE US ENVIRONMENTAL PROTECTION AGENCY ON DISINFECTION BY-PRODUCT CONTROL TECHNOLOGIES AND THEIR ASSOCIATED COSTS.

Chlorine disinfection is a long-used and highly effective means of preventing waterborne disease. However, chlorine reactions with natural organic matter (NOM) have created by-products, namely trihalomethanes (THMs) and haloacetic acids (HAAs), that also pose health risks. The US Environmental Protection Agency (USEPA) has implemented water quality standards to address these problems and to ensure the safety of the nation's drinking water.

Water utilities across the United States will soon face difficult choices as they formulate plans to comply with the requirements of the Stage 2 Disinfectants/Disinfection Byproducts Rule (D/DBPR) while working to continue controlling capital and operating costs. In December 2005 USEPA published a report on the technologies that can be used to control DBPs and their associated costs (USEPA, 2005). Since that time, a number of technologies have emerged as popular choices to achieve the Stage 2 treatment requirements. The costs associated with these technologies must also undergo significant adjustment in order to reflect current economic conditions and supply costs.

Although removal of DBPs from treated water may be economically feasible in some cases, in others prevention of DBP formation by changing the disinfectant or removing NOM would be more cost-effective. The use of alternative disinfectants is often considered an easily implemented and inexpensive means of reducing THMs and HAAs. There are, however, additional concerns with the use of alternative disinfectants, primarily the creation of other by-products that may pose their own health risks and ultimately prove to exhibit greater toxicity than THMs and HAAs—the "traditional" DBPs. A combination of treatment alternatives may be needed to produce the desired water quality.

Several treatment technologies are capable of achieving the desired treatment efficiency, often with ancillary benefits. The decision on which one or combination of these best suits a specific water utility often involves factors other than the cost of the technology.

This article reviews the popular treatment technologies used to limit production of DBPs in drinking water and updates their associated treatment costs, first published in 2005 by the USEPA. Consideration is also given to how the different technologies may be incorporated into larger treatment goals for future expansion and improved water quality.

CRITICAL QUESTIONS NEED TO BE ASKED

Before a technology assessment is done, it is often useful to conduct a detailed review of water quality parameters (both organic and inorganic), making sure to include changes that occur over the course of each year. Consideration must also be given to the additional treatment requirements of the Long Term 2 Enhanced Surface Water Treatment Rule and goals such as elimination of tastes and odors, inactivation of *Giardia* and *Cryptosporidium*, or removal of endocrine disrupting chemicals (EDCs).

Some questions commonly addressed before treatment technologies are assessed include:

- What is the available space for capital equipment?
- Is there any potential for integration with existing treatment?
- What is the potential for future expansion both in flow capacity and in scope of treatment?
- What are the local disposal options for process wastes?
- Is there a need for treatment redundancy?
- What amount and quality of operator attention can be provided to oversee the treatment?
- What needs are there for chemical storage?
- What safety considerations must be addressed in implementing a particular treatment technology?
- What are the monitoring requirements for the treatment technology and for compliance reporting?
- What permitting requirements must be satisfied in implementing a new treatment technology?

> Among the precursor technologies examined, the data suggest that activated carbon continues to be the most cost-effective method.

After these considerations have been assessed and prioritized, a short list of technologies can be selected for further review and/or pilot-testing. Then a list of prospective vendors can be developed.

ALTERNATIVE DISINFECTANTS ALSO HAVE DISADVANTAGES

Some of the alternative disinfectants used in place of or in combination with traditional disinfectants include monochloramine, chlorine dioxide, ozone, and ultraviolet (UV) light. The advantages and disadvantages of using these disinfectants are described in the following sections. Other less common disinfectants that may be considered in some applications include potassium permanganate, hydrogen peroxide, bromine, and iodine.

Monochloramine. Ammonia can be added to standard free chlorine disinfection processes to produce monochloramine, which has a much lower oxidation potential with NOM and exhibits a decreased potential to produce DBPs commonly found during free chlorine addition.

Advantages. Minimized production of THMs or HAAs; maintains a residual in the distribution system.

