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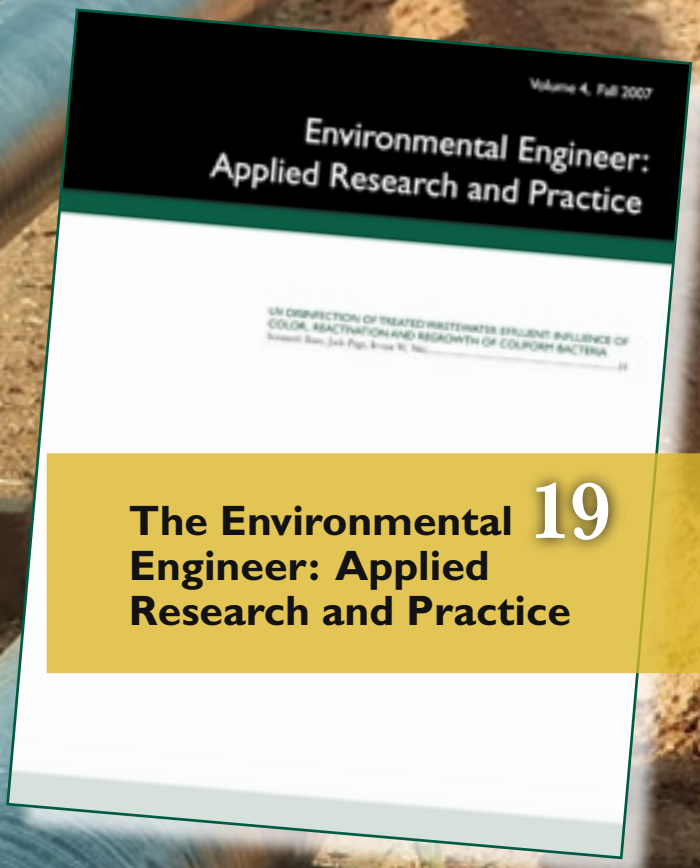

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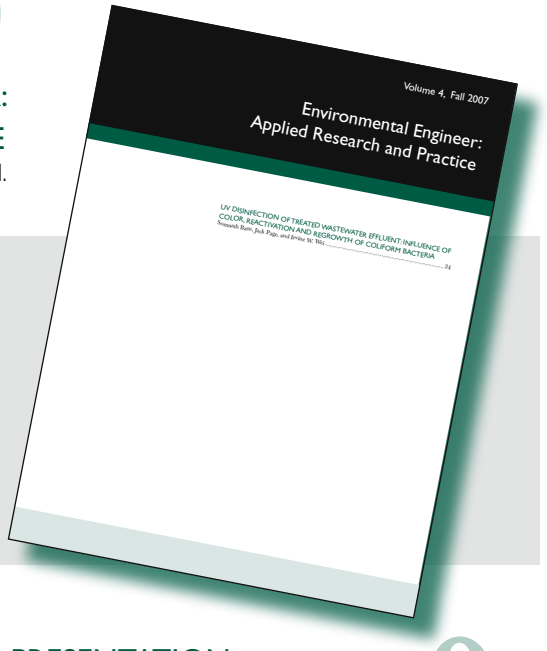

BY STEPHEN R. KELLOGG, P.E., BCEE

EXIT MESSAGE

A GREAT DEAL HAS BEEN ACCOMPLISHED OVER THE LAST YEAR AT THE AMERICAN ACADEMY OF ENVIRONMENTAL ENGINEERS AND MUCH REMAINS TO BE DONE. My commitment to the Academy in 2007 was to focus on a longer term vision that would give us a direction and a road map to achieve our mission. The Academy's Strategic Plan (see *The Academy's Strategic Plan* by Brian Flynn, P.E., BCEE, on page 10) has been launched and many hard working volunteers are making progress on the key 10 to 12 issues outlined, and identified by our membership as the major focal points for the next five years. These include significantly growing our membership, reaching out to younger potential members, increasing the Academy's profile, and working with our sponsoring organizations on workshops and technical conferences.

In my 20 years of leadership positions in the Academy, I have experienced very few years where so much has been accomplished by so many. We are tackling the major challenge of losing many of our members to retirement by working closely with the Association of Environmental Engineering and Science Professors (AEESP) to forge a link with potential student members. We have met with AEESP leadership and are now active in their conferences and interacting with their members. We have created a Student Membership category in AAEE, and will be encouraging graduates to follow a path leading to Board certification.

In keeping with development of a link with some Professors and other environmental engineers who, for various reasons, may have not obtained their Professional Engineering registration, the Academy has created a Board Certified Environmental Engineering Member category. All requirements, including testing, remain the same; however, we are welcoming non-PE professionals who meet our high standards. Outside of consulting, we recognize that many areas of our profession do not actively encourage registration. However, many of these qualified individuals are teaching environmental engineering students, running our public utilities nationwide, or involved in regulating environmental facilities. As environmental engineers, they belong in the Academy.

Financially, the Academy is healthier than it's been in more than a decade. Campaign 4000 to which many of you pledged support over three years (see *Donation/Pledge Form* on page 6), has helped provide the resources necessary to make improvements to our infrastructure to improve communications, upgrade systems, and implement the tools needed for us to support an Academy that will double in size over five years. As an example, in this year's budget Campaign 4000 has provided the resources to upgrade the Academy's server.

The Academy's Excellence in Environmental Engineering® Awards program continues to be a success. This year, AAEE E3 Award winners are automatically entered into an international competition through the International Water Association (IWA). Further, initial meetings have been held with the IWA to discuss expansion of Board Certification in Environmental Engineering to other countries. This effort will be continued over 2008 as our incoming President has been the lead person on this initiative.

On the consulting front, the core of the Academy's membership, I would like to acknowledge CDM's commitment to both membership recruitment and the outstanding support provided by the firm at our recent November Board of Trustees meeting. The time commitment to the Presidency of AAEE has been significant, and the accomplishments we achieved together could not have happened without the support of the firm. Many of our colleagues in other consulting firms are also making a commitment to encouraging Board Certification to satisfy the rising demand for BCEE's in our field. I challenge those with eligible candidates to do more to promote the credential of Board Certification.

I leave the Academy Presidency with a great deal of satisfaction regarding the vision that has been put in place. I look forward to serving on the Executive Committee as a Past President and supporting our new incoming President, Bill Dee, in continuing the momentum gained in 2007. Given the names of those who have historically served as President of this fine organization, I am humbled by the opportunity you have given me to serve in that role in 2007.

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2007 ANNUAL MEETING HIGHLIGHTS

The 2007 Annual Meeting of the Academy's Board of Trustees (BOT) was held November 2 at the Royal Sonesta in Cambridge, MA. The meeting was very well attended and much Academy business was discussed. Highlights of the meeting are as follows:

- 2007 Budget – Approved a Budget for 2007 that projects revenue of $524,950 and expenses of $522,786.
- New Board Certified Environmental Engineers – Approved 105 new BCEEs and four BCEEMs at the Annual Meeting. We would like to thank all of our members who take the time to recruit new applicants. Word of mouth and personal encouragement are still our best tools for recruiting new members.

NEW OFFICERS AND TRUSTEES

The new Officers and Trustees for 2008 were installed during the Annual Meeting November 2 and will take office January 1, 2008. The following were installed: William P. Dee, President, Debra R. Reinhart, President-Elect, Cecil Lue-Hing, Vice President, Christian Davies-Venn, Treasurer, and Stephen R. Kellogg, Past President. New Trustees Include: Pat Canzano will serve another three-year term representing AIChE, Richard Kuchenrither, representing WEF, Bob Baillod, Trustee-at-Large and Gary Logsdon, Trustee-at-Large.

2008 EXCELLENCE IN ENVIRONMENTAL ENGINEERING

The E3 Competition for 2008 electronic submittals are due February 1, 2008. Go to http://www.aaee.net for more information, entry materials, and profiles of past winning entries.

K-12 EDUCATION COMMITTEE CHAIR NEEDED

The Academy needs a member to volunteer to start and lead a new committee: K-12 Education. This committee is important to the Academy because of our basic educational mission and the need for environmental engineers in today's world. AAEE members who are employers of new environmental engineering graduates are competing for the few students who are graduating. The committee's goals are:

- To provide information to students in K-12 programs about the satisfaction of environmental engineering careers.
- Encourage college students to matriculate in Environmental Engineering through preparation of educational printed and web based materials and availability of speakers. If you are interested, please contact Larry Pencak, the Executive Director at LPencak@aaee.net.

UPCOMING MEETINGS

New England Water Environment Association will hold its Annual Conference and Exhibition January 27-30, 2008. Executive Director, Larry Pencak, AIChE Trustee, Pat Canzano, Past President, Jeanette Brown and BCEE, Stephen Seigal will participate in a session titled "The American Academy of Environmental Engineers proudly presents...and the Winner is YOU, the PROFESSION, and these 2007 AWARD WINNING Projects" on Monday afternoon, January 28 at the Marriott Copley Square Hotel. For registration information, go the NEWEA's website, www.newea.org.

