GENERAL

Regulations and Policies. Safeguarding the nation's public water system is a worthy and absolute imperative. However, the complex regulatory framework and administrative structure supporting this goal are in danger of collapsing. With each amendment of the Safe Drinking Water Act (SWDA), the paradigm applied to the regulation of drinking water contaminants has shifted. Pontius (2004) delineated the patchwork quilt of requirements specified in the Stage 2 Disinfectants/Disinfection Byproducts Rule (D/DBPR) and other upcoming regulations.

Evaluations of costs and benefits of US drinking water standards typically consider only a single contaminant or class of contaminants. However, treating for one contaminant (e.g., pathogens) may make it more difficult to comply with regulations for other contaminants (e.g., disinfection by-products (DBPs)). Gurian et al. (2004) developed a simulation model to assess the national costs and benefits of compliance with multiple drinking water standards. An integrated model could help utilities prioritize their regulatory options.

Chlorine and chloramine are not considered effective against Cryptosporidium, and no $C \times T$ (Concentration $\times$ Time) table for their inactivation of Cryptosporidium is included in the proposed Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). Najm et al. (2004) developed a $C \times T$ table for inactivation of
Cryptosporidium with chloramine downstream of ozone and indicated that synergistic Cryptosporidium inactivation with extended chloramine contact time downstream of ozone could provide substantial benefits to water treatment plants. A project, funded by American Water Works Association (AWWA), represents one of the first efforts to apply the United States' developing ultraviolet (UV) disinfection regulations to an existing, real-world installation. The objective was to evaluate the feasibility of implementing the requirements of the USEPA's Proposed Ultraviolet Disinfection Guidance Manual by applying them to an existing system. Several specific recommendations were developed and submitted to the USEPA (Swaim et al., 2004).

Health Risk. Despite strenuous efforts to prevent them, waterborne disease outbreaks continue to occur. Logsdon et al. (2004) presented the concept that multiple adverse events could often be associated with waterborne disease outbreaks, and encouraged people to maintain vigilance at all times so circumstances that might lead to a treatment failure and a disease outbreak could be avoided. Data from birth certificates were used to establish a relationship between DBPs levels and birth weight along with gestational duration. It was found that mean birth weight was lower with trihalomethanes (THMs) exposure that was above 40 µg/L, and in the third-trimester, when chloroform exposure was above 20 µg/L, and bromodichloromethane was above 5 µg/L. Elevated THMs exposures were associated with a reduced risk of preterm delivery (Wright et al., 2004). A concentration-dependent significant apoptosis-inducing effect was observed on human peripheral lymphocytes during an in vitro study using
water concentrates both before and after disinfection from a water treatment plant (WTP) in Hungary (Racz et al., 2004).

Drinking water produced by conventional surface water treatment plants with typical levels of Cryptosporidium oocysts in source waters might put public health at risk. A study by Aboytes et al. (2004) showed that 90% of the finished water samples positive for Cryptosporidium occurred in filtered drinking water samples with low turbidities and that microbial indicators such as Bacillus, Clostridium, and phage were not associated with Cryptosporidium occurrence. The authors recommended that treatment should be improved using alternative disinfection techniques to preserve public health.

The DBP concentrations of water samples collected from rural areas of Alberta, Canada were measured and four of the eleven communities were found to have THM concentrations >100 µg/L with total organic carbon (TOC) concentrations >10mg/L (Charrois et al., 2004). Five iodoacids were identified as the result of chloramination of a source water with moderate level of bromide and TOC at a full-scale treatment plant. Genotoxicity and cytotoxicity assays were performed and indicated iodoacetic acid as the most potent compound (Plewa et al., 2004).

