IUVA's First Steering Committee, April 25, 1999

(1-r) Norm Ammerer, Sylvester Hsu, Keith Carns, Bryan Townsend (back), Jen Clancy, Rip Rice, Tom Marshall, Rob Abermuthy, Jim Malley, Jim Bolton, Karl Linden. unavailable: Andreas Kolch, Bob LaFrenz, Alex Mofidi (cameraman)

Story on Page 5
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Factors Influencing Ultraviolet Disinfection Performance Part 1: Light Penetration to Wastewater Particles

Frank J. Loge, Robert W. Emerick, Donald E. Thompson, Douglas C. Nelson, Jeannie L. Darby


Abstract: A technique is described for measuring UV absorbance and internal scattering characteristics of wastewater solids. Wastewater solids developed as part of trickling filter and activated-sludge processes were observed to be strictly absorbing, with light attenuation following the Beer-Lambert law. Absorbance of solids ranged from 3300 to 569,000 cm⁻¹. Although absorbance was found to vary with treatment process type, even the lowest measured value is sufficient to block transmission of UV light to solid material. It is unlikely that wastewater treatment processes can be tailored to allow light transmission to solid material. Extremely high absorbance observed indicates that UV light can only penetrate particles because of high particle porosity, not by transmission through solid material. Also, regions exist within some particles that completely block applied UV light. Longer wavelength UV light was not observed to penetrate particles better than lower wavelength UV light.
What convinced me to move forward despite these reservations is rather simple – I have always wanted to help people and I believe in my heart and soul that the use of UV Technology will improve public health. Further, I believe it will take a focused organization like IUVA to help UV Technology to achieve its full potential.

My vision for the IUVA is that of a broad-based, multi-disciplinary association of professionals from around the world who share common interests in advancing the scientific and engineering understanding of UV light and technology. UV light is studied and applied by a diverse array of professionals from atmospheric chemists who are concerned with ozone layer depletion and global warming to environmental scientists and engineers who are concerned with hazardous waste treatment and/or the disinfection of wastewater, drinking water and water for reuse. One can find tremendous knowledge and expertise related to UV light and UV technologies spread throughout the world in UV equipment manufacturing firms, universities, consulting firms, research institutes and regulatory agencies. Yet these groups have never had an organized and dedicated forum through which to share ideas and plan collaborative projects. IUVA will provide this forum for the benefit of all.

With this inaugural issue of UV NEWS we move forward with the work of the IUVA. Soon to follow UV NEWS will be an IUVA Web site and plans are underway for holding the first World Congress on Ultraviolet Light. I hope you will join us at IUVA in our efforts to make a difference.

Sincere regards, and best wishes for the rapid and successful establishment of this fledgling organization

James P. Malley, Jr., Ph.D.
Chairman, IUVA Steering Committee

Why Start an IUVA?

Dr. James P. Malley, Jr.
Chairman, IUVA Steering Committee

My Dear Associates:

This is the question I have been pondering for several months. My name is Jim Malley, and it is both a pleasure and a privilege to write to you today. Some readers may know me but most will not. As a brief introduction, I am an Associate Professor in Civil Engineering at the University of New Hampshire (UNH), Durham, New Hampshire, USA, and the study of UV light for drinking water disinfection has been a passion of mine since my first AWWARF grant in 1992. On the personal side, I tend to express my feelings and my opinions bluntly and I am driven by my love for my family, my faith, my students and the fate of the NY Yankees and the NY Giants (the particular order of importance of these may vary on any given day ;+). Before agreeing to chair the Steering Committee for the formation of an International UltraViolet Association (IUVA), I thought long and hard about many issues and reflected upon comments made by associates whom I hold in the highest regard. Some of the more colorful comments were jabs like "are you trying to start a retirement fund for Rip Rice and Jim Bolton" or "is this a way to finally satiate Malley’s ego?" These were fun to contemplate but rather absurd upon close examination (new, fledgling associations can’t effectively fund anyone’s retirement and actually, it’s impossible to satiate my ego ;+). However, several other comments carried significantly more weight with me such as “do we need another interesting association with more interesting conferences to go to”. Lastly, my thoughts kept returning to one question: How could I justify to my loving family (Joyce, Brian and Shannon) and to my trusting UNH students the hundreds (or maybe even thousands) of hours I was going to steal from them? Hours I would need to devote as a volunteer to the IUVA over the next several years to help lead the association to the place I believe it deserves to be.
Meet Your IUVA Steering Committee

At the April 28, 1999 "IUVA Pre-Formation Meeting", a Steering Committee of interested persons was created to define IUVA organizational issues — such as all those little things that must be done to make sure the organization is legal, has acceptable by-laws, has an organizational structure, has people involved and has developed an agenda for growth and activities.

Many of the original 12-person Steering Committee of April 28 are shown in the cover page photo. However, by the time that picture was made, a few committee members had left to catch early planes. Since then, your IUVA Steering Committee has grown to the following 23 members, listed alphabetically. Countries of members are given, except for those in the USA.

Rob Abernethy — Calgon Carbon (Canada)
Norman Ammerer — Ozonia North America
Jim Bolton — Bolton Photosciences (Canada) (ex officio)
Andrew Campbell — DYNALAS (Norway)
Keith Carns — EPRVCEC
Jen Clancy — Clancy Environmental Consultants
Bob Cushing — Carollo Engineers
Oluf Hoyer — Wahnbachtsperrenverband and DVGW Test Lab for UV Devices (Germany)
Sylvester Hsu — Bonestroo, Rosene, Anderlik and Associates
Andreas Kolch — WEDECO GmbH (Germany)
Bob LaFrenz — Innovatech
Shawn Lin — Bio-Lab
Karl Linden — Univ. North Carolina @ Charlotte
Bruce Macler — U.S. EPA
Jim Malley (Chair) — Univ. New Hampshire
Tom Marshall — Malcolm Pirnie
Alex Mofidi — Metropolitan Water District, So. Calif.
Mike Murphy — Aquafine
Koji Nakano — Photoscience Japan Corp. (Japan)
Rip Rice — RICE Int’l. Consulting Enterprises (ex officio)
Dan Schmelling — U.S. EPA
Bryan Townsend — Univ. New Hampshire
G. Elliott Whitby — Suntec Environmental (Canada)

Under the Chairmanship of Jim Malley, the IUVA Steering Committee has been very active, with subcommittees exploring the various IUVA formation issues and preparing recommendations for ratification at the next meeting — in Chicago, during the AWWA meeting (specifically on Wednesday morning, June 23, 1999, starting at 0700 at the Hyatt Regency downtown — all interested parties are welcome).

One subcommittee has explored issues of incorporation and will recommend that IUVA be incorporated in the USA in the State of Delaware. The Finance Subcommittee is developing a proposed contract with Bolton Photosciences, Inc, to house the IUVA Head Offices in Ayr, Ontario, Canada and for Dr. Bolton to serve as IUVA’s Executive Director. A ByLaws Sub-committee has developed proposed IUVA ByLaws which have been approved by the Steering Committee and which are being reviewed by our “incorporation attorney” in Delaware. The Nominating Committee has been developing a list of candidates for the first IUVA Board of Directors, an Executive Committee and IUVA officers. Dr. Bolton has prepared a proposed budget for discussion and approval in Chicago by the full Steering Committee. Membership dues and a Membership Application Form have been developed (and are included in the mailing envelope for this issue of UV News), and a web site is evolving.

The IUVA is off and running folks. And if the enthusiasm and dedication of the members of the Steering Committee is any indication, it appears that your association is going to grow to adolescence rather quickly. We wish ourselves well.

Proposed IUVA Aims and Objectives

Here are the proposed Aims and Objectives of our IUVA for comment and/or approval on June 23. If there are comments, please send them to Dr. James R. Bolton, IUVA’s Executive Director pro tem at solaqua@ibm.net, Tel: 519-741-6283; Fax: 519-632-8941.