New York Water Environment Association will hold its 80th Annual Meeting February 4 and 5 at the Marriott Marquis Hotel. The AAEE breakfast will be held at the hotel on Tuesday, February 5 at 7 a.m. As soon as registration information is available, it will be posted on our website.

Campaign 4000
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Thank you for your financial support in helping the AAEE sustain its continuing growth.

MEMBER NEWS

HOWARD O. ANDREWS, JR., P.E., BCEE, has become a Diplomate of AAWRE. Mr. Andrews is Senior Water Resoures Engineer with Black and Veatch Corporation. He has been certified in Water Supply and Wastewater Engineering since 2006.

THOMAS F. BLOOM, P.E., BCEE, has been elected to the 2008 ACGIH Nominating Committee. Mr. Bloom is currently an Industrial Safety Consultant with the Ohio Bureau of Workers Compensation. He has been certified in Industrial Hygiene since 1993.

CRAIG A. CLOSE, P.E., BCEE, has joined HDR as National Director of Management and Planning Services. Mr. Close has been certified in Water Supply and Wastewater Engineering since 2002.

JOSEPH F. MALINA, JR., PH.D., P.E., BCEE, has become a Diplomate of AAWRE. Dr. Malina is Professor of Environmental Engineering at the University of Texas-Austin. Dr. Malina is a Life Member and has been certified in Sanitary Engineering since 1972.

IN MEMORIAM

ALFRED E. PELOQUIN, P.E., BCEE, of Peoria, Arizona, passed away in 2005. He was an Emeritus Member and had been certified in Water Supply and Wastewater Engineering since 1979.

JOHN REDMOND, JR., P.E., BCEE, of Eugene, Oregon, has passed away. Mr. Redmond had been certified in Sanitary Engineering since 1956.

DONALD J. SCHLIESSMANN, P.E., BCEE, of Atlanta, Georgia, has passed away. Mr. Schliessmann had been certified in Sanitary Engineering since 1969.

ROBERT W. SEABLOOM, P.E., BCEE, of Tacoma, Washington, passed away in February 2007. Mr. Seabloom was an Emeritus Professor of Environmental Engineering at the University of Washington. Mr. Seabloom was a Life Member and had been certified in Water Supply and Wastewater Engineering since 1980.

LETTERS TO THE EDITOR

I AM AMAZED AT THE SILENCE OF THE ACADEMY ON THE SUBJECT OF CLIMATE CHANGE OR GLOBAL WARMING, perhaps the greatest challenge the Environmental Engineering profession has ever encountered. I don't think that this subject is any longer controversial. The evidence is all around us, and it matters little whether it is a natural phenomenon or of anthropogenic origin. Nor can we look for solution from what is commonly referred to as environmental science. This is an applied science or engineering problem.

The areas in which we can look for solutions are also generally agreed on. If we must stabilize or reduce carbon emissions, what role can coal, our most abundant source of energy, play. Is it possible to use coal to yield electrical energy in such a way as to not emit carbon? If you separate the carbon, is there any practical way to contain it? What is the future of nuclear power, fission or fusion? Can we do it safely, as a process? Is it susceptible to terrorist activity? Can we deal safely with the waste products of the process? What changes in life style are necessary to increase our efficiency of energy use, such as changing from single family houses to apartments, or in transportation to change from the private car to public transportation, to get trucks off the interstate and onto the railroads, or to electrify our railroads, the way it is done in every other industrialized country? Why are we so adverse to utilizing our wastes to recover the energy they represent? All these are questions that require the expertise of the environmental engineer.

I feel that part of the reason for our lack of interest is the absence of a clearly defined clientele. Projects to conserve energy are not likely to be profitable in the conventional sense. There is as yet no reliable price tag on the potential cost of global warming. Even if there were, the costs are likely to be "externalities", costs not borne by those in the decision process.

The time to do something may be getting short. There is now overwhelming evidence that world wide temperatures are rising at rates never seen before. Glaciers are receding, hurricanes are getting stronger, and forest fires are getting more extensive. It is high time for those most qualified to deal with these problems to get involved.

John L. Rose, P.E., DEE
East Chatham, New York

AAEE-NCEES Presentation

This year marks the 100th anniversary of engineering licensure in the United States. The National Council of Examiners for Engineering and Surveying (NCEES) is celebrating this milestone by recognizing the successes of licensure's past 100 years.

The American Academy of Environmental Engineers presented NCEES with an Academy Proclamation on the occasion of the NCEES celebration of the 100th anniversary of the first U.S. engineering licensure law and its importance in protecting the health, safety, and welfare of the public.

The AAEE is a member of the NCEES Participating Organization Liaison Council (POLC). The Academy's POLC representative, Joseph Earl Herndon, Jr., P.E., BCEE presented the proclamation to NCEES Executive Director Betsy Browne at the NCEES office in Clemson, SC. Executive Director Browne presented the Academy with a NCEES 100 Years of Licensure commemorative medallion.

Joseph Earl Herndon, Jr., P.E., BCEE, presented the AAEE proclamation to F. Elizabeth "Betsy" Browne, Executive Director of NCEES.

Betsy Browne presented the NCEES 100 Years of Licensure Commemorative medallion to AAEE.

The Academy's Strategic Plan

by Brian P. Flynn, P.E., BCEE, Chair, AAEE Planning Committee

You can't do something unless you know what it is! This obvious truth has led the Academy's Planning Committee and Board of Trustees to develop and approve a five year strategic plan. The plan kicks off on January 1, 2008. We need your enthusiasm and help to implement it. It will result in a stronger and more vibrant Academy.

BACKGROUND

The Academy is alive and well after surviving a financial crisis five years ago. The Academy has been growing from a low point of 1900 members to 2400. However, the Academy's finances do not allow any margin for error, nor allow for major new initiatives. The Academy is, first and foremost, a certifying organization. There are other activities that support this function-see Table 2.

A rough breakdown of our membership is approximately: Consulting ~ 67%, Government ~ 12%, Academia ~ 10%, Industry ~6%, and all others ~ 5%.

The Academy has a place for any environmental engineer to belong as a member. Membership Categories are listed in Table 1.

ACADEMY VISION AND MISSION

A twelve person Planning Committee was charged with developing a five year Strategic Plan for the Academy in mid-2006. The first thing that the Committee examined was the Academy's mission statement. We developed a new one that was bifurcated into a vision and mission:

TABLE 1
AAEE Membership Categories

Years of Experience	Possess a PE License	Does not Possess a PE License
<0	N/A	Individual Student member, Tau Chi Alpha Member, Student Chapter Member
0-4	N/A	Member
4-8	Member	Member
8+*	Board Certified Environmental Engineer (BCEE)** or Diplomate Environmental Engineer (DEE)	Board Certified Environmental Engineering Member (BCEEM)**

* An engineer can become certified without a written examination if the individual has at least 16 years of engineering experience.
** Includes individuals selected by eminence.

TABLE 2
Current Academy Activities

Annual certification application appraisal and examinations
Continuous upgrading and development of specialty certification exams.
Recognition of significant individual contributions to the field of Environmental Engineering via an individual awards program, and certification by emininence.
Annual Excellence in Environmental Engineering project competition and awards.
Quarterly publication of an in-house magazine.
Activities in support of student chapters.
Serves as the lead organization for ABET accreditation of academic Environmental Engineering programs.
Operation of an on-line job matching service.
Kappe Lecture series.

Vision: To become the acknowledged leader in improving the practice, elevating the standards and advancing the cause of environmental engineering and science.

Mission: The mission of the American Academy of Environmental Engineers is to continually improve and promote the practice of environmental engineering and science by providing specialty certification services, recognizing significant environmental engineering and science projects along with the contributions of talented professionals, participating in the accreditation of environmental engineering university programs, and educating members of the profession and the public.

All of this is done to ensure the public health, safety, and welfare enabling humankind to co-exist in harmony with nature.

Neither statement differs radically from the past.

PLAN GOALS

The committee developed a number of goals in support of the Academy's mission. The Committee used an Internet survey to obtain the memberships feelings on these goals. The survey found no "showstoppers" in the proposed goals of the Strategic Plan, and helped us provide better focus in some areas of the plan. (See the last issue of *Environmental Engineer*® for details of the survey) The resulting plan goals can be broken down roughly into membership enhancement and programmatic goals. See Table 3. The plan, which took a full year to develop, goes further than most strategic plans: it also provides some fairly detailed guidance on methods to achieve each goal in the plan. We will attempt to summarize the logic and operation of the plan as follows.

We would like to double the size of the Academy over the next five years. This is a very ambitious goal. Programmatic goals will support and reinforce this activity. More and better activities will make the Academy more attractive to potential members. Even if we double the size of the Academy, certified environmental engineers will account for only about 5% of practitioners in the United States and Canada. It will still be an elite professional group.

The Academy intends to educate those who select environmental engineers for consulting engagements on the merits of certification ("Would you have your GP do your open heart surgery?). We would also like to help members understand how to educate their employers and clients on the merits of certification. All of this will help our members maintain and expand their competitive edge in the marketplace.