Disadvantages. Potential to form nitrosamines (*N*-nitrosodimethylamine; Choi & Valentine, 2002; Najm & Trussell, 2001); potential to form cyanogen chloride (Weinberg et al, 2002); can produce higher concentrations of iodated byproducts than chlorine disinfection (Krasner et al, 2006); not as strong a disinfectant for microbes other than bacteria; more complicated to produce than other disinfectants (must ensure dichloramine and trichloramine are not formed); less effective against viruses than other disinfectant processes; can create nitrification problems in distribution systems (Wilczak et al, 1996); toxic to fish (Seegert et al, 1979; Zillich, 1972).

Chlorine dioxide. This disinfectant is widely used in Europe. Generation usually involves the reaction of sodium chlorite with gaseous chlorine, hypochlorous acid, or hydrochloric acid.

Advantages. Minimized production of THMs and HAAs.

Disadvantages. Does not maintain a residual; requires secondary disinfection; safety concerns with sodium chlorite; can form by-products, including mutagenic compounds (such as MX and BMX), chlorates, and chlorites (Richardson, 2005); difficult to generate onsite; may produce a cat urine–type odor in the treated water; banned in some states.

UV light. Defined as electromagnetic radiation having a wavelength between 100 and 400 nm, UV light has been more commonly known as a means of disinfecting wastewater. Recently, because of its effectiveness for inactivatiing *Cryptosporidium* (Vrijenhoek et al, 1998), *Giardia*, bacteria, and viruses, UV has gained a much broader appeal for drinking water applications.

Advantages. Excellent disinfection for a wide variety of microbes; no DBPs produced; no chemical

TABLE 1 Capital cost comparisons—2005 and 2009

Treatment Technology	Capacity Cost—$ 1 mgd 2005	1 mgd 2009	17 mgd 2005	17 mgd 2009	76 mgd 2005	76 mgd 2009
Alternate disinfectants						
Chloramine	53,396	62,608	98,772	113,899	397,173	451,036
Chlorine dioxide	40,035	47,531	268,223	302,344	603,425	683,678
UV disinfection	317,091	359,359	1,418,926	1,625,710	3,569,168	4,078,398
Ozone	804,614	974,973	3,946,957	4,865,079	12,628,950	15,996,225
Organic removal technologies						
Granular activated carbon (annual exchange)	783,808	863,696	6,140,593	6,902,107	18,311,317	20,481,136
Nanofiltration	912,423	1,057,344	15,546,118	17,948,220	57,558,238	67,328,295
Microfiltration/ultrafiltration	1,594,911	1,786,445	15,991,348	17,940,217	61,150,358	69,100,740

TABLE 2 Operations and maintenance cost comparisons—2005 and 2009

Treatment Technology	Capacity Cost—$ 1 mgd 2005	1 mgd 2009	17 mgd 2005	17 mgd 2009	76 mgd 2005	76 mgd 2009
Alternate disinfectants						
Chloramine	4,443	4,861	11,333	13,528	31,538	41,078
Chlorine dioxide	18,571	21,217	35,939	41,818	87,061	102,220
UV disinfection	9,016	10,855	22,908	26,871	66,755	78,023
Ozone	76,470	91,862	455,559	652,134	1,974,401	2,906,241
Organic removal technologies						
Granular activated carbon (annual exchange)	57,078	61,531	227,710	251,037	709,287	777,712
Nanofiltration	112,309	133,392	1,780,761	2,161,229	7,914,024	9,684,873
Microfiltration/ultrafiltration	69,214	78,573	786,427	902,132	3,301,730	3,800,074

TABLE 3 Annual costs (based on a 10-year life cycle)—2005 and 2009

Treatment Technology*	Capacity Cost—$ 1 mgd 2005	1 mgd 2009	17 mgd 2005	17 mgd 2009	76 mgd 2005	76 mgd 2009
Alternate disinfectants						
Chloramine	9,800	11,122	21,210	24,918	70,800	86,182
Chlorine dioxide	22,600	25,970	62,700	72,052	147,300	170,588
UV disinfection	40,200	46,791	164,800	189,442	423,700	485,863
Ozone	156,900	189,359	850,300	1,138,642	3,237,000	4,505,864
Organic removal technologies						
Granular activated carbon (annual exchange)†	135,500	147,900	841,100	941,248	2,539,000	2,825,826
Nanofiltration	203,000	239,126	3,326,000	3,956,051	13,660,000	16,417,703
Microfiltration/ultrafiltration	228,700	257,218	2,385,000	2,696,154	9,420,000	10,710,148

*Additional details regarding each treatment technology are available from the author upon request.
†Recent developments regarding the custom reactivation of activated carbon would result in decreases of approximately 20% in the operations and maintenance costs for that technology versus what is shown in Tables 2 and 3 for 2009.

safety concerns; efficiency is not sensitive to pH or temperature.