The International Ultraviolet Association (IUVA) is established to serve the following aims and objectives:

1. To provide a forum for the discussion of all scientific and technological issues that relate to the use of ultraviolet light;
2. To provide a common voice for the interests of companies using ultraviolet technologies and manufacturing ultraviolet lamps or equipment;
3. To organize periodic international and national conferences focused on ultraviolet technologies;
4. To publish a regular Newsletter (UV News) to keep members informed of new developments in the applications of ultraviolet technology;
5. To encourage the establishment of rational terms, units and nomenclature in the fields of ultraviolet technology;
6. To encourage research into the advancement of the applications of ultraviolet technologies;
7. To encourage the adoption of rational environmental regulations that would encourage the use of ultraviolet technologies.

☐
INTERNATIONAL ULTRAVIOLET ASSOCIATION (IUVA)

Meeting of the Steering Committee

7:00 am, Wednesday, 23 June 1999, Hyatt Regency Hotel (downtown), Chicago, IL

Agenda

1. Call to order
2. Approval of the Minutes of the Steering Committee Meeting of 28 April 1999
3. Adoption of the IUVA Bylaws and Incorporation
4. Adoption of an Official IUVA LOGO
5. Formal constitution of the International Board of Directors and approval of its members
6. Report of the Nominating Committee and Election of Officers
   a. International President
   b. International President Elect
   c. International Vice Presidents (at least 2)
   d. International Treasurer
   e. International Secretary (Bylaws provide that this position can be filled by the Executive Director)
7. Appointment of members of the Executive Committee
8. Report of the International President (proposed is Jim Malley)
9. Report of the Executive Director (proposed is Jim Bolton)
10. Report of the Editor of UV News (proposed is Rip Rice)
11. Report of the Finance Committee
   a. Budget for 1999 and a Draft Budget for 2000
   b. Approval of Contract with Bolton Photosciences Inc. for the operation of the International Headquarters Office
   c. Approval of Contract with Rice International Consulting Enterprises, Inc. for operation of UV News
12. Membership
   a. Approval of Fee Structure
   b. Authorization to allow membership payment by credit card
   c. How to set up Regional Groups
   d. How to set up Topical Groups
13. Planning for IUVA Congress, Conferences, Symposia etc.
14. Planning for Ultraviolet Science and Engineering journal
15. Reports on Interactions with Other Associations (IOA, AWWA, WEF, etc.)
   a. IOA (Jim Malley)
   b. AWWA (Jen Clancy)
   c. WEF (Tom Marshall)
   d. Suggestions to Add Others
16. Other business – status of web site
17. First Meeting of the IUVA’s International Board of Directors (date, place, time)

Adjournment
Dear Colleagues:

This is my first contribution to UV News, so let me introduce myself and tell you about my proposed job as Executive Director of IUVA (subject to IUVA Board ratification).

I am a Professor Emeritus of Chemistry at The University of Western Ontario (UWO) in London, Canada. Since 1970, I have taught and have had a very active research program at UWO. I have published extensively in the fields of photochemistry, ultraviolet technology, advanced oxidation technologies and ultraviolet disinfection. In addition, I also have considerable experience with technical associations, having served as the founding President of the Canadian Society for Chemistry and as President of the Solar Energy Society of Canada.

The International Headquarters Office (IHO) for IUVA will be located in the town of Ayr, Ontario, Canada (the town where I live). It is a beautiful town, and if you are ever in the area, you are most welcome to come and visit.

I have been working actively in setting up the IHO and supporting the activities of the Steering Committee. Shortly, I will be hiring a secretary/bookkeeper (pending Board approval and ratification).

As Executive Director of IUVA, I intend to run an efficient and open IHO. Your comments and suggestions are always welcome.

Jim Bolton, Executive Director, IUVA
Tel: 519-741-6283; Fax: 519-632-8941
Email: solaqua@ibm.net

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Tel: 519-741-6283; Fax: 519-632-8941
Email: jbolton@boltonuv.com
or – “How Does It Happen?” “Why At This Time?” and “Who Is Rip Rice?”

By way of answering the last question first and introducing myself, I am Rip Rice, a septuagenarian who is sworn never to retire – I am simply having “more fun than a human being should be allowed to have”, as Rush Limbaugh is wont to say almost daily, and my constant thanks go to the Almighty (and my amazing wife, Billie) for allowing me the physical and mental wherewithal to continue in this happy manner. My current ambition is to initiate and be the Editor-in-Chief of this news letter, UV News.

What are my qualifications? They are many, but none come from my formal academic training – which is as a chemist (Ph.D. from Maryland University – major: Organic Chemistry; minor: Physical Chemistry). Ever since I was knee-high to the proverbial grasshopper, I wanted to be a chemist. On the other hand, what kind of chemist turned out to ride on the flying carpet of lady luck, opportunity, and some critical and timely guidance from “above”.

By the time I entered military service in 1943 and WW-II as a late teenager, I had two years of college under my belt majoring in chemistry. In 1947 I completed my undergraduate studies with a B.S. in Chemistry from George Washington University, and then started some graduate work in music, of all fields you will find out sooner or later that I play saxophone – might as well get that on the table now), and was happily on my way to “finding myself” (yes, folks, whiffenpoofs abounded when back in the “good old days” of yesteryear).

Thanks to my musical hobby, I had the excellent good fortune of meeting my bride-to-be, who, after the preliminaries were over and serious thinking began to take hold, uttered the words that turned my life around – “Why is it that you have a degree in Chemistry and are piddling around with music? What are you, an academic bum? You have no job, no prospects of a job, and you want to get married? Go get a real job, and then we can talk about the future!” So I got a job as an Analytical Chemist, at the then National Bureau of Standards. shortly thereafter. Billie and I married, and then came our offspring David. And I was very happy building a career and being a good husband and helping to raise a gifted boy-child.

You know the expression, “behind every successful man is a woman – who couldn’t be more amazed?” Well – one weekend morning in 1950, Billie was reading the paper and asked, “Ripper, how much GI Bill of Rights college eligibility time do you have left?” “Oh”, I said, “I’m not certain – but I think about two years.” “Well”, said Billie, “It’s either use it or lose it in a couple of years. What are you doing sitting on your hands? Go get registered for a Ph.D. somewhere!!”

Remember that scene in The Glenn Miller Story when a young, just recently married Glenn is asked by his wife, “Why aren’t you still studying music under Dr. so-and-so?” And Glenn says, “I guess I’ve been letting you down, huh?” And his wife nods. Well, something like that happened to me. So I put my saxophone in moth balls, and off I trotted to Maryland University where I enrolled in night/weekend school (keeping my day job, of course. But in order to qualify for even a Master’s degree in any kind of chemistry, I had to take so many organic chemistry courses that I might as well major in that discipline.

By 1957 I had made it, as they say, and then started looking around for new worlds to conquer, Ph.D. in-hand. I soon learned that although the Ph.D. is a nice toy to have, people always are looking for what a person does with his/her brains, and couldn’t give a fig for qualifications. Soon it became clear that I needed to find out what I really wanted to do when I grew up. So I spent time in aerospace, in the chemical industry, then finally became an independent consultant in 1972, and haven’t looked back since then. As a self-employed person, I work for the best boss and I can seize on any number of opportunities as they happen to pass my way.

What does all of this history have to with initiating the IUVA? That’s coming.

In 1972, my first client was W.R. Grace & Co./Davison Chemical Division (Baltimore, MD). Davison had just licensed a technology for the generation of ozone and was looking to develop market opportunities for this unique ozone generator. At that time, environmental pressures were beginning to mount, and ozone looked to be a natural for coping with innumerable environmental problems. My job assignment was to “take the gospel of ozone to the Feds and other interested parties”. So I asked, “What is the gospel of ozone?” My boss replied, “We don’t know, we just got into the game. Go forth and find it!”