TABLE 3
Strategic Planning Goals

Membership Enhancement
Double Size of the Academy
Develop Demand for Certified Environmental Engineers in the User Community
Significantly Increase the Academy's Profile in the Professional Community
Maintain Membership Retention
Improve Membership Diversity
Tau Chi Alpha Chapter Development
Programmatic Goals
Develop Alternate Sources of Funding
Start-up AAEE Workshops/Technical Conference
Educate K-12 and College Students on Environmental Engineering Careers
Startup of Environmental Engineering Foundation
Upgrade of the Environmental Engineer® Publication
Develop Input to College Programs and the Body of Knowledge (BOK)
Develop International Accreditation Programs

The Academy will be doing more to recruit student members, maintain our high rate of retention and improve our membership diversity. It is important that we actively recruit qualified candidates from groups currently underrepresented in the Academy.

With the exception of the ongoing Body of Knowledge program, all of the programmatic goals represent new initiatives. One of them (upgrade of the *Environmental Engineer*® magazine) has already occurred under the leadership of an aggressive Editorial Board. Just look at the back of this issue!

AAEE workshops will be developed in conjunction with our sponsoring organizations for use by members and non-members for satisfying PDH requirements. This is something that our members can use and at the same time support the Academy.

We are going to wrestle with the concept of international accreditation and develop a viable plan for expansion of membership overseas. The need is there. The world's largest environmental problems are located outside of the US and Canada.

The Academy is going to actively pursue new sources of funding including aggressive sale of this magazine on a subscription basis, web based seminars, fund raising activities (including the newly created Environmental Engineering Foundation) and anything else that makes sense given the Academy's mission.

There is not enough space here to adequately convey the rich detail of the Five Year Strategic Plan. If you would like a copy, simply email the Executive Director, Larry Pencak, at lpencak@aaee.net.

CALL TO ACTION

The Academy is gearing up to make this ambitious plan happen. The staff, along with an interested and committed membership will succeed. Initial indications are good: the Internet survey asked if the Members would like to work on any of the proposed goals. Fully 19% said yes (84 people) but on a related question, 142 members gave us their email address to serve as volunteers. This is a significant army of volunteers to organize. We are currently working on putting those members to work on Academy activities.

We look forward to the day when the Academy, 4800 strong, is recognized as a prime driver in the maintenance and enhancement of the practice of environmental engineering, such that potential members are clamoring to get in. These efforts will help ensure that our home remains healthy and environmentally secure for the benefit of its six and half billion citizens.

FARKAS & BERKOWITZ:

STATE OF THE INDUSTRY REPORT

Environmental And Infrastructure Engineering Firms Enjoy Robust Growth, As The Largest Firms Outpace Others

By Alan L. Farkas & Christopher S. Frangione

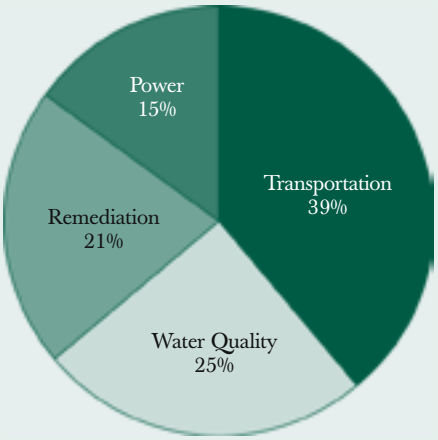
The U.S. environmental and infrastructure engineering market grew 12.4 percent in 2006, its highest growth rate in seven years. All major market segments enjoyed solid growth. Exhibit 1 shows the distribution of the infrastructure and environmental engineering market among the major market segments.

The top five to ten firms in each market segment grew considerably faster than their smaller competitors. As in years past, we calculate for each market how gross revenues from domestic and international projects are shared among three tiers: the top five firms, the next ten firms, and all other firms participating in the *ENR* Top 500 Design Firm Survey. This year we also calculated the growth rates for each tier. Because the market share statistics are based on both domestic and international revenues, the growth rates for each tier are not necessarily consistent with our estimate of the U.S. market growth rate.

In the transportation engineering market, the top 15 firms enjoyed an average growth rate of 14 percent versus just eight percent for firms too small to be counted among the top 15. In power engineering, the top five firms averaged a 55 percent rate of growth versus 33 percent for those in the third tier; in the water quality engineering segment, the top five averaged a 19 percent rate versus 11 percent for the third tier; and in the remediation consulting and engineering segment, the top five grew 13 percent versus only 2 percent for those in the third tier. Exhibit 2 shows details of growth rates by tier.

Part of the explanation for the faster growth rate among larger firms is their participation in international markets. The *ENR* survey shows that international revenue for U.S.-based firms grew faster than revenue from domestic projects. However, we believe that other more fundamental factors help to explain the faster growth rate among the largest firms in each market. First, market growth rates vary geographically, and the largest firms have systematically invested in those states and regions that are enjoying more rapid growth – states like California, Texas, and Florida. In industrial and federal markets, having a national and international presence is becoming an increasingly potent source of competitive advantage, one that only the largest firms enjoy. Finally, larger firms are better able to participate as members of design-build teams or as program management consultants. In every market, design-build and program management services are growing faster than engineering design services.

EXHIBIT 1
Distribution of the $24 Billion Market for Infrastructure and Environmental Engineering in 2006



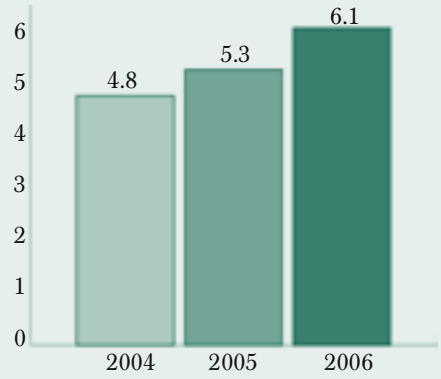
Source: Farkas Berkowitz & Company
Based on *ENR* Top 500 Design Firm Survey for 2006

EXHIBIT 2
Gross Revenue Growth Rate in 2006 of Firms Grouped by Size

Market Segment	2006 Growth Rate		
	Top 5 Firms	Next 10 Firms	All Other Firms
Transportation	11%	19%	8%
Power	55%	29%	33%
Water Quality	19%	13%	11%
Remediation	13%	10%	2%

Source: Farkas Berkowitz & Company
Based on *ENR* Top 500 Design Firm Survey for 2006

EXHIBIT 3
U.S. Water Quality Engineering Market
($ Billions)



Source: Farkas Berkowitz & Company
Net Revenues, Based on *ENR* Top 500 Design Firm Survey for 2006

WATER QUALITY ENGINEERING, DESIGN-BUILD, AND OPERATIONAL SERVICES

We estimate that the engineering market related to drinking water and wastewater treatment grew by 15 percent in 2006. This market now totals $6.1 billion (*see Exhibit 3*). The top five participants in this market were CH2M HILL, MWH, Tetra Tech, AECOM, and CDM.

2006 was the eighth consecutive year of double-digit or near double-digit growth in this market. Design-build, management advisory services, and water resources engineering are segments that are growing faster than the overall design market.

In the engineering realm, more work is being done on a fixed-price basis. Most of the leading firms are encouraging their municipal clients to use lump-sum contracts for design. When combined with the increasing use of design-build, fixed-price contracts represent close to 50 percent of revenue for some of the top firms.

Management advisory services are continuing to grow. These include program management and asset management – essentially helping municipalities to set their capital budgeting priorities. It also includes management consulting by helping the municipalities adopt best practices. The demographics are forcing municipalities of all sizes to outsource more management functions. The advances of information technology is one of the drivers of the growth of this management advisory service sector because the municipalities need help in understanding how to apply that information technology.

We think double-digit growth will continue. We are looking for 12 to 15 percent growth this year and next.

Design-builders enjoyed a great market in 2006. We saw the growth rate spurt up 25 percent in 2006 from a growth rate that we estimated at 10 percent last year. Speed of project completion seems to be the principal reason that municipalities are turning to design-build.

We estimate that the municipal water design-build market tops $1 billion. This is a gross revenue figure, and it includes the very substantial sums for construction subcontractors.

The top firms in this market are Black & Veatch, CDM, CH2M HILL, and MWH. We estimate they could represent as much as three quarters of the total market. We are seeing a seller's market leading to improved terms. So many opportunities exist that competitors can be much more selective. Where procurements have onerous terms and conditions, competitors increasingly elect not to bid. Some RFPs may not get any bids at all in today's overheated market.

The top five to ten firms in each market segment grew considerably faster than their smaller competitors.

Progressive design-build seems to be gaining favor. Progressive design-build is an approach where the municipality hires the designer, usually on a qualifications basis, to do a 30 percent design on a cost-plus-fixed-fee basis. Then on the basis of that 30 percent design, the parties will negotiate a firm fixed price for the remaining design work and for the construction. Where the parties cannot reach an acceptable price, the municipality always has the opportunity to go out and bid the construction conventionally.