Disadvantages. No residual disinfection produced; requires secondary disinfection; efficiency is compromised by turbid water; some replacement parts periodically required.

Ozone. Typically generated by passing filtered, dehumidified air through a high-voltage electric field, ozone has a long history of effectively disinfecting drinking water.

Advantages. High disinfection efficiency; easily produced; produces fewer THMs or HAAs if used to offset a portion of chlorine disinfection.

Disadvantages. Produces no residual; requires secondary disinfection; forms bromate if bromides are present in the water (Weinberg et al, 2002); cannot be stored because of decay back to oxygen; potential for trihalonitromethane formation; health risk, requires monitoring when producing; breaks down organics, creating the potential for biogrowth in the distribution system; potential formaldehydes formation (Weinberg et al, 2002); expensive compared with other alternative disinfectant technologies.

ORGANIC REMOVAL TECHNOLOGIES SHOULD BE PAIRED WITH A DISINFECTANT SWITCH

Switching disinfectants in the absence of additional treatment is unlikely to be an effective long-term solution for the control of DBPs in drinking water. This is because most alternative disinfectants have negative side effects, including the formation of emerging DBPs likely to be regulated in the future. Technologies that target the removal of compounds that serve as precursors for the formation of DBPs can offer the best potential for overall water quality improvement.

Organic removal technologies can offer additional treatment benefits aside from the reduction of DBPs, but they will result in higher costs than a change of disinfectant alone. A number of treatment technologies have been shown to be effective in the reduction of DBP precursor compounds. Several of the more common are described in the following sections.

Other lesser known treatment technologies can be considered for NOM removal, but are not included because of limited information. Piloting would be advisable before committing to a technology without a proven history in a variety of applications.

Activated carbon adsorption. Used in fixed beds of granular carbon or added as powdered carbon to an agitated tank, adsorption technology is well known for its effectiveness for organic removal and is considered best available treatment (BAT) for many targeted organics as well as taste, odor, and color. There are few data regarding the effectiveness of this technology for *Cryptosporidium* removal, but it is believed that removal via activated carbon adsorption would likely be similar to that achieved with conventional granular media filtration.

Advantages. Known to effectively reduce NOM, tastes, odors, and color; BAT for THMs and HAAs; effective for removal of many endocrine disrupting and pharmaceutical chemicals; simple to operate and maintain; spent granular product can be reactivated and reused, further reducing cost; can remove DBPs formed by prechlorination treatment; generally cost-effective in relation to other processes.

Disadvantages. Does not remove inorganic bromides; depletes oxidizers used for predisinfection; pretreatment to remove solids may be required for treatment of surface water; effectiveness is a function of molecular size, polarizability, and ionic strength of the organics in the water.

Microfiltration and ultrafiltration. These low-pressure membrane filtration processes are commonly used for high-efficiency particulate removal applications. Operating at 10–30 psi, microfiltration has a nominal pore size of 0.2 µm and ultrafiltration has a nominal pore size of 0.01 µm. These treatment processes remove organics above 10,000 molecular weight.

Advantages. Simple to operate and automate; effective for particle and microbial removal.

Disadvantages. Limited effectiveness for DBP precursors when used alone; may require the addition of coagulant or powdered activated carbon to achieve desired treatment; ineffective for color, tastes, odors, and endocrin disrupting chemicals; expensive even at smaller installations; significant residual waste for disposal.

TABLE 4 USEPA 2005 cost elements

Commodity	Cost—$
Electricity	0.076/kW•h
Diesel	1.48/gal
Natural gas	0.009/scf
Building energy use	102.6 kW/sq ft/year
Alum	300/ton
Chlorine (cylinder)	600
Ferric chloride	400/ton
Lime (hydrated)	110/ton
Polymer	1.00/lb
Sodium hexametaphosphate	1,300/ton
Sodium hydroxide	350/ton
Sodium chloride	100/ton
Sulfuric acid	100/ton
Granular activated carbon	1.00–1.20/lb

Nanofiltration and reverse osmosis. These higher-pressure membrane processes are well known for the extremely high purity they are capable of producing. Operating at 90 psi, nanofiltration has a nominal pore size of 0.001 µm.