My first step was to look around for associations involved in ozone, particularly ozone for water and wastewater treatment – but none was to be found. So I got the idea that there should be
an International Ozone Association, and proceeded to assemble people in various regions of the world that I could reach with that proposition, even though I had no credentials at that time in the world of ozone.

In 1973, the IOA was started formally, on a wing, a prayer, but with little or no funding. Without going into the details, except to say that a great many people in the ozone industry donated a great deal of their time to nurture the IOA through its childhood years, the IOA has grown in stature to the point of having a strong presence all around the world. In 1998, the IOA celebrated its 25th Anniversary, an accomplishment that I am very proud to have helped bring about.

The point is that in 1972, someone was “out there” who saw the need and the possibilities to organize those (a) in the ozone industry and (b) interested in having an organization to which people can come to learn something about ozone technologies and applications thereof. That “someone” was not a recognized expert in ozone technology, yet was able to serve as the catalyst to bring interested parties together.

Over the course of time since IOA was created, I have served on the IOA’s International Board of Directors, on many IOA Committees, and have been Editor-in-Chief of Ozone: Science & Engineering (the peer-reviewed now 6-times-annually journal of the IOA) and also of Ozone News (the bimonthly news letter of the IOA).

Today in 1999, I am still an independent consultant, albeit with 27 years of experience in many fields involving ozone and its applications, and now a recognized expert in the field. But I still have imagination, enthusiasm, and the ability to serve as a catalyst. And so, when the U.S. EPA drinking water folks (bless their hearts) saw the need to convene a “Workshop on UV Disinfection of Drinking Water” in late April 1999 in the Washington, DC area, the bells started ringing again. Here, I figured, is an opportunity to catalyze the formation of another needed association.

A few calls and many e-mails to Jim Malley ensued, then with Jim Bolton, and the “Is an IUVA Ready to Form” memo went out to as many people as we could find that might have interest. We called a special meeting, outside of the UV Workshop, for the night of April 28, 1999, and the rest, as they say, “is history”. But it really isn’t history yet – because we still are in the formative stages of putting together the IUVA.

Here is a brief synopsis of what occurred the night of April 28th, what has happened subsequently, and what is likely to happen in the next few months:

- At the IUVA formation meeting (attended by 56 interested parties), a Steering Committee of about 12 people was created to proceed with the legal formation of the IUVA.
- Dr. James Malley (Univ. of New Hampshire, USA) was elected Chairman of the Steering Committee.
- Dr. Jim Bolton (Bolton Photosciences, Ayr, Ontario, Canada) was appointed by the Steering Committee to be IUVA’s Executive Director pro tem.
- It next befell the Steering Committee to define critical organizational issues and to assign small subcommittees to develop each of these issues for Steering Committee action, e.g., propose IUVA office location, staffing, arrange for incorporation of the IUVA, agree on association Aims and Objectives, agree on a budget and logo, develop by-laws, recommend formation of several operating committees, establish a dues structure, establish an IUVA web site, and initiate planning for the First International Symposium on UV Technologies.
- Rip Rice proposed the initiation of UV News and offered to be its Editor-in-Chief. Rice believes that if sufficient advertising income can be developed, UV News should be self-sustaining. He pointed to his seven years of service as Editor-in-Chief of Ozone News, the news letter of the IOA, during which time Ozone News was self-sustaining.
- A second meeting of the Steering Committee and other interested parties was planned for Chicago during the AWWA meeting to vote on the Committee’s recommendations (Wednesday, June 23, 1999, 0700 to at least 0900, at the downtown Hyatt Regency – not the Hyatt adjacent to McCormick Center). A draft Agenda (not yet finalized) is included elsewhere in this issue to indicate the scope of activities.

The date, April 28, 1999, should go down in history as the date that IUVA was created. But the jazz musicians in the organization can remember that date as being the night before Duke Ellington’s 100th birthday.

So – How does an Association happen? In this case by one individual picking his head up from the daily grindstone and recognizing that there appears to be a need. But anyone can do that, given the right circumstances. What happens next is the real test of whether the fetus will be born, or will be aborted. Many people must recognize the same need and agree to put their collective shoulders to the wheel to bring the fetus to birth. They then must be willing to nurture the new-born child at least to adolescence, and finally to adulthood.

The IUVA is at that gestation stage following conception. And I am pleased to report that all appears to be going well. The Steering Committee now has 23 members and a dynamic leader (Dr. Jim Malley) who is a “take charge, no nonsense” kind of guy who believes in the future of UV, and in the concept of the IUVA, and who is an effective organizer and administrator. We
are also fortunate that Dr. Jim Bolton has just retired, has entered the domain of "independent consultant", and is eager (and able) to be IUVA’s Executive Director.

And here is the very first issue of *UV News* for your perusal, comments, and approval. Although we do not yet have sufficient advertisers to have passed the financial "break even" point, my take is that there just was not sufficient time to develop the cadre I am sure will evolve over the next few months.

As the Steering Committee continues its work of laying the basic building blocks for the incorporation and formation of the IUVA as a non-profit scientific and UV-educational association, I shall sit back, observe, help whenever I can, and beam with fatherly pride, knowing that I have been able to make yet another (hopefully worthwhile) contribution for the benefit of mankind.

The question "Why IUVA at this time?" I think has been answered. Believe it or not, some colleagues and I thought very seriously about starting an IUVA in the late 1970s. However, there were only a few UV suppliers at that time, and very little interest, except for radiation curing of plastics, a little in potable water treatment (mostly in Europe), and the possibility of using UV in municipal wastewater disinfection. We even developed a letterhead to survey the potentials - but gave it up due to the press of other business and apparent lack of interest.

Today, however, is a different time. There is lots of interest in UV. Many applications are proven and more are being developed. UV radiation in combination with other oxidants (e.g., ozone and hydrogen peroxide, in particular) has given rise to the field of Advanced Oxidation, which was unheard of twenty years ago. UV/ozone systems are proving of technical and cost-advantage in reducing COD levels in European landfill leachates and in destroying refractory organics in some contaminated groundwaters. And UV systems are routine in the pharmaceuticals and electronics industries, not solely for its "normal" uses, but to destroy residual ozone in process waters.

The potentials for ever-increasing applications of UV systems continue to grow. Surely now is the time to form a UV association which will focus on all of the aspects of the technology, from generation, to application, to development of industry standards, to research on UV and its existing applications, and research on new applications and applications in combination with other oxidants, catalysts, and the like.

In closing this rather logorrheal orientation, I want all to know that my phone/fax/e-mail lines are open for discourse and discussion at any time. As time passes and the IUVA grows, it is my hope to meet many people in UV technologies that I do not yet know. UV people that I have met over the years because of the many overlaps with ozone technologies are wonderful, and I treasure their acquaintances.

Welcome to the IUVA, people, and many successes in the IUVA’s future!

And oh, yes – if any firm (including consultants) is interested in placing advertisements in future issues of *UV News*, we shall be pleased to make room for you.

Rip G. Rice, Ph.D., Editor

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Trojan Technologies has been awarded European and Canadian contracts to supply ultraviolet disinfection systems valued at C$4.3 million and contracts valued at C$10.2 million in the USA.

In the European market, contracts for 12 Trojan wastewater disinfection systems and 18 drinking water disinfection systems were ordered recently for the European market valued at C$1.9 million. Nine separate sites in Southern Italy installed wastewater systems during the month of October, 1998. Combined, these systems have a peak flow of 250,000 m³/day. Wastewater treatment systems also were contracted for Palestine, Spain.

Drinking water treatment systems have been ordered for installation in Spain and Scandinavia. Since chlorination typically is not used in Europe for the disinfection of drinking water, the Trojan ultraviolet light systems provide an approved option.

The company also has secured contracts in three Western Canadian cities. The cities will install LTV4000™ systems for wastewater treatment that will have a combined peak flow of 199,600 m³/day.