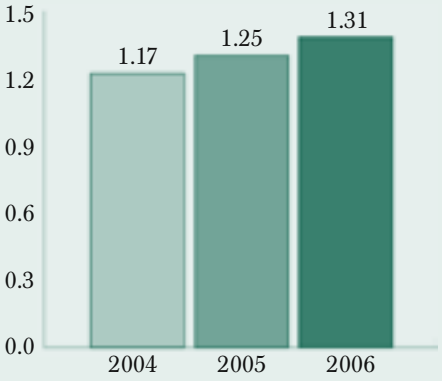
The advantage of the progressive design-build approach for the owner is that they have an opportunity to really influence the design, which they are accustomed to doing under traditional design-bid-build procurements. The advantage of this approach for the service provider is that they avoid the cost of doing some preliminary design to bid the job. Conventional design-build still has the largest market share, but this is an approach to design-build that we are seeing gaining pace in a wide variety of states.

More firms are looking to get their toes wet in the design-build market and for good reason – because we see a strong outlook. We are looking for a 15 to 20 percent growth rate this year and next.

We find another year of slow growth for public-private partnerships. The five percent growth we saw in 2006 was actually slower than the 8.5 percent growth we saw in 2005. The government operations and maintenance (O&M) market in the U.S. was $1.3 billion in 2006 (*see Exhibit 4*). This is a highly concentrated market; the top 6 account for 87 percent of the market. Veolia is number one with a 29 percent share; the next five are United Water, CH2M HILL through OMI, American Water, Severn Trent Services and Southwest Water.

The operators are certainly looking for growth drivers to improve their businesses. Some growth drivers potentially include public sector personnel shortages

EXHIBIT 4
Water Public-Private Partnership
O&M Market ($ Billions)



Source: Farkas Berkowitz & Company
Based on a survey conducted by *Public Works Financing*

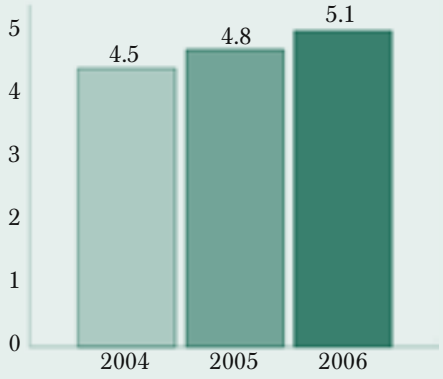
and ballooning employee benefit liabilities. But, we think the core business outlook remains unchanged, and that we are in for very slow growth.

REMEDIATION CONSULTING AND ENGINEERING

A strong industrial market enabled an overall growth rate of 6 percent to just over $5 billion in 2006 for the remediation consulting and engineering market (*see Exhibit 5*). For the past three years, this market decelerated in its growth rate; in 2004 there was 11 percent growth and in 2005 there was 8 percent growth. Undoubtedly this deceleration of growth is a function of the ever weakening federal market.

The top five firms in this category grew 13 percent. The top five firms include, URS, Bechtel, ERM, ARCADIS, and Parsons.

EXHIBIT 5
U.S. Remediation Consulting Market
($ Billions)



Source: Farkas Berkowitz & Company
Based on a survey conducted by *Public Works Financing*

In the broader industrial market, energy is leading the way. For several years, there has been an emergence of a two-tier structure for firms serving the industrial market. The top-tier firms have a national presence, and in some cases an international presence, serving the top of the Fortune 500; this is a group of probably six-to-eight firms. The second-tier firms serve more local and regional markets.

As mentioned, the top tier realized a 13 percent growth rate overall, for both remediation and environmental consulting. Remediation continues with very good growth; however, if the industrial piece of the market were broken out, the growth would most likely be somewhat over 10 percent. Guaranteed fixed-price remediation strengthened last year. This is work done on a fixed-price basis with an insured cap on costs and future liabilities. This work is most often done in the context of transactions or with brownfields.

FEDERAL MARKETS

Turning to Department of Defense (DOD) remediation, we find that spending declined for another year. We estimate that the DOD remediation market contracted last year by over 15 percent. This is the second year of a declining remediation market for DOD, and to a certain extent, the story line is much the same as it was in 2005. It is all about budget uncertainty and the war effort. Although the remediation account did receive appropriations eventually in 2005, the delay caused significant disruption. We saw the same story in 2006, with the appropriation bill being passed in fall of 2006. We did not see the appropriation bill for FY2007 pass until this February. That has created a lot of budgetary uncertainty, and the DOD is very careful about husbanding its resources.

More firms are looking to get their toes wet in the design-build market and for good reason — because we see a strong outlook. We are looking for a 15 to 20 percent growth rate this year and next.

The discretionary spending seems to be very low as the war effort in Afghanistan and Iraq siphons off most of the money.

We think the DOD remediation market could decline again in 2007. The first quarter in 2007 was weaker than even the weakest quarter of 2006. We look for this market to continue its decline.

Now let's turn to Base Realignment and Closure (BRAC) and military construction (MILCON). Last year, the BRAC plan had been put in place and had been accepted. We expected that even though the remediation market was weak, we would see dollars flowing from BRAC and MILCON, but here we are a year later, and we find ourselves with more questions than dollars. The lack of appropriations here slows spending. BRAC

The top-tier firms have a national presence, and in some cases an international presence, serving the top of the Fortune 500; this is a group of probably six-to-eight firms. The second-tier firms serve more local and regional markets.

in FY2006 and now in FY2007 has been operating under a continuing resolution. When you operate under a continuing resolution, it means you need to look back to the appropriations of 2005 for the ceiling on what you can spend.

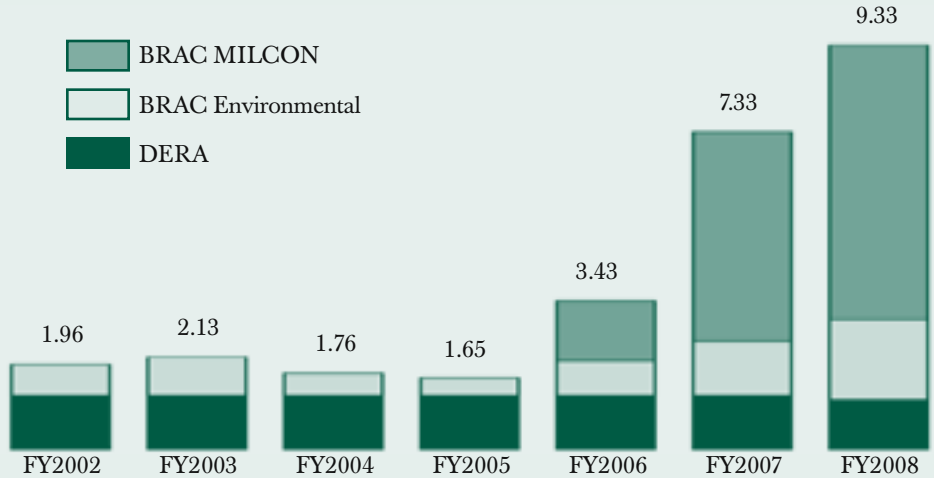
Certainly when we begin to see BRAC contract opportunities, vertical construction experience is going to be key. In the prior rounds of BRAC, it seemed that closure was the more significant element, and remediation skills were very important. In this fifth round, it is realignment that really is most important. Now what it is going to take to win these contracts will require not just vertical construction experience per se, but it will be extremely helpful for people to have on their teams, the architects and the contractors with whom the local base has experience working.

We think BRAC spending should spike in 2008 and 2009. It is unimaginable that Congress would decide to carry this program another year under a continuing resolution.

Authorization levels for BRAC and MILCON certainly presage a better future. Exhibit 6 shows the actual appropriations through 2005, while 2006, 2007, and 2008 are the requested amounts. Had those requests translated to appropriations, 2006 was practically 100 percent greater than 2005, and 2007 increases by 100 percent again. EPA's superfund program continues at approximately the same level over the last eight to ten years at $1.2 billion.

At DOE we find a flurry of procurements which test capacity. Delays are pushing some of the major contracting to 2007. We have final RFPs pending with three major contracts. In fact, we have seen the greatest number of opportunities since 1999.

EXHIBIT 6
BRAC and DERA Funding
($ Billions)



Source: Farkas Berkowitz & Company

ABOUT THE AUTHORS

Farkas Berkowitz & Company is a management consulting firm serving companies that provide design, construction, and operational services for government and industry. Established in 1983, the firm assists clients with strategy, mergers and acquisitions, and operations improvement. Inquires should be addressed to Chris Frangione at 202-833-7530 or frangione@farkasberkowitz.com or visit their website: www.farkasberkowitz.com.

AAEE Exhibits at WEFTEC'07

The Academy returned as an exhibitor to WEFTEC '07 in San Diego, Oct. 15-17.

Board of Trustee members Steve Graef (WEF Trustee), Mike Selna (Trustee-at-Large), and Sandra Tripp (Trustee-at-Large) led and coordinated the 3-day exhibit effort as well as recruited AAEE members to staff the booth.