Advantages. Effective for water softening; effective for microbe removal; shown to achieve 50–90% removal of total organic carbon, depending on its molecular size, shape, chemical characteristics, and ionic character.

Disadvantages. Very expensive technology; prone to fouling in surface water treatment; no more effective for microbe removal than ultrafiltration; adsorption of organics by the membrane can be irreversible and decrease membrane life; significant wastewater volume to be treated.

Enhanced oxidation. Using UV light in combination with hydrogen peroxide or ozone, this technology serves to destroy much of the NOM by breaking chemical bonds between the

TABLE 5 2009 economic update

Product/Service	Commodity Code	February 2005 Index	February 2009 Index	Increase—%
Accommodations	721	129.1	139.7	8.2
Aluminum compounds	0613-0209	108.8	150.5	38.3
Building Cost Index (NAICS 235221)	N/A	100 (December 2004)	130.7 (January 2009)	30.7
Building Cost Index (Turner)	N/A	655	866	32.2
Capital equipment	N/A	143.9	157.4	9.4
Chemical and allied products	06	186.4	228.4	22.5
Chlorine, sodium hydroxide, and other alkali	0613-0302	100 (June 2005)	205.6	105.6
Concrete ingredients and related products	132	180.4	236.2	30.9
Electric machinery and equipment	117	113.4	113.8	0.4
Employee compensation per hour (private industry)	N/A	$24.17 (Q1, 2005)	$27.35 (Q4, 2008)	13.1
Engineering and scientific instruments	1185	177.8	193.1	8.6
Engineering services	54133	103.0	114.4	11.1
Environmental controls	1181	149.1	159.7	7.1
General purpose machinery and equipment	114	165.9	199.7	20.4
Heavy equipment leasing	532412	104.5	117.3	12.2
Industrial chemicals	061	179.2	226.2	26.2
Industrial commodities	N/A	153.6	170.9	11.3
Industrial electric power	0543	148.0	189.7	28.2
Industrial natural gas	0553	211.9	235.3	11.0
Inorganic acids	0613-0224	79.7	155.5 (November 2008)	95.1
Integrating and measuring instruments	1172	148.1	156.4	5.6
Legal services	5411	137.1	164.6	20.0
Lime	0613-0213	140.2	219.6	56.7
Medical and diagnostic laboratories	6215	104.2	108.3	3.9
Metal and metal products (iron and steel)	101	179.8	183.0	2.8
Metal valves (except fluid power)	1149-02	186.9	245.4	31.3
Miscellaneous general purpose equipment	1149	183.7	226.4	23.2
Natural sodium carbonate and sulfate	0613-0301	99.8 (March 2005)	174.7	75.0
No. 2 diesel fuel	0573-03	149.5	145.6	–2.6
Potassium and sodium compounds (except bleaches)	0613-0217	105.6	289.1	173.8
Process control instruments	1182	162.2	196.4	21.1
Pumps, compressors, and equipment	1141	175.4	212.8	21.3
Sodium hydroxide	0613-0108	145.9	N/A	N/A
Steel pipe and tube	1017-06	193.8	206.6	5.0
Sulfuric acid	0613-0232	166.7	254.8 (November 2008)	52.8
Synthetic ammonia	0652-0135	123.2	181.3	47.2
Transformers and power regulators	1174	145.2	205.9	41.8
Water treatment compounds	325998-A	152.1	182.8	20.1
Water treatment compounds	0679-0961	168.4	181.9	8.0

N/A—not applicable, Q—quarter

constituent atoms. The NOM is converted to CO_2 or a simpler organic compound that has less potential for DBP formation. This technology has also been effectively used to treat many synthetic organic compounds.

Advantages. Effective in reducing NOM in water; potential for destruction of endocrine disrupting chemicals in water; capability of *Cryptosporidium* and *Giardia* inactivation; no THM or HAA produced; no residual waste to dispose (Shin et al, 2000; Bolton Et al, 1998).