Microbiological analyses were conducted to treat drinking water from a lake in Italy to determine the toxicity and genotoxicity. Sodium hypochlorite produced the highest levels of DBPs while peracetic acid produced the lowest. A Vicia faba/micronucleus test showed the highest sensitivity for water DBPs. The highest genotoxic activity resulted from a Saccharomyces cerevisiae test and a Comet test on human leukocytes (Monarca et al., 2004). Bolognesi et al. (2004) performed a genotoxicity assessment on water from a lake in Italy using Comet and micronucleus assays in zebra mussel cells.
The mussels were exposed to waters treated with three disinfectants (sodium hypochlorite, chlorine dioxide, and peracetic acid) for 20 d in different seasons and showed that DNA migration was lower in the coolest period, and an increase in chromosomal damage was observed in the micronuclei frequencies in gill cells. Disinfection with peracetic acid did not induce adverse effects, but some interaction with DNA was observed for the other two disinfectants. The toxicity of two DBPs, bromochloroacetic acid (BCA) and dibromoacetic acid (DBA), was evaluated in a frog embryo teratogenesis assay. The EC\textsubscript{50} and LC\textsubscript{50} values for BCA were within 10 000 - 12 000 parts per million (ppm) and a decrease in embryo length was observed at 8 000 ppm. No adverse effects were observed in DBA-exposed tadpoles (Weber et al., 2004).

Samples of drinking water from Spain were analyzed for their amount of indicator bacteria and bacteriophages. Indicator bacteria were found more frequently in springs, household water wells, and rural water supplies; bacteriophages were detected more frequently over bacteria indicators in metropolitan water supplies. The levels of chlorine found in water supplies samples that tested positive for indicator organisms were detailed (Mendez et al., 2004). The Sub-Basin Pollution Source Tracking Program in Louisiana was established by a private, non-profit environmental organization to track pollutants from their source. The program targets sub-watersheds of the basin for identification, investigation, and correction of fecal pollution sources (Bourgeois-Calvin et al., 2004).
Recent Construction/Upgrades. Two beaches in southern California have experienced high bacterial levels and were subjected to public health posting. An ozone disinfection facility is currently under construction to treat dry-weather urban runoff. Ozonation was chosen due to high levels of iron, manganese, total suspended solids (TSS), and turbidity (Rasmus and Cover, 2004). A $187 million combined sewer overflow (CSO) screening and disinfection facility in Michigan is designed to be an “unmanned” facility. The facility is to achieve a daily fecal coliform limit of 400 colony forming units per 100 milliliters (/100 mL) and a monthly limit of 200 /100 mL with five minutes of contact time at the ten-year, one-hour peak flow (Maurer et al., 2004). Pilot testing was performed as part of the initial design phase of the wet weather treatment facility designed by the City of Toledo’s Bay View Wastewater Treatment Plant (WWTP) to double the existing treatment capacity to 400 million gallons per day (MGD). One of the primary goals is to assess the feasibility of coupling high-rate clarification and UV technologies (Nitz et al., 2004).

The State of California Department of Health Services granted a conditional acceptance of the Aquaray® 40 HO UV disinfection system of Infilco Degremont, Inc. in reclaimed wastewater disinfection applications upon a validation study. Biodosimetry was used for the validation testing and results showed the system can be sized for wastewater reuse applications through the utilization of a ratio of target dose to dose delivered per module (Ferran et al., 2004). One of the largest UV disinfection systems, for wastewater treatment (158 MGD), underwent analysis of its compliance and changed various operating strategies to include additional operational time for cleaning
of the reactors. These changes were made in order to comply with one of the coliform limits and to improve the performance of the UV system (Hunter et al., 2004).

**Challenges.** A study was conducted to assess the utility of monitoring efforts targeting male-specific RNA coliphages as indicators of sewage contamination in streams of Hawaii. The results showed that substantial concentration of these coliphages remained in treated sewage effluents where traditional fecal indicator bacteria concentrations were significantly reduced (Luther and Fujioka, 2004). Rural areas of Canada experience a high percentage of waterborne diseases due to the lack of water treatment legislation. Corkal et al. (2004) summarized the findings from the Rural Water Quality Program that was conducted from 1997 to 2002, and disinfection for farm water needed was addressed.

Wastewater treatment plants usually rely on electricity for process operation including disinfection. The Northeast Ohio Regional Sewer District was impacted by a massive power failure that occurred in 2003. However, this event led to the evaluation of plant operations and emergency response as well as the possible refinement of procedures (Blanc and Ambler, 2004).

Cost analyses were performed for Membrane Bioreactor (MBR) process and subsequent disinfection. The results showed total costs ranging from $1.48-$2.24/1000 gal for 1-MGD MBR water reclamation systems (DeCarolis et al., 2004).

Due to occasional high fecal coliform test results in the final effluent at the Detroit Wastewater Treatment Plant, a study was conducted to investigate the cause of the high results and found that total residual chlorine in the final effluent was not always an
effective indicator of disinfection. The accuracy of chlorine demand, original coliform concentrations, and organic nitrogen contents played important roles in disinfection efficiency (Zhang et al., 2004a).