The exhibit featured a drawing of a free application fee and a free exam fee which were won by two lucky drawing entrants. Activity at the booth was brisk with many interested WEFTEC attendees picking-up exam application packages and AAEE members stopping by to hear what's new at the Academy and renew acquaintances.

Top Row Left and Center
The AAEE Display Booth

Top Row Right (left to right)
Tom C. Fang, P.E., BCEE, Brian Villacorta, P.E., BCEE, Alan H. Vicory, Jr., P.E., BCEE

Far Left (left to right)
Donald G. Munksgaard, P.E., BCEE, Jon D. Ganz, P.E., BCEE, Michael Wang, P.E., BCEE

Left
Eric H. Snider, Ph.D., P.E., BCEE, greets fellow Academy-certified members.

Coming in the Winter issue of Environmental Engineer —

The Class of 2007, Kappe Lecturer 2008, Auditing Recertification Requirements, and the 2009 Officer Nominees.

Volume 4, Fall 2007

Environmental Engineer: Applied Research and Practice

APPLIED RESEARCH AND PRACTICE SECTION

Useful Peer Reviewed Papers Emphasizing Technical Real-World Detail

PURPOSE AND SCOPE

Environmental Engineer: Applied Research and Practice, is a peer-reviewed journal focused on practical research and useful case studies related to the multi-disciplinary field of environmental engineering. The journal strives to publish useful papers emphasizing technical, real-world detail. Practical reports, interesting designs and evaluations of engineering processes and systems are examples of appropriate topics. Papers relating to all environmental engineering specialties will be considered.

MANUSCRIPT REQUIREMENTS:

Manuscripts should follow the general requirements of the ASCE authors' guide (http://www.pubs.asce.org/authors/index.html#1) and should be submitted electronically in WORD format to the Editor and Assistant Editor.

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REVIEW PROCESS

All papers submitted to the journal are subject to critical peer review by three referees, who have special expertise in a particular subject. The Editor will have final authority over a paper's suitability for publication.

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Papers may be submitted in the following areas:

Applied Research

Original work presented with careful attention to objectives, experimental design, objective data analysis, and reference to the literature. Practical implications should be discussed.

Review

Broad coverage of an environmental engineering application or a related practice with critical summary of other investigators' or practitioners' work.

Practical Notes

Novel methods that the author(s) have found to be sufficiently successful and worth recommending.

Case Studies

Recently completed projects or studies in progress that emphasize novel approaches or significant results.

Design/Operation

Conceptual or physical design or operation of engineering systems based on new models or techniques.

Management

Papers describing novel approaches to problems in environmental management, or to the global, sustainability or business asects of environmental engineering.

ABSTRACT

An abstract of up to 200 words should be provided, including a statement of the problem, method of study, results, and conclusions. References, tables, and figures should not be cited in the abstract. Up to six key words or terms should be included for use by referencing sources.

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A letter of consent must accompany all photographs of persons in which the possibility of identification exists. It is not sufficient to cover the eyes to mask identity.

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UV DISINFECTION OF TREATED WASTEWATER EFFLUENT: INFLUENCE OF COLOR, REACTIVATION AND REGROWTH OF COLIFORM BACTERIA

Somnath Basu[1], Jack Page[2] and Irvine W. Wei[3]

ABSTRACT

Disinfection is a very important unit process to deactivate coliform bacteria in treated wastewater. However, regrowth potential of coliform bacteria raises human health and safety concerns associated with reuse of treated wastewater in various applications. Both post chlorination and post UV disinfection regrowth have been reported in the literature. In view of increasing use of recycled wastewater for reuse, it is necessary to address this phenomenon from both technical and regulatory standpoints. A case study of fecal coliform regrowth in a full scale operating plant is reported here. This is expected to aid in further understanding of the phenomenon and its causes so that proper technology may be selected on a case by case basis in the design of treatment plants. The results demonstrated that effectiveness of UV disinfection system is largely compromised by the presence of residual organics and color in the treated effluent.

INTRODUCTION

Ultraviolet (UV) disinfection has been increasingly finding applications in wastewater treatment plants. It avoids the two major disadvantages of using chlorine based disinfectants – i) the safety hazards associated with storage, transportation and handling of chlorine, and ii) the potential formation of disinfection byproducts. However, the UV disinfection process suffers from a serious disadvantage, e.g. reactivation and regrowth of bacteria.

UV radiation causes microbial damage by deactivation of cells. In very simple terms, this occurs because of the nature of energy absorption by DNA molecules, resulting in cell inactivation. When inactivated, the cells cannot replicate and infect a host. The spectral characteristics of various biological molecules demonstrate that the absorption of UV radiation maximizes in the region of $\lambda = 260$ nm (Jagger 1967). Because mercury emission spectrum peaks at $\lambda = 253.7$ nm, mercury lamps are ideally suited and widely used for commercial UV disinfection systems. Thymine groups in DNA strands are most active groups and are responsible for transcription and replication. The inactivation mechanism involves photocatalytic dimerization of two adjacent thymine monomers to two forms of dimers: cyclobutane thymine dimers and 6-4 photoproduct, as shown in Figure 1 (Matthews and van Holde 1990).

The extent of inactivation is a function of energy dosage in the form of UV radiation over the time of exposure, as expressed mathematically by the following relationships.

$$\frac{N_{to}}{N_o} = f(D), \text{ and}$$

$$D = \int_0^t I(t).dt$$

where:

N_{to} = Coliform count just after UV disinfection
N_o = Coliform count just before UV disinfection
D = Cumulative dosage of energy over the time of exposure to UV
I(t) = Intensity of radiation as a function of time

Both inactivation and cumulative dosage are maximized at a UV radiation wavelength of $\lambda = 254$ nm.

Regrowth of bacterial cells become pronounced when the cells are damaged, as opposed to being completely destroyed, due to the ability of the cells to repair the damage. Several studies of the regrowth and reactivation phenomenon have been reported in the literature as presented below.

The repair follows two possible pathways – photoreactivation and dark repair (Cairns, 1993). Photoreactivation is catalyzed by photolyaze enzyme in presence of visible light ($\lambda = 370$ nm). The energy of light photons (hv) splits the dimers, leading to reformation of the DNA molecules, as shown in Figure 2. Following repair they recover the ability to replicate and infect a host in a way similar to before the inactivation caused by UV.

Dark repair is much slower than photoreactivation. Three mechanisms of dark repair have been postulated: excision repair, recombinational repair and SOS-error prone repair (Brown, 1998). Excision is the dominant form of dark repair mechanism, where repair is done by physical incision (cutting out) of the dimer from damaged DNA strand by an enzyme complex. Thus it is removed and the DNA is repaired. The relative roles of these mechanisms in the regrowth phenomenon of specific cases are still unknown.

Hancock and Davis (1999) proposed an altogether different mechanism for regrowth. They observed that *daphnia* species, present in secondary clarifiers, ingested coliform bacteria and subsequently shielded the ingested bacteria from UV radiation

in the downstream disinfection process. Eventually, when the *daphnia* species die in the collected samples or downstream from the disinfection process, those bacteria are released and able to regrow.

As part of a comprehensive study on treated wastewater effluent disinfection efficacy by commonly used agents, e.g. UV radiation and chlorination/dechlorination, Gong (2002) examined the regrowth of fecal coliform and total bacterial count at four North American treatment plants in Lafayette, IN; West Lafayette, IN; St. Petersburg, FL; and Tampa, FL. At the three plants, excepting West Lafayette's, the author observed rapid increases in FC concentration, and the FC to Total Bacteria ratio between 24 and 48 hrs after UV disinfection, when compared with the numbers just after the application of UV radiation. However, the growth rate gradually dropped off after 72 hours through 144 hours. Interestingly, the results at the West Lafayette facility indicated a total destruction of FC population within the first 24 hrs after application of UV disinfection, with no subsequent return. The total bacteria count, in this case, did increase and eventually dropped off to the level achieved just after the application of UV radiation.