Disadvantages. The process is compromised by turbid water, may require pretreatment; requires chemical storage; produces no residual disinfectant; requires secondary disinfection; other DBP formation possible; some replacement parts are periodically required.

Enhanced coagulation. Many surface water treatment plants use chemical coagulation with alum, ferric chloride, or lime for the removal of suspended solids from the raw water. By increasing the coagulant dose and optimizing pH, coagulation can be adapted to the removal of DBP precursors (Bolton et al, 1998).

Advantages. Requires little additional capital equipment than that typically needed for turbidity removal; BAT for THMs and HAAs; can achieve 50% reduction in humic acids by forming insoluble humates; improved disinfection efficiency by reduced organic oxidant demand; some *Cryptosporidium* and *Giardia* removal; complements activated carbon treatment by removing high-molecular-weight, negatively charged organics.

Disadvantages. Larger sludge volumes created; increases coagulant use (up to five times that required for solid removal); optimum pH (5.5 for ferric chloride and alum) requires two pH adjustments; postprecipitation in distribution systems; corrosion potential in distribution systems; waters with high bromide

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TABLE 6 Capital cost factors and cost escalators

Cost Factor (Capital)	Escalator (Commodity Code)
Analyzer	Engineering and scientific instruments (1185)
Chemical feed system	Capital equipment (general BLS category, no code)
Discharge pipeline	Steel pipe (1017)
Effluent ozone quench	Environmental controls (1181)
Electrical and instrumentation	Process control instrumentation (1182)
Housing	Accommodations (721)
Land	Percentage of direct capital cost (varies with technology)
Operator training	Engineering services (54133)
Ozone contactor	Capital equipment
Ozone generation system	Capital equipment
Ozone off-gas destruction system	Environmental controls (1181)
Permitting	Percentage of capital premultiplier (varies with technology)
pH adjustment	Environmental controls (1181)
Piloting	Engineering services (54133)
Pipes and valves	Steel pipe (1017) + metal valve (1149-02)*
Process monitoring equipment	Process control instrumentation (1182)
Public education	Engineering services (54133)
Pumping	Pumps, compressors, and equipment (1141)
Scrubber	Environmental controls (1181)
Stocked spare parts	Miscellaneous general purpose equipment (1149)
Treatment equipment	Capital equipment (general BLS category, no code)
Ultraviolet reactors	Capital equipment (general BLS category, no code)

BLS—Bureau of Labor Statistics

*In determining the escalation of costs for pipes and valves an assumption will need to be made about the percentage of cost that will be related to each item individually and that portion escalated.

concentrationss can produce higher brominated DBPs; adds inorganics (manganese, aluminum, sulfate, chloride, and sodium) to the water supply; may increase floc fragility.

TREATMENT SYNERGIES ARE POSSIBLE

The effectiveness of most of the treatment technologies will be limited in some regard because of the diverse nature of NOM. Combinations of treatment technologies may prove to offer significant advantages in terms of cost-effective achievement of treatment goals. For example, combining the two technologies currently designated as BAT (USEPA, 2001) may provide a significant benefit over their individual performance.

Activated carbon adsorption is most effective for the portion of NOM composed of smaller-size organic compounds without charged functional groups (DeSilva, 2000). Conversely, enhanced coagulation is generally considered to be most effective for the portion of NOM composed of large organic molecules with negatively charged functional groups (Uyak, 2007). By using a combination of technologies, the percentage reduction of DBP precursor compounds can be increased and possibly maintained for a longer duration. Combining treatment technologies with an alternative disinfectant may be a course of action worth considering for many source water applications.

CAPITAL AND OPERATING COSTS ARE CRITICAL CONSIDERATIONS

In uncertain economic times, capital and operating costs are vital considerations in the selection of best available control technologies. Although the specific capital costs for different technologies can differ greatly, general estimates have been used to account for project costs aside from the direct costs of the capital equipment. The past few years have seen significant cost increases, particularly for commodity chemicals. Rapid international growth along with production capacity limitations have resulted in significant cost increases for most water treatment chemicals. Rising fuel and energy prices have added to chemical costs as well as transportation costs. Steel and other building materials costs have also risen during this period.