Presence of Cryptosporidium in watersheds poses health risks and challenges to water utilities. A major source of the parasite is beef and dairy farms where manure from infected animals drains into surface water supplies. Finstein (2004) reviewed the diverse and scattered literature related to the methodologies of managing manure to accomplish oocyst inactivation.

DISINFECTION METHODS

Chlorination/Dechlorination. In an effort to meet the California Oceans Plan's bacteria requirements, the Orange County Sanitation District met their disinfection goal, <180 000 MPN/100mL, for two WWTPs of a combined flow of 245 MGD. Sodium hypochlorite was chosen as the disinfection agent and sodium bisulfite was used for dechlorination prior to discharge to the ocean. Hypochlorite was added to the primary influent to provide longer contact time and save the chemical costs (Hetherington et al., 2004). New York City Wastewater Pollution Control Plants (WPCPs) evaluated the chlorine demand, hydraulic efficiency of the chlorine contact tanks, and disinfection kinetics. The results showed that the initial dilution of sodium hypochlorite with final settling tank effluent accounted for 80% of the total chlorine demand. Fillos et al. (2004) also formulated two sets of kinetic equations for inactivation of fecal coliform bacteria and fecal enterococci.
A study was conducted at Lawrence, Kansas, WWTP to determine the maintenance required for on-line chlorine analyzers as well as their reliability. Five analyzers were tested and process control issues of automating chlorine feed systems were discussed (Wood et al., 2004). Total residual chlorine (TRC) in the ocean outfall and its potential toxic impact to aquatic life is a concern to South Florida wastewater utilities. An approach focused on TRC decay measurements and analysis, indicated that the specific effluent minimum and maximum TRC levels for each WWTP could be determined to comply with TRC level at the ocean outfall discharge point (Vinci et al., 2004). To optimize disinfection through mixing and ORP control, a primary wastewater treatment plant in Alaska installed a new data-recording program and relocated the induction mixer to inject axially into the flow (Stella et al., 2004).

A multilayer perceptions neural network, with one hidden layer of transig neurons and each receiving as inputs a weighted sum of input variables as well as a bias, used to describe the inactivation of Giardia lamblia by free chlorine was found to fit disinfection data better than classical kinetic models (Haas, 2004). Although widely applied, the C × T approach is an overly simplistic description of the disinfection process in continuous-flow reactors that can result in process operational inefficiency. Greene et al. (2004) demonstrated that a computational fluid dynamics (CFD) design approach can predict disinfection levels just as well, without the need for full-scale tracer testing, and offers several advantages over traditional approaches.

In a study for alternative agents for residual chlorine reduction, ten agents were used with the following four model compounds for a simulation of chloramines typically found in municipal wastewaters: an inorganic chloramine, a secondary organic
chloramine, and two peptidic chloramines. The most promising alternative agents were thiosulfate, Iron (Fe) metal, and iodide-mediated sulfate (Bedner et al., 2004).

After the Washington, D.C., Water and Sewer Authority (WASA) switched from free chlorine to chloramine disinfectant, serious problems with lead leaching started to occur. In many cases, the highest lead concentrations emerged from the tap after about one minute of flushing and were as high as 48 000 µg/L. Bench-scale experiments showed that compared with free chlorine, chloramine sometimes significantly worsened lead leaching from brass but had little effect on new, pure lead pipe (Edwards and Dudi, 2004). Utility managers may question whether long-term exposure to chloramines will compromise the functioning and/or shorten the life of their rubber gasketed ductile-iron pipe joints. Bonds (2004) concluded that the effect of chloramine on elastomers is application-specific, but that chloramination will not compromise the life of elastomer gaskets supplied with push-on and mechanical joint ductile-iron pipe.

**Ozonation.** The simultaneous prediction of *Cryptosporidium parvum* oocyst inactivation and bromate formation in ozone bubble-diffuser contactors can be achieved through a developed mathematical model. Ozonation experiments with synthetic waters containing bromide and *C. parvum* oocysts were conducted and the overall experimental results agreed with the model predictions. The hydrodynamic conditions had a greater effect on inactivation than bromate formation, while the opposite was found in terms of the influence of pH (Kim et al., 2004). A bench-scale study was conducted to determine the efficiency of ozonation on filtered water from a full-scale treatment plant containing *C. parvum* oocysts. The CT value (product of disinfectant
concentration C and contact time T) was determined to be 19.5 mg-min/L at 15°C to achieve 99% inactivation of oocysts (Li and Haas, 2004).