In the USA, a System UV4000™ will be installed at the Wayne County-Wyandotte, Michigan Wastewater Treatment Plant to disinfect primary and secondary wastewater. The Wyandotte facility is the second largest WwTP in Michigan and, when in operation (in 1999), will be the largest capacity UV installation in the U.S., treating a peak flow of more than 1 Bn L/day.

The North Shore Sanitary District in Gurnee, Illinois will receive three Trojan Systems UV4000™ for the Gurnee, Waukegan and Clavey Road Treatment Plants during the Spring of 1999. When in operation, they will treat a combined flow of 541 ML/day.

Clark County, Nevada plans to install a System UV4000™ just outside of Las Vegas by June 1999. This site will disinfect a peak flow of 477 ML of wastewater per day, representing the largest UV disinfection system in the U.S. Mountain States.

**Beating Pool Budgets With UV**

One UK swimming pool authority, Islington, found that the high costs of maintaining levels of hygiene and water quality in their Highbury public swimming pools necessitated a closer look at the alternative, though less well known, options. Aquaterra, managers of eight leisure centers for Islington Council were experiencing significant problems with controlling the combined chlorine levels in the Highbury pool. The company had taken some remedial action using a bromide additive and installing a fresh water flow system with some success, but not enough to maintain the high health and safety standard requirements.

A solution was found after the Highbury Pool complex was invited to take part in a trial conducted by UV Systems plc, with the backing of the DTI SMART Award for Innovation. The objective of the trial was to prove the effectiveness of UV disinfection of public swimming pools, the improvement in water quality, reduction in levels of chlorine and the environmental and economic benefits.

A UV treatment unit was provided by UV Systems Plc for the main pool. A further unit was purchased for the teaching pool. Both units were installed by Reltek Engineering Ltd, who specialize in this field and in the installation of commercial pool plants. The system works by circulating water through a chamber containing a number of double skinned high efficiency low pressure UV lamps. UV Systems are the UK’s only manufacturer to use this multi-lamp design to ensure an even distribution of light throughout the treatment chamber. The low-pressure lamps are the most efficient for producing high energy UVC photons, and consume around one third of the electrical power of older single lamp designs.

The results were dramatic. Within days of operation there was a substantial improvement in water quality. Combined chlorine dropped to consistently low levels, and the pool operators were able to reduce the free chlorine levels at the same time (independent reports are available on request -- see below).

Significant economic and environmental advantages of using the UV treatment unit were highlighted in the trial:

- UV reduced the need for dilution with fresh water, saving water, sewerage and energy costs.
There was a significant drop in expenditure on chlorine. The atmosphere and swimming conditions encouraged greater usage of the pool which, in turn, brings in revenue. UV also is at its most beneficial when the pool is heavily utilized. Lower running and maintenance costs compared with alternative ozone systems. Another benefit is the smaller footprint of the UV plant. With no extra filtration equipment needed, plant room floor space can be better utilized. Significant reductions are possible in combined and free levels of chlorine. Water clarity had noticeably improved and the air quality was better.

**Ozone System Replaced By UV**

As a result of the Highbury trial, Islington Council turned their attention to the ozone system at Archway pools which had been in place for five years. Although it was achieving acceptable water quality standards, there were particular problems causing concern. Primarily, five years on, the costs of maintaining the ozone plant to the required levels of performance had become prohibitive. Regular maintenance by service contract is part of the ozone package and necessary to keep the system operating effectively. As, the maintenance requirements increased to keep the levels of ozone in the pool effective, so the running costs had spiraled. A cost analysis of installing the latest UV unit from UV Systems, including the initial capital investment (significantly less than that of an ozone system), illustrated that in real terms utility costs would be halved and the lack of any on-going maintenance contract (UV treatment units only require annual lamp changes), would result in substantial cost savings. “We had not really considered UV disinfection as a viable alternative, until the trial at Highbury,” said Terry Beech, spokesman for Aquaterra.

“The results were so impressive that we could see a real advantage in removing the ozone system at the Archway pool and replacing it with UV. What could be seen as an extreme decision became an obvious one, based purely on the commercial facts evident to us.” The UV units at Highbury worked faultlessly for over a year before any maintenance was performed; their automatic self-cleaning systems and long life UV lamps certainly made for a “fit it and forget it” project!

Removing an operating system and replacing it with an alternative before its designated replacement time is a radical step and highlights the significant benefits the new UV system must offer, particularly in terms of immediate economic savings. The new UV treatment plant for the Archway Pool was installed and operational by mid-August, 1998.

“UV Systems is the leading British manufacturer of ultraviolet disinfection equipment, with over forty years experience in ultraviolet water disinfection,” said Managing Director, Mark Mathieson. “The SMART Award has given us an invaluable opportunity to fund research into the development, manufacture and field testing of UV treatment for municipal, commercial, domestic and hydrotherapy swimming pools. The trials have been enormously successful and our confidence has been justified by Islington’s decision to adapt Archway pool. As Terry quite rightly points out, it makes firm economic sense. We anticipate many more councils will follow their example.”

UV Systems plc now have 12 pools operating with their latest UV disinfection system throughout the U.K., with many more in progress.

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[Source: Recreation, 58(3), April 1999]
DATES: Written comments by July 9, 1999.

ADDRESSES: Submit written comments to the Dockets Management Branch (HFA-305), Food and Drug Administration, 5630 Fishers Lane, rm. 1061, Rockville, MD 20852. Individuals or organizations wishing to receive copies of draft amendments or related documents distributed for review during the development of these amendments may have their names placed on a mailing list by writing to the Office of Science and Technology (HFZ-114), Center for Devices and Radiological Health, Food and Drug Administration, 5600 Fishers Lane, Rockville, MD 20857, FAX 301-594-6775, e-mail: "HWC@CDRH.FDA.GOV".

FOR FURTHER INFORMATION CONTACT: W. Howard Cyr, Center for Devices and Radiological Health (HFZ-114), Food and Drug Administration, 5600 Fishers Lane, Rockville, MD 20857, 301-443-7179.

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**EPA’s TWG Forms UV Group**

The U.S. EPA has established an Advisory Committee under the Federal Advisory Committee Act (FACA) to negotiate regulatory options for the upcoming Stage 2 Disinfectants/Disinfection Byproducts Rule (Stage 2 DBPR) and the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). These rules, termed the Microbial and Disinfectants/Disinfection Byproducts (M/DBP) rules, are to be negotiated by the FACA Committee by April 2000. The advisory committee will determine whether current requirements for controlling microorganisms and DBPs in drinking water are sufficiently protective of the public health.

In support of the Advisory Committee, a Technical Working Group (TWG) was created to provide the Advisory Committee with technical information on costs and benefits stemming from potential rule options. Under the 1996 Amendments to the Safe Drinking Water Act, EPA is required to consider whether the benefits of a regulatory requirement justify its costs.

At its meeting of May 18-19, 1999, the TWG formed several subgroups, including a UV subgroup to focus on UV disinfection of drinking-water. This subgroup was initiated recognizing that if UV disinfection of potable water is to be considered as a “Best Available Technology”, it might reduce costs associated with certain rule options significantly when compared to other technological options. However, given the relative lack of experience with UV disinfection of drinking water in the United States, questions remain as to the efficacy, safety, and reliability of this technology when applied under the wide range of conditions encountered in municipal water treatment plants.

The UV subgroup is charged with bringing to the TWG, and thence to the Advisory Committee members, sufficient information to make an informed decision about the role of UV disinfection in M-DBP regulations.

The UV subgroup will be chaired by Dr. Daniel C. Schmelling of EPA’s Office of Ground Water and Drinking Water. Dr. Schmelling is the regulatory manager for the LT2ESWTR. The membership of the UV subgroup is still under development, but is expected to consist of 10-12 persons representing a range of backgrounds and interests in the UV field.