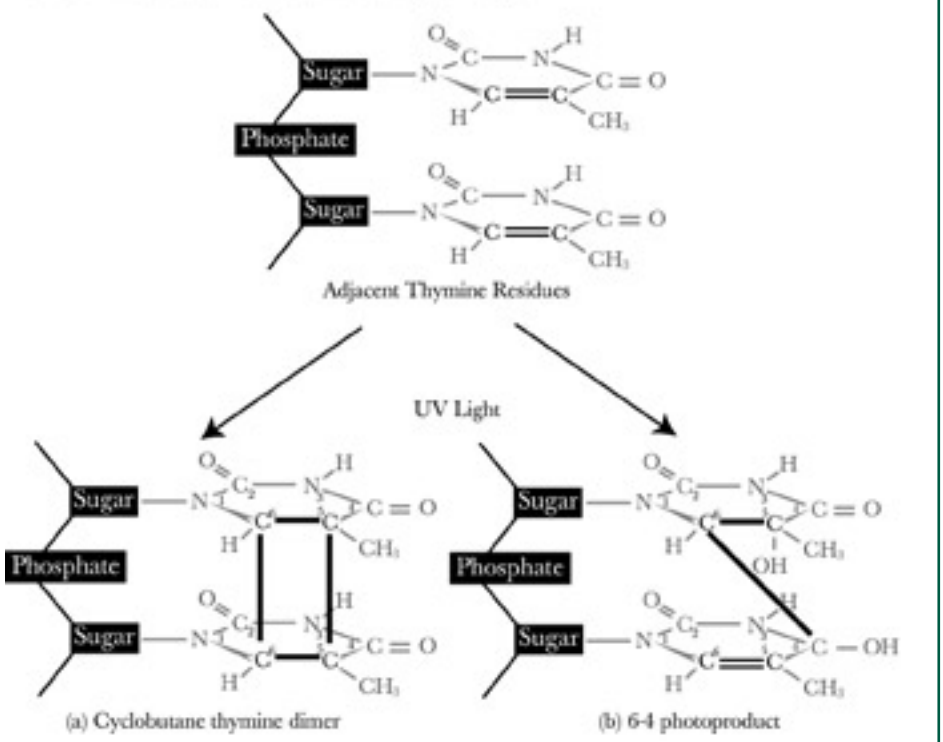
In 1995 Anjou Recherche of Maisons-Laffitte, France, conducted a study sponsored by the Compagnie Generale des Eaux on the post UV population dynamics of thermotolerant coliforms (TTC) and fecal streptococci (FS) bacteria. The results (Baron 1997) did not indicate any growth in samples collected from the treated effluent upstream of UV treatment for both TTC and FS. The TTC concentrations (colony count/100 mL) gradually decreased over time, with 90% reduction occurring between 15 and 40 hours. However, the post UV treatment population multiplied with time by the repair mechanism. The investigators monitored the growth with the help of a parameter called Repair Rate (RR) = $(Np_r - Nt_o)/(N_o - Nt_o)$, where N_o = bacteria count before UV dose, Nt_o = bacteria count immediately after UV radiation, and Np_r = bacteria count after several hours of incubation time following the UV irradiation, all measured in terms of MPN/100 mL. They observed that for both TTC and streptococcuii the repair rate was at its maximum when the dosage of the applied UV radiation was 40 mJ/cm^2. However, it diminished significantly as the dosage was increased to 50 and 60 mJ/cm^2. At the dosage of 40 mJ/cm^2 the TTC repair rate increased with time until 24 hours after UV irradiation, after which the RR values declined. In case of streptococci, the value of RR value rose till 2 hours of post UV irradiation, after which the RR values decreased.

In a similar study conducted by Lindenauer and Darby (1994) at the University of California, Davis wastewater treatment plant the results suggested a strong inverse relationship between the UV dose and the extent of photoreactivation. High TSS in the effluent also affected proper penetration of UV, thus impeding its reach to the target organisms and creating a condition favorable for regrowth. They concluded that regrowth is a significant phenomenon and conditions discouraging it should be a part of the design strategy.

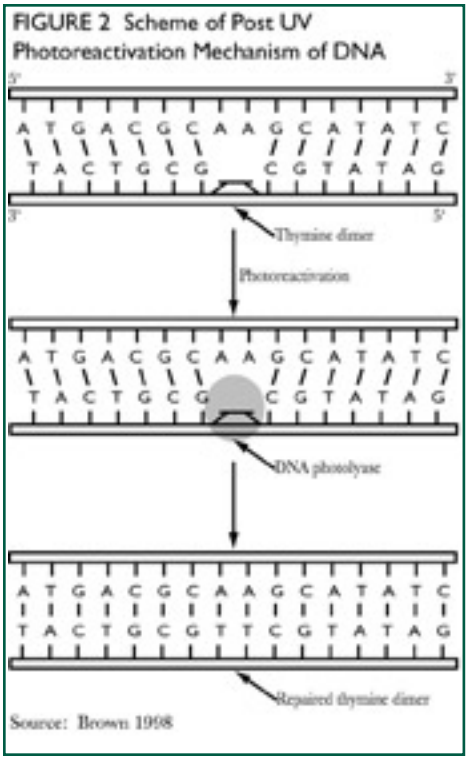
Tosa and Hirata (1999) used the strains of enterohemorrhagic *E coli* (EHEC) O26 and O157:H7 as the indicator organisms to investigate the effect of UV light and post UV reactivation potential on these isolated strains. They observed photoreactivation of EHEC O26, but not EHEC O157:O7 by visible fluorescent light. They concluded that the organisms that respond to photoreactivation require 2.2 times as much UV dosage to achieve 90% inactivation compared to those which do not photoreactivate. Therefore, for treated wastewaters which are discharged to a natural body of water and are exposed to visible light, an increased UV dose must be considered during the design stage in order to effectively compensate for the effect of photoreactivation.

Kruithof, et al (1992) reviewed the reactivation potential of UV disinfected water and wastewater from the data collected from over 1500 waterworks in Switzerland, Austria, Norway and the Netherlands. Many of these did not use any post UV residual disinfectant. He reported that these plants consistently supplied safe drinking water by destroying E coli and Aeromonas bacteria and decreasing total colony counts even at a low dosing intensity of 20 mJ/cm^2, depending upon the age of the lamps, quality of water, flow rate, etc., as long as the water does not contain nutrients to support growth.

FIGURE 1 Inactivation of Microbial Cells by UV Light



Source: Matthews and van Holde 1990



Drescher (1999) reported the fate of microbial population over ten days from a study conducted in South Africa on a post UV disinfected mixture of treated wastewater and tap water. The mixture, which originally had a few thousand colonies of various types of bacteria, showed only 2 colonies of E. coli/100 mL of sample on the first day after UV disinfection. The total colony count exhibited an overall growth with time, which became rapid for the last three days before the population started to die off as a result of limiting nutrient. This indicates that the residual BOD in treated and disinfected wastewater supports regrowth of bacterial population under favorable environmental conditions. On the contrary, disinfected drinking water does not offer that opportunity because of the absence of carbonaceous substrates to support metabolic activities leading to growth.

Based on the results of a collaborative study conducted by USEPA, Wisconsin State Laboratory of Hygiene and the DynCorp Biology Studies Group, Alexandria, VA, on surface water, Pope, et al. (2003) concluded that "most E. coli samples analyzed by the common methods can be analyzed beyond 8 h after sample collection while still generating comparable E. coli data (meaning that the E coli data just after sample collection and eight hours after samples collection were similar), provided that the samples are held below 10°C and are not allowed to freeze. Notwithstanding this conclusion, to ensure that the most accurate data are generated, E. coli samples collected from surface waters should always be analyzed as soon as possible and within 8 h when on-site facilities are available or when a qualified laboratory is within driving distance".

The results of the recent research on the subject, as above, can be summarized as follows:

1. Regrowth of fecal coliform after UV disinfection is a real concern in treatment plants.
2. Presence of residual organic substrate in the treated effluent supports regrowth;
3. Increased temperatures and sample holding time accelerate the rate of regrowth.
4. In a preserved sample, the population regrowth progresses with time as long as substrate and other environmental conditions are favorable, but eventually dies off, typically between 24 and 48 hrs of incubation, due to substrate limitation.
5. Photoreactivation diminishes with the dosage of radiation. Within the specified range of dosage (40 to 60 mJ/cm^2), it may be an issue at the lower limit, but reduces drastically beyond 50 mJ/cm^2.
6. Reactivation is rather insignificant at UV doses typically used in wastewater treatment (25-35 mJ/cm^2), however, if the unit is malfunctioning or the transmittance of the water is poor (< 70%) and if the delivered UV dose is < 5 mJ/cm^2, then reactivation is a strong possibility.

This paper reports the experience gained from the full scale operation of the UV disinfection system at a wastewater treatment plant in the US midwest. This study was undertaken to investigate the reasons behind chronic failure of the plant to meet the fecal coliform requirement in the discharge. The purpose of this paper is to demonstrate the weakness of UV as a disinfection process if prior consideration is not given to the wastewater matrix.

METHODOLOGY

A. The Test Site

This study was conducted at an operating wastewater treatment plant of 7.57 MLD (million liters/day) capacity. It treats a combination of domestic and industrial wastes by primary and activated sludge processes. The industrial contribution forms the major component of the influent to the plant, varying in the range of 55 to 65% of the total flow. The wastes disposed by a meat processing facility accounts for 99% of the industrial waste The flow, composition and pH of the industrial wastewater are first equalized in an equalization tank. The equalized waste is screened to remove large solid objects and then is sent to a dissolved air floatation (DAF) clarifier. The domestic waste is screened as it enters the treatment plant, pumped to combine with the aqueous phase from the DAF, and then routed to secondary treatment by activated sludge process.