**UV Disinfection.** Filtration of wastewater prior to disinfection effectively removes the presence of particles, which can hinder the performance of UV disinfection by shielding coliform bacteria from UV light (Bourgeois et al., 2004). A study was conducted using a fractionation technique in order to separate particle-associated bacteria into three sizes. It was found that particle size greatly influences the amount that the particles interfere with UV disinfection. The fraction containing the smallest particles (< 5 µm) resulted in the fastest disinfection rate. Tailing was observed only in the large fraction and particle shielding was the primary mechanism (Madge and Jensen, 2004a). Passantino et al. (2004) studied the effects of low concentrations of drinking water particulates and algae on UV disinfection performance. Results indicated that UV light successfully inactivated MS2 in the presence of clay, algae, and naturally occurring turbidity. Madge and Jensen (2004b) used size fractionation to model disinfection and modified the Scheible model, which relates the non-inactivated bacterial density with TSS. The Water Environment Research Federation (WERF) model described the disinfection data well, and dose and initial fecal coliform concentration were observed to be the most significant factors.

There are different germicidal properties associated with the three ranges of UV; at the high end UV kills target organisms by shifting electrons and breaking bonds in the DNA. The dosage requirements for different species of microorganisms were outlined by Siddiqui (2004). Salveson et al. (2004) studied the impacts of fouling of protective
quartz lamp sleeves to the UV delivered dose. The results showed that UV light transmittance through the sleeve can decrease from <1% per day to >95% per day. The fouling potential of water should be considered in selection of cleaning system.

Previous research on the effects of UV for control of Cryptosporidium in drinking water have focused only on Iowa strain oocysts. A study investigated the effect of UV doses ranging from 5 to 40 mJ/cm² on five strains of C. parvum. Results indicated that all five strains of C. parvum were highly susceptible to low levels of UV light (Clancy et al., 2004). The effects of water quality and sample depth on inactivation of MS2 coliphage were evaluated for 17 filtered waters (Batch et al., 2004). The study also compared the inactivation performance of low-pressure (LP) and medium-pressure (MP) lamp types. Study findings indicated that at the UV doses customarily used in water treatment, turbidity and particle count and size do not significantly affect LP and MP disinfection efficiency of seeded MS2 in filtered water.

Oguma et al. (2004) studied the photoreactivation of pure cultures of Legionella pneumophila after inactivation with low or medium pressure UV lamps and compared the data with Escherichia coli cultures. Legionella pneumophila showed a faster and higher DNA repair than E. coli and complete repair was observed 1 h after inactivation.

Computer simulation of UV light technology can be used to determine the exact requirements for a system. Microorganism response to the treatment can be measured using CFD and irradiance modeling (Nisipeanu and Sami, 2004). Lawryshyn and Scheible (2004) explained a dose-distribution theory for use in validation of the dose-delivery performances of commercial UV reactors. The MS2 coliphage may be ineffective at identifying poor performance of a reactor at lower dose levels. Indigenous
organisms, or surrogates of similar UV sensitivity, should be used when validating and sizing reactors at lower dose levels. Petri and Sakaji (2004) discussed practical methods for describing UV reactor performance from validation data. The methods include using a multiple linear regression approach and developing a performance equation to aid in the UV reactor design and system operation to meet water quality objectives. The technique can be used with multiple variables [flow, UV transmittance (UVT), and power setting] and varying parameter values of bioassay validation. Hofmann et al. (2004) presented a conceptual process for the design and operation of a UV disinfection system for drinking water, citing experiences gathered from Ontario, Canada. Three key steps in the process are to select the intended UV dose, ensure the delivering capacity of the UV reactor to perform under various conditions, and perform monitoring of the dose. Results of collimated UV beam testing of secondary and blended effluent of the largest WWTP of City of Winnipeg, Canada showed that UV disinfection during wet weather conditions would prove difficult to meet the disinfection standards. The results provided the city with data to their application for some relaxation of permit limits (Baker et al., 2004).