The Advisory Committee and TWG will meet in regularly scheduled public meetings until April, 2000, at which point Advisory Committee members will provide EPA with their regulatory recommendations. The M/DBP rules are scheduled for proposal in February 2001, with promulgation in May 2002. The next scheduled meeting of the TWG is July 19 and 20 in Washington, DC. These are the two days immediately preceding the next scheduled meeting of the FACA Advisory Committee. EPA officials expect that FACA Advisory Committee meetings during this coming Fall, presentations will be made from the various TWG subgroups – these will include at least one presentation on the status of UV disinfection technology.

Persons desiring information about the meeting schedules and agendas for the Advisory Committee and TWG may contact Eddie Scher of Resolve, Inc., at (Tel) 202-944-2300; e-mail: escher@resolv.org.

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On April 28 and 29, 1999 I had the distinct pleasure of being part of the U.S. EPA Workshop on UV Disinfection of Drinking Water that was organized by Dr. Dan Schmelling (U.S. EPA) and moderated by Abby Arnold (Resolve, Inc.). The purpose of this article is to review the events leading up to and including this workshop and present opinions on where the issue of UV Disinfection of Drinking Water will go from here. Let me begin by thanking both Dan and Abby for doing an excellent job putting together a very diverse and interesting program of invited speakers and keeping the discussions focused on UV research needs throughout the two-day event.

The need for a UV workshop was created by a series of recent research findings relevant to the ability of UV disinfection to cost-effectively inactivate Cryptosporidium oocysts. The workshop was designed to provide new information about UV and identify remaining data gaps and research needs for stakeholders concerned with negotiating pending and future drinking water regulations. These regulations include the: Groundwater Rule (GWR), Stage I Disinfectants/Disinfection By-Products Rule (D/DBPR), Long Term Stage I Enhanced Surface Water Treatment Rule (LT1ESWTR), Stage 2 D/DBP Rule and the Long Term Stage 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).

The recent findings stem from two research projects: the AWWARF/EPRI jointly funded project entitled "Innovative Electrotechnologies for Cryptosporidium Inactivation" and the U.S. EPA/NSF ETV Program-funded project entitled "Performance Evaluation of the Sentinel™ Ultraviolet Tower for Inactivation of Giardia and Cryptosporidium." In the first project, the team of Jen Clancy (Clancy Environmental Consultants, Inc.), Marilyn Marshall (University of Arizona) and John Dyksen (then of Malcolm-Pirnie, Inc., now with United Water Services) identified two promising UV technologies for Cryptosporidium inactivation: the Safe Water Solution Cryptosporidium Inactivation Device (CID) and the Innovatech Pulsed UV Unit.

However, the most significant finding of that project was that the technique chosen for determining Cryptosporidium viability when testing UV technologies was critical. It became quite clear that attempts to use excystation or vital dyes to determine Cryptosporidium inactivation by UV produced erroneous results. The only valid measure of the ability of UV to inactivate Cryptosporidium used in that study (recently, cell culture techniques have been developed that may prove as effective) was animal infectivity. This finding was critical to understanding why previous UV research had concluded that the UV dosages needed to inactivate protozoan cysts were in the hundreds to thousands of mJ/cm² (mW-sec/cm²) and thus were not deemed cost-effective.

With this new understanding about measuring inactivation, the second study conducted under the U.S. EPA NSF ETV Program by Calgon Carbon Corporation, Cartwright, Olsen and Associates, LLC, and Clancy Environmental Consultants, Inc. was able to show that a conventional, continuous wave, medium pressure UV system could inactivate greater than 4-logs of Cryptosporidium oocysts (based on mouse infectivity assays) at UV dosages as low as 41 mJ/cm². This study also showed that 3.9-logs of inactivation were achieved at a UV dosage as low as 19 mJ/cm² (see Bukhari et al., 1999, J. Am. Water Works Assoc. 91(3):86-94).

The findings of these research studies suggest that conventional UV technologies can inactivate Cryptosporidium oocysts cost-effectively. Literature estimates place the production costs (amortized capital cost plus annual O&M costs) of UV technology in the range of $0.01 to $0.03 per 1,000 gallons. In addition, studies by UNH and others have shown that conventional UV is unlikely to form DBPs directly or to increase DBP formation by secondary disinfectants. When all these facts are considered together, it spurs tremendous excitement that UV disinfection of drinking water can greatly improve public health protection at a very reasonable cost. This leads us then to the UV workshop.
Many of us went to the UV workshop with important questions in mind and anticipated that data would be presented to answer them. My questions were:

1. Does low pressure, continuous wave UV technology work equally as well at inactivating Cryptosporidium as medium pressure?
2. Has data been generated which shows that UV technology can also effectively inactivate Giardia?
3. Does there exist a strong enough full-scale data base (from international applications of UV to drinking water to North American applications of UV to wastewater) to verify these projected low costs of applying UV?
4. Will UV be accepted by federal, state and local regulatory agencies and what guideline will be provided for required dosage, design redundancy and required safety factors?
5. What experiences have this collection of UV experts had with the practical issues of UV process control through sensors, hydraulic performance in UV reactors which have a small number of UV lamps and fouling of UV sleeves in medium pressure applications?

Unfortunately, few questions were fully answered at the workshop. As for answers to my specific questions, I came away with the following:

1) The very preliminary disinfection data that was presented at the UV Workshop does show promise that low pressure will work as well as medium pressure for inactivation of Cryptosporidium oocysts.
2) It was also encouraging that preliminary data suggests UV will effectively inactivate 2 to 3 logs of Giardia cysts at cost-effective dosages. I do caution the readers, however, that all the presenters of disinfection data were very careful to admit their data was very preliminary and needed a good deal more scrutiny before it could reach the fully peer-reviewed stage.
3) There were several excellent talks by UV equipment manufacturers, some of whom brought a wealth of international drinking water experience to the workshop. However, it was clear that U.S. consulting engineering firms and U.S. drinking water utilities had virtually no experience or comfort with designing and costing out full-scale applications of UV for drinking water treatment. In addition, no regulatory guidance is in place to establish critical design parameters such as UV dosage versus disinfection credit that would be granted or the type and level of redundancy that would be required. For these reasons, I left the workshop with the distinct feeling that developing a better level of comfort with the true cost estimates of applying UV to comply with U.S. drinking water regulations is several years away.

4) In light of these remaining questions, it would be unfair and unrealistic to assume that regulatory guidance can be provided at this time. Nevertheless, it was very encouraging that representatives of U.S. EPA clearly expressed an interest in seeing UV technology included in upcoming regulatory discussions and negotiations. However, I was troubled that the UV Workshop ended without a clear timetable or a clear strategy of how the needed research would be funded and then used to develop the needed information [e.g., disinfection (CT type) tables for UV] which would allow clear regulatory guidance and design requirements. The only new research project funding related to UV disinfection on the public horizon is AWWARF RFP 2593 due July 15, 1999, but that explicitly excludes research on Giardia and Cryptosporidium in order to focus on emerging pathogens.

5) In listening to the speakers and more importantly in talking with some of the experts during the breaks, I learned that several groups share my concerns and experiences that many UV sensors operate poorly and that frequent calibration checks are critical. I also learned that concerns with assuring effective hydraulic designs for UV reactors, especially those that employ very few medium pressure lamps (the same could be extended to pulsed UV reactors) is a significant design concern. Lastly, I spoke with several experts who strongly support the need for continuous UV lamp cleaning mechanisms, especially for medium pressure lamps, due to increased and unexpected rates of fouling caused by complex thermal gradients at the lamp sleeve's surface and water quality matrix effects.