The secondary treatment consists of two parallel trains, each containing a selector tank, an oxidation ditch and a clarifier to achieve BOD removal and nitrification. The selector tank is intended to maintain a healthy population of biomass, which is difficult because of uncontrolled release of cleaning and sanitizing chemicals in the night shift and large concentrations of brine present in the industrial waste during the day. The concentration of sodium chloride in the combined wastewater frequently exceeded 2,000 mg/L. These conditions used to give rise to extreme settling problems, leading to occasional washout of sludge. However, this situation improved significantly as a result of reductions in the disposal of brine by the industry. The clarified effluent is disinfected by UV system before final disposal of the treated waste. Discharge requirements are: BOD < 30 mg/L, TSS < 30 mg/L, Ammonia < 10 mg/L, and Fecal Coliform < 200/100 mL April through October, and < 2000 November through March.

B. UV System Details

The details of the UV system at the treatment plant are specified in Table 1.

C. Sampling and Analysis

A sampling and analysis program was undertaken to investigate the effectiveness of UV disinfection system in the light of

frequent violation of Fecal coliform limit of the final effluent. The program was conducted in two phases. In the first phase sampling and analyses were performed only for the determination effluent fecal coliform to a limited extent to ensure that all the testing protocols were properly followed as per Standard Methods (1998) and the frequent failures to meet the FC count were not attributable to the differences in analytical protocol. The analytical methods followed in this study were – SM 5210 B, SM 5220 C and SM 9222 D for BOD, COD and Fecal Coliform, respectively. Transmittance was checked by vendor supplied instrument.

The second phase was more extensive than the first, and was conducted for two months in the summer of 2004. Twenty-four hour composite samples were withdrawn from the industrial and sanitary influent streams for BOD and COD analyses. UV transmittance values were measured on grab samples upstream and downstream of the disinfection system. Finally, FC counts were measured on grab samples taken from the DAF effluent and upstream and downstream of the UV.

The fecal coliform (FC) test results from in house and commercial laboratories differed significantly. The in-house laboratory and all the outside commercial laboratories were certified by the state for FC tests. To handle the routine analytical load for regulatory and process control purposes, the plant uses several outside laboratories on contract, which are also certified by the state. On most occasions, the FC count results obtained from the contract laboratories were higher than those from the in-house laboratory by several orders of magnitude. This led to reliable analyses for FC count on only a limited number of samples collected under controlled conditions under the Phase 1 program. Some of the outside laboratories are located quite far from the plant location and samples for analyses by such laboratories were preserved and shipped following the protocol defined by the Standard Methods (1998).

TABLE 1 Specifications of the UV Disinfection System

Lamp Length, ft	6
Power Input/lamp	65 watts @ 425 mA
Power Output/lamp	26.7 watts, 190 μw/cm^2 (intensity of radiation in air 1 m away from each lamp = 190 microwatts/cm^2)
Number of Lamps / Module (Rack)	8
Number of Modules (Rack)/ Bank	13
Number of Lamps/Bank	104
# Banks / Channel	2 (both operated all the time)
# Channels	1
Effluent Flow Rate, MLD	7.5
Design UV Intensity, watts/gal	12.6
Effective Channel Volume, Liters	4,374
Hydraulic Retention Time in UV Channel, seconds	50
Dosing Intensity, Joules/Liter	64

TABLE 2 Example of Differences in the Results of FC Tests on Treated and Disinfected Effluent between In-house and Contract Laboratories

	In-house Laboratory	Contract Lab 1	Contract Lab 2
FC Count/100 mL	93	1,100	33,000
Time between Sampling and Analysis	4 hrs and 15 minutes	4 hrs and 40 minutes	21 hrs and 50 minutes

TABLE 3 Phase I Results of Fecal Coliform Test on Standard Samples

Sample	Known Standard Samples from Contract Lab 3	In-house Lab Test Results	Contract Lab 1 Test Results
Standard A: FC Count/100 mL	26 (5 to 26 Acceptable Limit)	28	Non Detect (Detection Limit 100 Colonies)
Standard B: FC Count/100 mL	<1 (5 to 26 Acceptable Limit)	24	Non Detect (Detection Limit 100 Colonies)
Time between. Sampling and Analyses	N/A	40 minutes	4 Hours 30 Minutes

Note: ND = Non Detect

RESULTS AND DISCUSSIONS

There were consistently wide variations in the treated effluent FC count results from various contract laboratories and those from the plant in-house laboratory. An example of this is presented in Table 2 for a split sample of the treated and disinfected waste analyzed at the in-house laboratory and contract laboratories no. 1 and 2. The plant verified that the in house Quality Assurance (QA) procedure was the same as that followed by the contract laboratories and confirmed that the in-house laboratory followed the correct protocol for the test.

The Phase 1 sampling and analytical program consisted of analyzing three sets of samples for FC count. To investigate the reasons for the disparity in the test results, the plant obtained a set of known standard FC samples from laboratory 3 (a third outside, contract lab), split them into several parts, prepared them for shipping, and hand carried them to Contract Laboratory 1. These standards were also analyzed by the in-house laboratory. The results (Table 3) on the standards between the in-house laboratory and Contract Laboratory 1 were within an acceptable range. This confirmed that the in-house lab testing procedure, and the sample collection, handling and shipping practices for tests to be conducted by outside commercial labs were in accordance with the Federal and State regulatory requirements. However, it is unclear why the results between the in-house lab and Contract lab 1 in Table 2 were ten fold different for the difference of time of analysis by only 25 minutes. This difference is not within the limits of error due to uncertainty of experimental results. A possible reason for such a large difference is the exposure of

the sample to warmer, ambient temperature during shipment and handling of the sample in transit to Contract lab 1.

At this point the Phase 2 sampling and analytical program was undertaken to investigate the potential for post disinfection coliform regrowth and redevelopment. All the analyses during this phase were conducted by Contract Laboratory 1 with the preservation, shipping and handling done strictly following the Standard Methods protocol. The UV lamps and the quartz sleeves were replaced with new ones before the start of this phase of testing. The details of the findings from these programs are presented in the next section.

i) BOD and COD

Samples of the industrial and sanitary influent streams were analyzed for COD and BOD values. The results from Contract Laboratory 1 for the industrial stream are shown in Figure 3. These data indicate that the COD/BOD ratio for the industrial influent was around 4. Additional data (not shown) indicated that the COD/BOD ratio for the sanitary stream was about 6 and that the COD/BOD ratio for the treated effluent before UV disinfection was around 25. Generally, the COD/BOD ratio for untreated wastewater range from 1.25 to 3.33, and that for treated effluent is between 3.33 and 10 (Metcalf & Eddy 2003). The high COD/BOD ratio for the treated effluent suggests that, because of the presence of chemicals, a good part of the industrial influent COD is not biodegradable at this plant. The plant, however, routinely fulfills the discharge BOD requirements, as the indicator of the organic matter in the treated effluent. The plant was originally designed for a food to microorganism ratio of 0.17 day^{-1} based upon BOD and MLVSS, and at the time of this study the average operating ratio was observed quite close to the design.

ii) UV Transmittance

The percent transmittance results on the samples of the final effluent at $\lambda = 254$ nm were only 8 to 17% before UV, and 9 to 15% after UV. These values were far below the 65% recommended by UV lamp vendors for the disinfection of treated wastewater. This is because of the color associated with the industrial waste. The compounds responsible for the color are not well removed by biological treatment, and

FIGURE 3 COD (mg/L) and BOD (mg/L) Profiles of the Industrial Influent to the Plant