Due to the high peak flow rate of 5 000 MGD of CSO through the outfall of City of Richmond, Virginia, an 80% reduction of bacterial loading was desired. UV disinfection showed 80% efficiency in the 12-month pilot study. Multivariable regression models were finalized to predict the delivered UV dose (Chandler et al., 2004). A low-pressure, high-intensity UV system was selected to replace chlorination at a 45.9 MGD WWTP in Michigan. Kang et al. (2004) presented the methodology used in the selection process
of the system. Consistently good results have been obtained with the full-scale system since start-up in 2003.

**Physical/Biophysical Processes.** Conventional treatment is a good treatment barrier for some pathogens, but a poor one for others. A study was undertaken to compare the removal of several emerging pathogens. The work revealed that *A. hydrophila* was removed more effectively than *C. parvum*, and *E. intestinalis* spores and *E. coli* O157:H7 were the least effectively removed. By setting filter effluent turbidity goals below 0.2 NTU, significant improvements in microbiological quality could be obtained (Xagoraraki et al., 2004). Until recently, little was known about *Cryptosporidium* removal by filtration during non-ideal operating periods. Emelko and Huck (2004) demonstrated that oocyst-sized microspheres might be a useful tool. These microspheres are easier, safer, and cheaper to work with than *Cryptosporidium*. This approach could be useful to utility managers in assigning log removal credits for regulatory purposes. Vaughn et al. (2004) conducted a side-by-side comparison of protozoa removal using two types of filters under various hydraulic loading rates and chemical coagulants. The removal of *C.* oocysts and *Giardia* cysts and indicator bacteria was compared.

The performances of two pilot-scale MBR plants were studied. Both MBR plants achieved > 6 log removal of coliforms and > 5 log removal of indigenous coliphage (Mansell et al., 2004). A WERF project was conducted to determine the reduction of pathogens and indicators throughout each treatment step of six wastewater treatment and reclamation processes. The paper was focused on filtration, and removal varied
with filter design, depth, chemical addition, and backwash strategies (Levine et al., 2004).

**Other Disinfection Alternatives.** Wastewater from a WWTP in central Italy undergoes sand filtration in its tertiary treatment followed by disinfection by peracetic acid upstream of UV irradiation. The tertiary effluent met microbiological limits and was suitable for irrigation in the plant nurseries of the area (Lubello et al., 2004). Use of chlorine dioxide (ClO$_2$) to treat a hospital's water supply is not common in the United States. Sidari et al. (2004) studied one Pennsylvania hospital that adopted a ClO$_2$ system to disinfect its water supply. Complete eradication of Legionella was achieved after 21 months. Cho et al. (2004) conducted experiments to examine how hydroxide (OH) radical was related to the inactivation of *E. coli*. A slurry of titanium dioxide (TiO$_2$)/*E. coli* was mixed and five sets of photocatalytic experiments were performed. A linear correlation was found between OH radical formed and *E. coli* inactivation, while more rapid inactivation occurred at higher light intensity and TiO$_2$ concentrations.

Two types of solar disinfection pouches, an absorptive pouch with black plastic for temperature increase and a reflective pouch with metallized plastic to reflect light, were evaluated for their disinfection of inoculated spring water. The reflective pouch yielded a higher level of inactivation than the absorptive pouch and both were less efficient in reducing viruses than *E. coli* (Walker et al., 2004). The daily fluctuations of *E. coli* in beach waters can be measured using time-dependent regression models to evaluate their response to sunlight exposure. Data from 63$^{rd}$ St. Beach in Chicago showed limited *E. coli* decline in deeper waters as well as night recovery (Whitman et al., 2004).
A first-order model of disinfection was developed from data collected from a pilot-scale high-rate pond treating dairy-farm wastewater. The results showed that most of the disinfection was due to sunlight exposure, and an improvement to the model was made with the inclusion of a dark inactivation term (Craggs et al., 2004).

**Comparison Among Disinfection Alternatives.** A decision mapping model was used to aid in the selection of the combined disinfection alternatives required for a disinfection project. The project faces challenges such as the conflicting requirements of the multiple reuse and recharge discharge points (Wallis-Lage et al., 2004). The City of Elkhart, Indiana, WWTP conducted a disinfection alternatives evaluation study and concluded that UV disinfection was the most favorable alternative to the existing gaseous chlorine system. An unranked-paired comparison technique was used in selecting a UV system (Margheim et al., 2004).