At first I was disappointed by the UV Workshop's lack of complete answers, since I firmly believe UV will improve public health and would like to see it employed (where appropriate) as soon as possible. But after reflection, it is not surprising that it is going to take time to develop all of the answers we need. This should in no way prevent utilities from considering the use of UV or moving forward with planned studies. History has shown us that quite often we implement full-scale technologies in drinking water treatment (e.g., filtration, carbon adsorption, membrane filtration, and ozonation) with great success before many of the issues, questions or implications are fully understood or resolved.

**So where do we go from here?** In my presentation at the UV Workshop, my take-home messages were:

1. The Application of UV to Drinking Water Disinfection Holds Tremendous Promise (for improving public health) and Could Save $ Billions;
2. With A Focused Effort and Rapid Technology Transfer, Widespread Acceptance of UV in Drinking Water is About Two Years Away,
3. The Most Significant Obstacle to UV Acceptance is the Lack of Good Process Control/Performance Monitoring Equipment (UV Sensors); and
4. Confirmation Studies and Dosage Tables for UV Inactivation of Giardia and Cryptosporidium Must be Completed (to provide a sound basis for a regulatory guidance manual on UV design and operation).

I believe each of these messages remains accurate. However, it has become clear that it is going to take an unprecedented desire, drive and effort on the part of our drinking water industry to achieve the proposed two-year time frame - I would not be surprised if that estimate slips to five years before UV gains widespread acceptance. Nevertheless, important steps have begun:

1) U.S. EPA is rethinking its position on UV for surface water treatment;
2) AWWA is planning to establish a UV disinfection workgroup to identify ways to address UV research and technology development needs;
3) Several major water utilities have talked about approaching AWWARF to start a UV research focus group;
4) Several water utilities soon will begin performing engineering (paper) and pilot plant studies on the feasibility of applying UV to meet the needs of their customers; and
5) UV will be considered by the EPA’s Technical Work Group and discussed during the reg-neg-2 (FACA) negotiations for the Stage 2 D/DBP Rule and LT2ESWTR.

In closing, the UV Workshop was timely, useful and served to move us further along the right track. I am more confident than ever that the benefits of applying UV disinfection technologies to drinking water will be realized and achieved. Further, the newly-formed International UltraViolet Association (IUV, spurred on by the holding of a U.S. EPA UV Workshop, will greatly assist all stakeholders interested in applying UV technologies to drinking water disinfection.

James P. Malley, Jr., Ph.D.
As many of the new U.S. EPA drinking water regulations move towards full enactment, the role of UV treatment technologies in helping public water supplies comply with these regulations becomes more important. The draft preamble to the Groundwater Rule published recently by U.S. EPA has formalized the ability of communities to use UV to comply with this regulation. In light of recent research showing possible promise of several UV technologies to inactivate Cryptosporidium at cost effective dosages, there is much water industry activity in the area of using UV to comply with pending and future EPA rules such as the Interim Enhanced Surface Water Treatment Rule, the LT1ESWTR, the LT2ESWTR and the Disinfectant-Disinfection By-Product Rule. Most notably:

1. A UV Workshop to evaluate where we are with the application of UV technology to drinking water treatment and identify key data gaps was held by U.S. EPA on April 28 and 29, 1999 in Washington, D.C.

2. AWWARF has solicited three RFPs for research relating to applications of UV or UV-Advanced Oxidation Processes for Drinking Water Treatment (see AWWARF’s web site (www.awwarf.org).

3. On March 4, 1999 the University of New Hampshire's Environmental Research Group launched a new research initiative and formed the UV Team. The UV Team is a multidisciplinary (environmental engineering, environmental microbiology, polymer chemistry and chemical engineering) research team dedicated to research on UV Irradiation. UV Team research has a focus on three primary areas: disinfection (in air, drinking water, wastewater); advanced polymer development for UV equipment (fouling resistant sleeve materials, new sensor materials, etc.); and use of UV in advanced oxidation processes to treat organics (in air, drinking water, wastewater). The UV Team was formed to build upon the existing eight years of experience, including twelve projects, that UNH-ERG has completed in the area of UV research. The UV Team initiative has a broad funding base with four on-going projects currently supported by: federal grants (NOAA, U.S. EPA and U.S. DOD), foundation grants (AWWARF and EPRI) and private sector companies. Part of this research initiative includes the development and distribution of UV Mail to aid in rapid technology transfer. For more information contact Jim Malley (jim.malley@unh.edu).

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A Brief History of Waterborne Cryptosporidiosis

Since the first outbreak of waterborne cryptosporidiosis was reported in Braun Station, Texas (D’Antonio et al, 1984), dozens more have been reported world-wide in the U.K. (Lisle and Rose, 1995), USA (Kramer et al, 1996), Sweden (DeLong et al, 1997), Canada (Ong et al, 1997), and Japan (Kuroki et al, 1996). The largest outbreak to date occurred in Milwaukee in 1993, with an estimated 400,000 people affected and over 100 deaths (MacKenzie et al, 1994). The following year, an outbreak of cryptosporidiosis in Las Vegas, Nevada led to 20 deaths in immunocompromised individuals (Roefer et al, 1996).

Most of the cryptosporidiosis outbreaks (D’Antonio et al, 1985; Lisle and Rose, 1995; and Kramer et al, 1996) which have been investigated thoroughly can be related to a deficiency in treatment, improper operations, equipment failure, or inadequate source protection of groundwater supplies. Solo-Gabrielle and Neumeister (1996) reviewed the U.S. outbreaks from an operations viewpoint, and reported that half of the cryptosporidiosis outbreaks were associated with groundwater sources. However, the majority of affected individuals have been served by surface water plants using coagulant addition, filtration and chlorine disinfection. While treatment deficiencies and sub-optimal operational practices were found in some situations, all plants were in compliance with federal and state regulations.

Solo-Gabrielle and Neumeister have questioned how much protection is provided by conventional sand filtration processes, and suggested that filtration systems should be operated at optimum levels exceeding regulatory requirements in an effort to maximize public health protection. The water industry has responded to the threat posed by Cryptosporidium with programs such as the voluntary Partnership for Safe Water that assists plants in optimizing their treatment processes to consistently achieve water quality goals beyond those required by law. However, water utility managers are still haunted by the possibility of a cryptosporidiosis outbreak in their system even though every effort has been made to prevent it from occurring. This is due in part to our incomplete understanding of the sources and occurrence of the parasite and its fate and transport in the environment, coupled with the inadequacy of existing controls even when standards are met.

Regulatory Response

Cryptosporidium control now has become a primary focus of regulatory agencies in the U.S. and U.K., and this pathogen now is regulated as a drinking water contaminant in both countries. In the U.S., Cryptosporidium has just been regulated by means of the Interim Enhanced Surface Water Treatment Rule (IESWTR). The rule addresses control of Cryptosporidium through establishment of a maximum contaminant level goal (MCLG) of zero and treatment requirement in the same manner that Giardia was regulated in 1986 under the Surface Water Treatment Rule (SWTR). Surface water systems that require filtration must achieve at least a 2-log removal of Cryptosporidium. Turbidity requirements have been lowered to a level of 0.3 NTU in combined filtered water in 95% of the monthly measurements and cannot exceed 1 NTU at any time. Groundwater systems under the direct influence of surface water (GWUDI) also must comply with the new rules.

Cryptosporidium is added to the watershed protection requirements for systems avoiding filtration. Monitoring of the parasite at a maximum contaminant (MCL) still is not required due to problems in method reliability. Whether these new requirements will protect consumers from cryptosporidiosis remains uncertain. Two outbreaks, Las Vegas, NV (Roefer et al, 1996) and Waterloo, Ontario (Pett et al, 1993) occurred in systems which were meeting these new requirements at the time of the outbreaks.