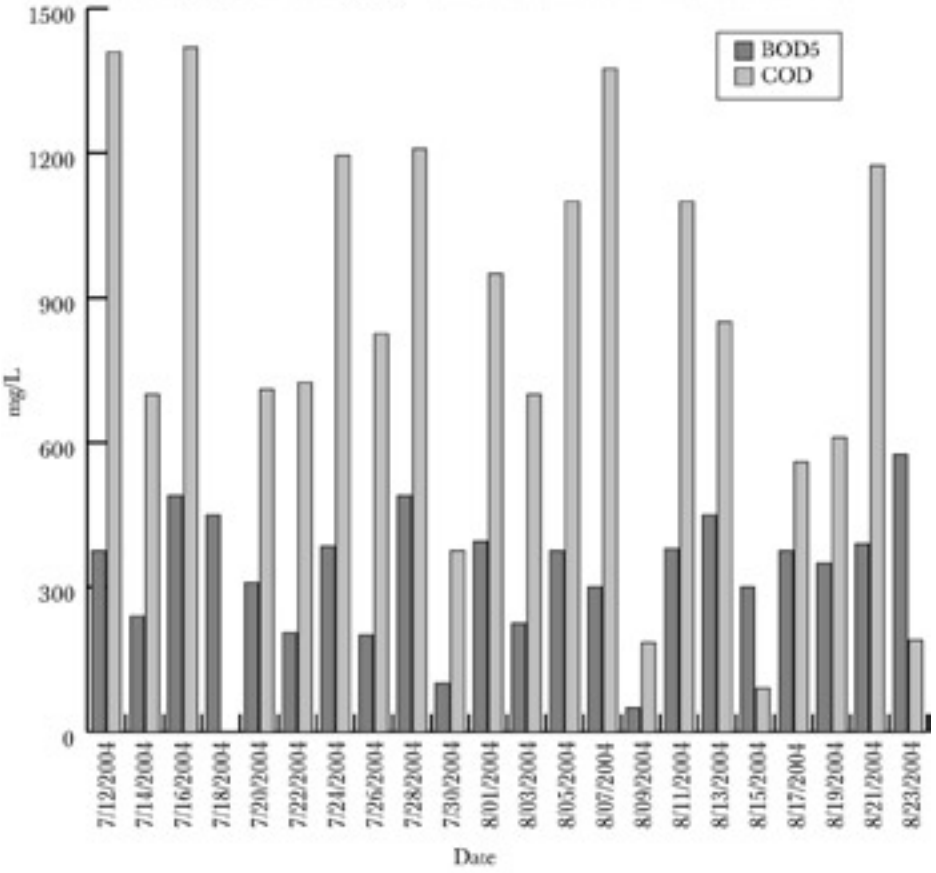
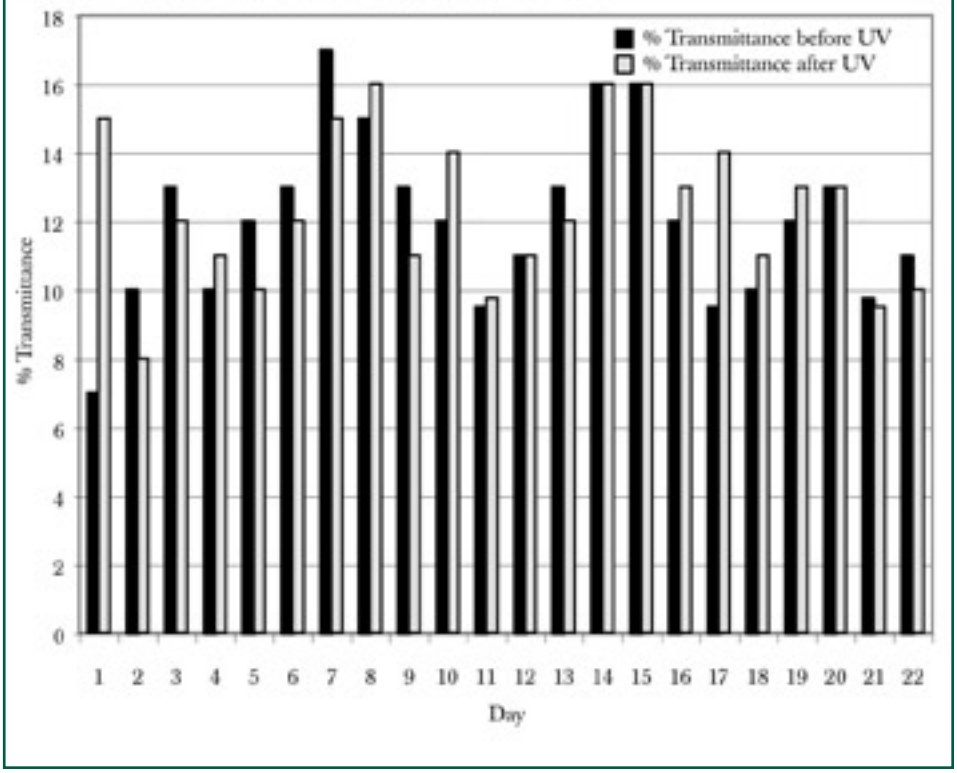


FIGURE 4 Treated Effluent Transmittance Before and After UV



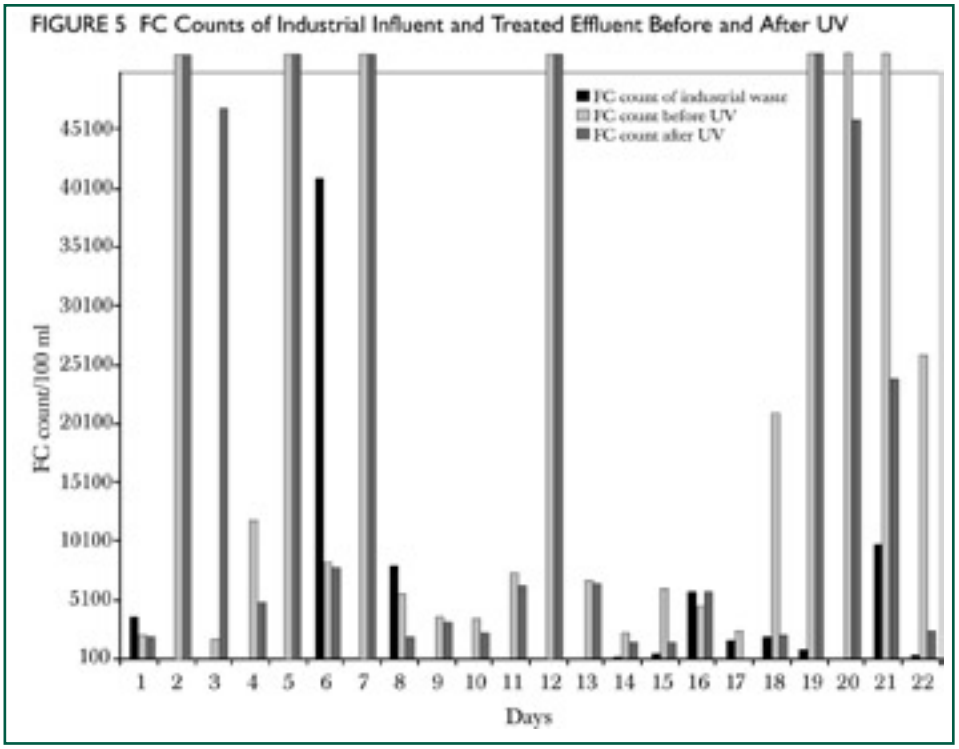


FIGURE 5 FC Counts of Industrial Influent and Treated Effluent Before and After UV

absorb UV light impeding its penetration through the water. This interferes with the effectiveness of UV disinfection. Figure 4 shows very little differences between the % Transmittance values of the treated effluent before and after the UV radiation.

iii) Fecal Coliform Count

Figure 5 demonstrates the variations in FC count through the treatment plant. It may be observed that the FC count for the industrial influent was very low for several of the days. The FC counts for the combined industrial/sanitary influent (not shown) were higher as expected.

Fecal Coliform concentrations in the effluent before disinfection were also high. Although a decrease in the coliform counts after UV treatment was observed for most of the days of monitoring, the results did not appear to be consistent, and the effluent standard was not met.. These results illustrate the inadequacy of the UV disinfection process at this plant. It is believed that reactivation and regrowth during the holding times between sample collection and analysis contributed to the high FC concentrations after disinfection.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Based on the plant data and the results from the test program it is concluded that the excursions in the FC results in the past were due to the following possible reasons despite the fact that the plant followed all the protocols for sample collection, handling, shipping and analysis.

1. Poor effectiveness of UV disinfection systems due to the presence of colored chemicals that absorb light and hinder its penetration into the effluent stream, leading to partial injury, as opposed to death of the microorganisms;
2. In the light of the findings reported by Darby (1999), the poor effectiveness of UV disinfection may also result from the shielding effect provided by larger particles in the effluent in protecting coliform bacteria associated with those. However, the exact cause could not be determined for lack of supporting data; and
3. Large holding times between sample collection at the plant and its analyses in the commercial labs.

In summary, the effectiveness of the UV disinfection system was adversely affected at this plant because of inconsistent and insufficient effectiveness caused by the presence of color from the colloidal and particulate matter in the waste that were not sufficiently removed by the treatment process. The situation was further magnified by the coliform regrowth phenomenon.

The presence of large amounts of organic chemicals in the form of untreated COD may also have served as a substrate for regrowth of the microorganisms after their reactivation following the well documented mechanisms, although there are no such experimental data to support such a statement.

This study reveals the limitation of the state-of-the-art UV disinfection process and the limitations of existing methods to evaluate disinfection performance. Large variability in the final results is possible even after strict adherence to the sampling and analytical protocol. A thorough understanding of the post disinfection regrowth phenomenon and its impact on the regulatory compliance by a treatment is necessary.

The City has decided to change the disinfection process from the existing UV treatment to chlorination/dechlorination. Microorganisms that have been inactivated by chlorination cannot undergo photoreactivation, the major repair mechanism of damaged cells by UV radiation, but post disinfection regrowth, following alternate pathways, has been reported in the literature when chlorination/dechlorination is used (Gong, 2002). One other major drawback of chlorination is the formation of disinfection byproducts (DBPs), many of which have been identified as carcinogens. Presence of large quantities of various untreated organic chemicals in the effluent will give rise to chlorinated organics after disinfection. This may be detrimental to the aquatic organisms. Therefore, regardless of the type of disinfection, UV or chlorination/dechlorination, it is advisable to remove the untreated COD from the wastewater after biotreatment, before it is subjected to disinfection. An advanced chemical oxidation process may be utilized for this purpose.

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