Taking an active approach to upcoming requirements of LT2ESWTR, the Greater Cincinnati Water Works investigated UV disinfection as an additional treatment process for a multibarrier approach. Results showed that UV alone or UV followed by chlorine effectively controlled all microorganisms tested. There were no apparent signs of synergistic effects between sequentially applied UV light doses and free chlorine (Kashinkunti et al., 2004). Ballester and Malley (2004) demonstrated that adenovirus inactivation can be effectively achieved with the combination of UV, free chlorine, and conversion to chloramines. They showed that UV disinfection at typical doses of 40 mJ/cm² followed by the sequential chloramination could effectively achieve a 4-log
adenovirus inactivation. This method would enable water utilities that have difficulty maintaining a free Cl₂ residual to meet the new LT2ESWTR using UV-Cl₂ chloramines.

MICROBIOLOGY AND DISINFECTION CHEMISTRY

Formation of haloacetic acids can occur during the preservation and storage of drinking water. Pepich et al. (2004) added ammonium chloride to quench the free-available chlorine in treated surface water and found it to prevent most of the haloacetic acid formation after 28 d of storage. The observed increase in haloacetic acids occurred mostly over the first two days, and was mainly dichloroacetic acids. A comparison study was conducted to evaluate the trihalomethane yields for bromine (Br) and chlorine in separate experiments involving reaction with model compounds and natural organic matter. The Br haloform substitution efficiency was found to be approximately ten times higher than the substitution efficiency for chlorine. Aqueous Br substituted into organic structures, whereas aqueous Cl tended to cleave carbon bonds and have a more significant impact on natural organic matter (NOM) structure (Westerhoff et al., 2004). The humic-substances content in raw water was determined and its effect on DBPs after chlorination was studied using water from two water-treatment plants in Greece. The concentrations of total trihalomethanes, chloral hydrate, 1,1-dichloropropanone, 1,1,1-trichloropropanone, trichloroacetic acid, and dibromochloroacetic acid exhibited the strongest effects from the humic-substances content (Nikolaou et al., 2004).

Pharmaceuticals containing phenolic, amine, and/or aromatic ether functional groups were studied to observe their reactions during chlorine disinfection. All the
compounds used in the study were transformed by free chlorine with the exception of ibuprofen and ketoprofen, and the rate of reaction was higher than with combined chlorine (Pinkston and Sedlak, 2004). The concentration of amoxicillin, which was added to the influent of two water reclamation systems, was measured at the end of two treatment trains. The biological portion of the treatment train degraded the amoxicillin easily, and UV disinfection was also effective (Morse and Jackson, 2004). Antibiotic resistance was seen in isolated aeromonads found in samples of untreated groundwater and treated drinking water in Lebanon (Tokajian and Hashwa, 2004). A decrease in estrogenic potency under the influence of free chlorine was suggested by data obtained from assay tests intended to identify the effect of chlorine disinfection on the estrogenic potency of 17-beta-estradiol, nonylphenol, and bisphenol A. The effects were highly time-dependent and toxic reaction products were formed with insufficient chlorine dosage and reaction time (Lee et al., 2004). Three estrogenic compounds were used in the evaluation of endocrine disruptor (EDC) removal in the treatment units of a WWTP. Although not statistically significant, the UV disinfection process appeared to result in a slight change in soluble phase estrogens (Cicek et al., 2004).

A study was conducted to evaluate the mechanisms of inactivation of hepatitis A virus by ClO₂ using cell culture, enzyme-linked immunosorbent assay, and reverse transcription-polymerase chain reaction (PCR). A ClO₂ concentration of 7.5 mg/L with a 10-min exposure time resulted in complete hepatitis A virus (HAV) inactivity (Li et al., 2004). The addition of H₂O₂ positively impacted the inactivation rate for E. coli in a study on the photolytic and photocatalytic disinfection processes. Bacterial sensitivity to sunlight was observed upon the addition of certain inorganic ions and a negative impact
to photocatalytic disinfection was observed during the presence of organic substances regularly found in natural waters (Rincon and Pulgarin, 2004).