In December 2005, USEPA published cost estimates (along with their component cost elements) for many of the treatment technologies that can be used to assess the cost of compliance with the Stage 2 D/DBPR (USEPA, 2001). These estimates, which include both capital and operating costs, are summarized in Tables 1 and 2, respectively; each table has been updated to also provide 2009 costs for each parameter. A simple 10-year life cycle cost analysis for 2005 (and updated here for 2009) is given in Table 3. USEPA's 2005 cost elements are listed in Table 4.

Using the cost escalations of the matching elements contained in the 2005 USEPA publication, a revised set of projected capital and operating costs for the respective technologies was generated. As the 2009 data in Tables 1–3 show, taken as a whole these price differences do not change the comparative economics of the respective technologies.

Capital costs include major equipment cost, pilot-testing, permitting, land cost, operator training, housing, pipes and valves, instrumentation and control, chemical addition systems, and on-line analyzers. As the major equipment is priced, general additions are included for initial budgeting. Typically, the following can be assumed:

- add 20% for site work and installation,
- add 10% for electrical and instrumentation and control (more if full automation is needed),
- add 20% for engineering and administration, and
- add 20% for contingencies.

Initial operations and maintenance costs (labor, power, maintenance materials, performance monitoring, media replacement, chemicals) can be estimated by using the estimates for annual chemical costs and power costs for major equipment and by adding 3% of capital cost for annual materials, labor, and maintenance.

Over the past few years, there have been several changes in costs for both products and services. Calculated from US Bureau of Labor Statistics data, values for products, services, and cost indexes for both 2005 and 2009 are shown in Table 5.

In the nearly five-year period since the initial development of USEPA's cost estimates, some capital and operating costs have changed significantly. The largest price increases

TABLE 7 Operations and maintenance cost factors and cost escalators

Cost Factor (Operations & Maintenance)	Escalator (Commodity Code)
Chemicals (activated carbon)	Vendor quote
Chemicals (antiscale)	Water treatment compounds (0679-0961)
Chemicals (chloramine)	Synthetic ammonia (0652-0135) + chlorine (0613-0302)
Chemicals (ClO_2)	Chlorine (0613-0302)
Electricity	Industrial electric power (0543)
Labor	Employee compensation per hour (private industry)
Maintenance materials	Miscellaneous general purpose equipment (1149)
Parts	Miscellaneous general purpose equipment (1149)
Performance monitoring	Medical and diagnostic laboratory (6215)
Tank lease	Heavy equipment lease (532412)

have been in commodity chemicals as a result of increasing demand from developing countries and in non-water-treatment industries, and limitations in manufacturing capacity. Costs for water treatment chemicals have increased at a somewhat slower pace than those for commodity chemicals. Energy prices have experienced significant fluctuations during this period, and they currently stand substantially below their peak levels. General prices for wages and other services have increased slowly by comparison. Tables 6 and 7 provide escalators for many of the components used to derive the projected 2009 capital and operating costs for the various treatment technologies.

SUMMARY

Ensuring safe drinking water supplies is an ongoing process. As new health risks are identified, they must be addressed. The solutions are seldom simple or inexpensive. Water utilities will soon be challenged to meet DBP regulations without creating additional health concerns, which may be the case with some of the alternative disinfectants (Krasner et al, 2006; Weinberg et al, 2002). Clearly, a number of treatment alternatives are available, and careful assessment must be made to determine which ones will provide the best performance for DBP control and other water quality objectives. Because of increasing costs, particularly those for commodity chemicals, it will be equally important to carefully evaluate the different treatments and perhaps combinations of treatments along with the respective vendors in order to ensure that an effective treatment is guaranteed while costs are kept reasonable.

Although the capital and operating costs for all of the technologies have increased from 2005 to 2009, the relative rankings of the technologies on an economic basis remain the same. On the basis of this reexamination of the technologies currently available to address compliance with the Stage 2 D/DBPR, it seems clear that precursor control—versus switching to an alternate disinfectant—is the preferred primary approach to compliance. Further, the data suggest that among the precursor technologies examined, activated carbon continues to be the most cost-effective method available.

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Detailed information regarding the alternative disinfectants and technologies discussed in this article is available from the author. E-mail your request to alroy@comcast.net.

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