In the U.K., the Drinking Water Inspectorate (DWI) has introduced a monitoring requirement which has set an MCL and monitoring is expected to begin in late 1999. The requirement will be for continuous monitoring of certain surface water supplies. The requirement is unusual in that the monitoring will be daily and continuous (22 hours out of 24). The sampling point will be treated water at the outlet of the plant. The requirement is not health-based, but is a treatment-based standard, with an enforceable limit of 1 oocyst per 10 L. The rationale is that a plant should be removing oocysts to a level of <1/10 L as determined by a new analytical method with
similarities to the U.S. EPA Method 1622: Cryptosporidium in Water by Filtration/IMS/FA (U.S. EPA, 1999). While the monitoring data can and are expected to be used for enforcement, the details of this are still being developed.

The U.K. is the first country to regulate Cryptosporidium in drinking water directly by setting a numerical standard and requiring testing to meet that standard. There is a general requirement in the U.K. that drinking water “does not contain any element, organism, or substance .... at a concentration or value which would be detrimental to public health”. Put another way, the water provided must be “fit for human consumption”. Water that is likely to cause cryptosporidiosis is unfit for human consumption and supplying it would be an offense under Section 70 of the Water Industry Act of 1991 [Water Supply (Water Quality) Regulations, 1989]. The new Cryptosporidium regulations would not change this offense nor the penalty. An unlimited fine could be imposed on a water supplier convicted of this offense in a Crown Court.

The U.K. program will require a large effort to support the regulation, both in implementation of the program and continued oversight. The regulation was developed based on what is believed to be achievable analytically, i.e., it is considered possible to detect 1 oocyst in 10 L of water using the new DWI method. However, even if this standard is achievable, there is no guarantee that meeting this standard will prevent an outbreak of waterborne cryptosporidiosis. The regulation is based upon the premise that outbreaks occur when high and intermittent levels of oocysts pass into the distribution system during plant upsets. The DWI feels this regulation will allow them to detect such events and act on them through enforcement, causing plants to tighten operations to avoid prosecution. Whether this rule can predict or prevent outbreaks remains to be seen after implementation. A survey of water suppliers and regulatory agencies worldwide indicated that Cryptosporidium is not currently regulated elsewhere at this time, and monitoring for the parasite remains voluntary (Clancy and Hansen, 1999).

**Cryptosporidium Control Through Water Treatment**

Like Giardia, Cryptosporidium oocysts can be controlled by physical removal through filtration processes, although oocyst removals can be expected to be lower than for Giardia, due to their smaller size. Cryptosporidium removal has been assessed using a variety of treatment techniques and removals range from 2- to 4-logs in conventional systems (Ongerth and Pecoraro, 1995; Nieminski and Ongerth, 1995; Plummer et al, 1995; Hall et al, 1995). Diatomaceous earth filtration was shown to provide 3.8- to 6-logs of oocyst removal in bench-scale studies (Ongerth and Hutton, 1997). Membrane processes (ultrafiltration and microfiltration) are known to provide high levels (>6-logs) of oocyst removal (Jacangelo et al, 1995).

Unlike Giardia, Cryptosporidium oocysts which escape the filtration process are resistant to chlorine-based disinfectants at the concentrations and contact times practical for water treatment (Korich et al, 1990). This makes the physical removal process (coagulation, sedimentation, filtration) the most critical step in conventional water treatment in plants using chlorine for disinfection. Alternative disinfectants do exist.

Ozone is highly effective for Cryptosporidium control. Korich et al (1990) demonstrated that oocysts exposed to 1 mg/L ozone reduced oocyst viability from 84% to 0% after 5 min at 35°C, and exposure times of 5 or 10 min resulted in 90% to 99.9% reduction in neonatal mouse infectivity, respectively. These data are further supported by Finch et al (1993), who also treated oocysts with ozone and found it to be highly effective for oocyst inactivation. Further work by Finch et al (1997), has shown that a synergistic effect occurs using combinations of certain disinfectants, resulting in a higher log inactivation of oocysts when the chemicals are applied sequentially than when each one is used individually. For example, an initial residual of 2.0 mg/L chlorine for 240 min resulted in a 0.4-log inactivation of Cryptosporidium; an ozone dose with an initial residual of 0.75 mg/L for 3.7 min resulted in 1.6-logs inactivation; but treating the oocysts firstly with the ozone, followed by chlorine, resulted in a 2.9-logs inactivation. Other combinations - ozone/monochloramine (1.8-logs), chlorine dioxide/free chlorine (2.9-logs), and even free chlorine/monochloramine (0.6-log) - have proved more useful than each oxidant when applied individually. The discovery of the effectiveness of sequential disinfection provided the first real option for water suppliers to provide a final barrier for Cryptosporidium control after filtration.

**Let There Be Light**

Ultraviolet light (UV) appears to be the newest addition in the war against Cryptosporidium, but was almost overlooked in the search for ways to inactivate oocysts. In retrospect, it appears that the early discovery of oocyst resistance to chlorine-based disinfectants left us with the prejudice that oocysts were extremely resistant to “anything and everything”. However, when we review the literature, it appeared that the work that was conducted with UV was positive, but was not immediately capitalized upon as data became available. Only in the last six months has the scientific community begun to accept that UV may be a highly effective tool for Cryptosporidium control. The history of Cryptosporidium inactivation using UV light is brief, as is the review of the published literature that follows.
Lorenzo-Lorenzo et al (1993) used mouse infectivity experiments in a bench top system to assess Cryptosporidium parvum oocyst inactivation. There is a lack of clarity in the experimental details and the paper is difficult to interpret. Dr. Andrew Campbell communicated directly with the author to ascertain the details and interpret the findings (Andrew Campbell, personal communication). Lorenzo-Lorenzo used a single inoculum (2.5 x 10⁴ oocysts), and assessed overall infection intensity after treatment by using low pressure (LP) UV. The results estimated a >3-log inactivation at 100-300 mJ·cm⁻², although these data cannot be gleaned from the published paper.

Following this work, Campbell et al (1995) examined the Safe Water Solutions, Ltd. Cryptosporidium Inactivation Device (CID) designed for oocyst inactivation in clean (<1 NTU) water. These researchers demonstrated 2- to 3-logs inactivation of oocysts using the DAPI/PI (4',6'-diamidino-2-phenylindole and propidium iodide) vital dyes assay and excystation with a dose of LP-UV dose of 8,748 mJ·cm⁻². They postulated that their ability to assess the limits of inactivation was restricted by the limits of the standard enumeration procedures that are used with the in vitro assays. Additionally, this study also tested the CID in a static rather than flowing mode for which it is designed to be used. These authors recommended a definitive study using mouse infectivity and operating the unit in the flow through mode according to its design.

In 1996, the American Water Works Association Research Foundation (AWWARF) and the Electric Power Research Institute/Community Environmental Center (EPRI/CEC) jointly funded a study to assess innovative electrotechnologies for inactivation of Cryptosporidium. This research was undertaken to determine if any commercially available innovative electrotechnologies were capable of inactivating Cryptosporidium oocysts in drinking water. Five electrotechnologies were challenge-tested using live oocysts under carefully controlled laboratory or field conditions. The five systems tested included:

- advanced UV light (represented by the CID),
- pulsed UV,
- conventional UV,
- acoustic shock, and
- resonant electric current.

Only advanced and pulsed UV were shown to inactivate oocysts under the experimental conditions tested. In retrospect, the study design used could have missed the potential of UV to inactivate oocysts entirely had lower doses of UV been applied (Clancy et al, 1998). Depending on one’s beliefs, serendipity, blind/dumb luck, or divine intervention occurred next. In the AWWARF/EPRI study, the objective was to demonstrate whether a given electrotechnology had any potential for oocyst inactivation. The study did not assess levels of inactivation, various doses of energy, or attempt to optimize any technology - it was a quick look-see to screen the various electrotechnologies for further study if warranted. To do this, the research team decided to use the in vitro surrogate assays (DAPI/PI, SYTO®-9, SYTO®-59, and maximized in vitro excystation) to make initial measurements as these assays are simple to perform and are inexpensive and were thought to correlate to animal infectivity. For those electrotechnologies that showed promise, additional studies would be conducted using animal infectivity, thought by the U.S. EPA and North American researchers to be the ‘gold standard’ for demonstrating loss of infectivity in disinfection trials. The vendors supplying equipment for assessment were asked to “give it their best shot a/k/a providing a high dose” as this was an initial demonstration and the electrotechnology had to pass this hurdle for future consideration.