**ANALYTICAL METHODS**

A method has been developed to unmask a toxic response resulting from a false-positive indicator of toxicity in Whole Effluent Toxicity (WET) tests. The method involves a split effluent sample being treated with UV radiation, and both samples then undergo a Chronic WET test. By examining the concentration responses, biological interferences can be determined from comparing samples with and without UV radiation, which can indicate a false-positive toxicity indication (Russell, 2004).

An electrospray ionization-tandem mass spectrometry (ESI-MS/MS) was used on three Cl-containing compounds and a chlorinated humic substance. The chloride ion fragments produced from the Cl-containing compounds by MS/MS may aid in the analysis for chlorinated DBPs in drinking water. Maximizing the production of chloride ions by MS/MS required a relatively high collision energy and gas pressure (Zhang et al., 2004b). The presence of the Cl$_2$O$_4^-$ complex, which forms in ClO$_2$ solutions in the presence of chlorite ion, can result in significant error in the spectrophotometric measurement of ClO$_2$. Körtvélyesi and Gordon (2004) demonstrated the significance of the Cl$_2$O$_4^-$ complex and reported the formation constant and the molar absorptivity of this complex. The authors suggested the use of one equation that could reduce the error of the determined ClO$_2$ concentrations to the level of errors associated with the spectrophotometric measurements.
DISINFECTION BYPRODUCTS

N-nitrosodimethylamine (NDMA) is an emerging DBP of concern from chlorine disinfection. A study showed that UV photolysis and advanced oxidation (UV/peroxide) was successful in NDMA destruction. Hydrogen peroxide addition improved NDMA removal efficiencies and reduces reformation potential after chlorination with free chlorine. Sunlight exposure was also effective in NDMA destruction (Soroushian et al., 2004). Samples from municipal wastewater treatment plants were collected to study the occurrence and fate of NDMA. The median concentration of NDMA in untreated wastewater was approximately 80ng/L, and the median concentration of NDMA prior to disinfection in secondary effluent was 46ng/L, and additional NDMA was formed by NDMA precursors after chloramines disinfection (Sedlak et al., 2004).

Chen and Lu (2004) studied the biodegradation differences of the natural organic matters of p-hydroxy-benzoic acid (PHBA) and 4-hydroxy-3-methoxy-benzoic acid (VA) utilizing a slow sand filter. The results showed a higher potential of DBPs formation with the PHBA than the VA. A comprehensive model to predict chlorine and ozone residual and DBP formation in raw and coagulated waters was developed and additional D/DBP simulation programs were evaluated. A model based on dissolved organic carbon parameters showed a strong correlation between measured and predicted THMs and haloacetic acid formation in raw waters. Predictions for coagulated waters can also be made. Ozone decay and bromate formation equations were also developed (Sohn et al., 2004).

Wastewater effluent organic matter characteristics were examined during subsurface wetland treatment. The wetland-treated waters exhibited higher aromaticity
and chlorine activity than effluent organic matter, and had the potential for higher yields of DBPs, including trihalomethanes upon chlorination (Quanrud et al., 2004). In a study to determine the best technique for DBP reduction while maintaining corrosion control in the distribution systems, air stripping, permanganate addition, and chloramination were found to reduce DPB concentrations below 20 parts per billion (ppb) and Stiles-Kem 7840 performed best to control lead and copper concentrations (Nnadi et al. 2004).

Cyanide levels have previously been found in WWTP effluents at levels higher than those found in the influent and are believed to be due to chlorination. Deeb et al. (2004) presented an overview of the WERF project, “Cyanide Formation and Fate in Complex Effluents and Its Relation to Water Quality Criteria”, focusing on analytical laboratory issues and discharge compliance strategies for cyanide-impacted wastewater.

The effect of biological nutrient removal on chlorination was studied. Effluent nitrogen species and their effect on chlorine dosage and total chlorine concentration were evaluated by examining nitrogen species concentrations resulting from nitrification/denitrification (Chandran et al., 2004).

Ozdemir and Dursun (2004) collected wastewater samples from the beginning of a discharge channel in Turkey to investigate THM removal. The THM concentrations decreased with increasing distance from the discharge point, and simple aeration was effective in chloroform removal. To study temporal and spatial variability of DBPs in a chloraminated distribution system, Pereira et al. (2004) demonstrated that a system can be sampled relatively simply to obtain the median concentrations of DBPs in the tap water of a large population served by a single supply.
DISTRIBUTION SYSTEMS/REGROWTH AND BIOFILM

In a study of various factors affecting the survival of Mycobacterium avium, nutrient levels of >50 µg/L assimilable organic carbon/L were found to support substantial biofilm growth, and biofilm levels were found to be higher on pipes composed of iron and galvanized surfaces as compared to copper or chlorinated polyvinyl chloride (PVC). Following chlorination, heterotrophic plate count levels decreased on all pipe surfaces except on iron surface (Norton et al., 2004). Recent tests of the occurrence of Aeromonas spp. in biofilms showed positive results of aeromonads isolated from a Modified Robbins Device in 3-10% of stainless steel and unplasticized PVC pipes in contact with simulated recycled wastewater (Bomo et al., 2004). Regrowth rates of various microorganisms of effluent from a WWTP in Spain treated by UV radiation or ozone, were studied and compared. Ozone was more effective than UV for the more resistant species. Clostridium sulfite-reducers and Pseudomonas aeruginosa exhibited significant regrowth over time, which was believed to be due to the presence of nutrients in the water (Alonso et al., 2004).

In a study to observe the effects of low free chlorine residual and addition of a carbon source on regrowth of coliform bacteria, coliform regrowth was observed at Cl residual doses lower than 0.07 mg/L and a 4-h hour incubation. Coliform bacteria regrowth was observed upon exposure to increasing C:N ratios from 1:40 to 11:40 (Rizzo et al., 2004). An assessment of biofilm formation was conducted at sampling points in a water-treatment plant in Germany, a municipal drinking-water distribution system, and at a surface-water embankment filtration site using PCR, denaturing gradient gel electrophoresis, and southern blot hybridization. The majority of the
organisms identified belonged to beta-Proteobacteria, and *saprophytic mycobacteria* and *legionellae* were detected in all biofilms of the distribution system. Following UV disinfection, *Pseudomonas aeruginosa* and facultative pathogenic mycobacteria were identified (Emtiazi et al., 2004).

A model was developed to characterize water nutrient status, as well as to predict behavior of indigenous bacteria. The model can predict bacterial population dynamics with respect to nutrients, which is beneficial for water treatment optimization and as a component of a dynamic water-quality model for distribution systems (Jegatheesan et al., 2004).

**BIOSOLIDS**

The regrowth of fecal coliforms of eight types of Class A biosolids was studied and was observed in two samples that were incubated at 35°C after 48 h. It was observed that fecal coliform regrowth was affected by anaerobic bacterial consortium presence; the final fecal coliform concentration exceeded $10^4$ /g in the undigested biosolids sample and remained below $10^3$ /g in the thermophilic biosolids sample (Jolis et al., 2004). A study conducted by Iranpour et al. (2004) also suggested that fecal coliforms are a poor indicator of pathogen content in biosolids after digestion due to their recurrence rate, whereas recurrence of Salmonella sp. was not observed. The dewatering centrifuge was suspected to be the location of fecal coliform recurrence originated. A study was conducted using limed sludge to determine the effect of heat and alkaline pH levels on the inactivation of Ascaris eggs. A negligible level of viable Ascaris eggs was observed in artificially contaminated milk of lime after 2 min at 60°C.
The inactivation threshold established in milk of lime was lower than that obtained in naturally contaminated sludge (Capizzi-Banas et al., 2004).

A closed alkaline system was utilized to treat municipal solids at each of two WWTPs in Louisiana, and the optimum disinfection conditions were studied. The data suggest greater enhanced pathogen inactivation with the closed alkaline system, with the inactivation of Ascaris enhanced from 50% to 99% in temperatures from 35°C to 55°C. In addition, the alkaline biosolids are being reused by both facilities (Fitzmorris et al., 2004). Lime treatment of sludge resulted in an increase of temperature and pH, while reducing the numbers of pathogenic organisms and heavy-metal contents and preventing leachate release. Use of this sludge as a soil conditioner caused a high heavy metal content in crops; however, stopping the sludge application for one following the continuous applications for four growing seasons dramatically reduced the heavy metal content in edible parts of plants (El-Naim et al., 2004). Gattie and Lewis (2004) provided an overview of the risks associated with sludge in land applications and the levels of disinfection required for pathogen destruction in the sludge. A recent public poll suggested that more than half of the poll participants desired a ban on land application of sludge.

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