Two electrotechnologies appeared to be successful at oocyst inactivation - pulsed UV and advanced UV (low pressure over an extended exposure period). Pulsed UV (Innovatech, Inc.) at 1900 mJ·cm⁻² in a 10 gpm system provided >2 logs inactivation and the CID at 8,748 mJ·cm⁻² at 400 gpm full scale provided >4-logs oocyst inactivation. Initial studies showed promise with the in vitro surrogates and animal studies supported the results. Conventional low pressure UV (180 mJ·cm⁻²) appeared to have no effect on oocyst viability as measured using the surrogates alone, and based on data accrued with in vitro viability assays, Clancy et al (1998) reported that it was ineffective for oocyst inactivation.

At this same time, Clancy et al (1999) were involved in another AWWARF study (in conjunction with the United Kingdom Drinking Water Inspectorate (DWI)), to determine which of the four in vitro surrogate assays (DAPI/PI, SYTO®-9, SYTO®-59, and maximized in vitro excystation) most closely predicted results of animal infectivity. The objectives were to identify one or more in vitro surrogates that correlated well with animal infectivity, allowing disinfection research to continue using an inexpensive, faster, but equally reliable assay. The study was large with a robust statistical design, and involved two U.S. and two U.K. labs so that identical trials could be conducted in both countries. The results of the UV trials using the Innovatech pulsed UV system showed that all four of the surrogate assays significantly underestimated oocyst inactivation when compared to oocyst inactivation as measured by mouse infectivity. It appeared that doses as low as 40 mJ·cm⁻² (fresh oocysts) and 14 mJ·cm⁻² (aged oocysts) provided over 2-logs inactivation by mouse infectivity while the surrogates showed less than 0.5-log inactivation. Further work on this project has shown that this phenomenon (lack of correlation between the in vitro assays and animal infectivity) extends to oocysts exposed to ozone as well.
At this same time, Finch et al. (1997), examining sequential chemical disinfection, also conducted experiments with UV light, and used mouse infectivity to assess inactivation. The unit used was a bench scale low pressure system and they calculated that UV doses of 1280 and 41,400 mJ/cm² were applied. The oocysts were stirred in a batch reactor which was a Wheaton glass bottle, with UV applied 11 cm from the glass. Finch et al (1997) reported “no detectable loss of infectivity” but also mentioned that the “data were not comparable with oocysts exposed in thin layers in a Petri dish or membrane filter”. They went on to say that their “results are consistent with those reported by others where UV is not a very effective control of cysts or oocysts”. These seemingly inconsistent results to those of Clancy et al (1998) can be easily explained. In the Finch experiments, the UV never reached the oocysts as glass is an effective barrier to UV light. Although high UV doses as calculated by lamp output were thought to be delivered, in reality no UV reached the oocysts.

By now the Clancy Environmental Consultants, Inc. (CEC) team – Jen Clancy, Marilyn Marshall (University of Arizona), Zia Bukhari, and Tom Hargre - had conducted dozens of UV inactivation studies since 1995 using mouse infectivity and the in vitro surrogate, and were feeling confident that UV was very effective for Cryptosporidium oocyst inactivation. The next work focused on medium pressure UV, and work was conducted in conjunction with Calgon Carbon Corporation, using bench-scale collimated beam (CB) units, followed with a demonstration project at >200 gpm using the Calgon Carbon Corporation Sentinel™ demonstration-scale unit. The objectives of this work were to:

• Determine the UV dose required from medium-pressure lamps for 3- to 5-logs inactivation of Cryptosporidium oocysts in finished water.
• Establish a dose-response curve for oocyst inactivation by using a CB apparatus at bench scale.
• Conduct demonstration-scale studies and compare oocyst inactivation data from the bench-scale studies to data obtained with the demonstration-scale studies.
• Compare the in vitro surrogate assays versus animal infectivity assays.

Oocyst viability was assessed using in vitro (DAPI/PI and maximized in vitro excystation) and in vivo (neonatal mouse infectivity) assays. Using the neonatal mouse infectivity assay, the bench-scale studies showed >4-logs inactivation at UV doses as low as 41 mJ/cm²: the in vitro surrogate assays showed little or no inactivation at this and higher UV doses. The in vitro assays, which indicate oocyst viability, grossly overestimated the UV doses required to prevent oocyst infection in susceptible hosts. The demonstration studies, carried out under the National Sanitation Foundation (NSF)/EPA Environmental Technology Verification (ETV) program, provided results that agreed with the bench-scale results and showed that a UV dose as low as 19 mJ/cm² provided 3.9 logs inactivation of Cryptosporidium oocysts (Bukhari et al., 1999). Recent work by Finch and Belosevic (unpublished data) using CB studies appears to support the Bukhari et al. (1999) data. Additional work on medium pressure UV conducted at CEC using CB bench scale studies has shown that doses in the range of 6 to 9 mJ/cm² provide oocyst inactivation at >3.5-logs (unpublished data).

Where Are We Now and Where Are We Headed?

As usually is the case, what we know is much less than what we need to know. Regarding the situation of Cryptosporidium oocyst inactivation using UV light, the following statements appear to be true:

✓ Oocysts (the Harley Moon isolate) are highly susceptible (3- to 4-logs inactivation) to UV light (MP and pulsed) at relatively low doses (10 to 20 mJ/cm²) using the neonatal mouse (CD-1) assay.
✓ Advanced UV is highly effective at high doses (8,748 mJ/cm²); no information is available for this system at lower UV doses.
✓ Animal infectivity is needed to determine inactivation; the in vitro surrogates seriously underestimate inactivation.
✓ These generalities apply to filtered drinking water, as all experiments have been conducted using this matrix.
✓ UV is not a new technology and there is a high level of experience in disinfection applications for both water and wastewater worldwide.

What we don’t know is all the rest. Issues to be resolved on the biology of Cryptosporidium include:

• Are there strain differences or differences based on oocyst production, processing, or storage that affect UV susceptibility?
• Are there differences in the mouse model (different mouse strains, infectivity assays, etc.) which need to be assessed?
• Is oocyst reactivation, as seen in bacteria, possible? If so, what are the minimal UV doses at which this can be prevented?
• Can UV disinfection of surrogate organisms (MS2 coliphage, Bacillus subtilis, etc.) be used to predict effectiveness against Cryptosporidium?
• Can alternatives to animal infectivity studies be used to demonstrate disinfection effectiveness, allowing significantly more research to be conducted?

Issues to be resolved on the engineering/operations side include:
Are oocysts which penetrate conventional filters shielded by persistent coagulant or other particles, thereby reducing the effects of UV irradiation?

How can UV systems best be monitored to ensure consistent and effective operation in varying water quality or over time?

It appears that UV light may be able to provide control of Cryptosporidium in drinking water. However, there is never a panacea in drinking water treatment. If UV proves to be as effective for Cryptosporidium control as the early studies indicate, it will be simply an additional tool for water suppliers to use. It is now our challenge to make this happen.

REFERENCES


Some minerals fluoresce in various hues and intensities when irradiated by the appropriate wavelengths of ultraviolet radiation. Such minerals can be found in mines, mine dumps, road cuts, quarries, or just dug from natural bedrock exposures. Generally, observing the fluorescence in these minerals requires a UV light source that has an ultraviolet-transmitting visible-absorbing filter over the UV lamp, since all UV sources (other than lasers) produce enough visible light to wash out the fluorescence in most cases. Likewise, normal room light levels and always sky or direct sunlight will wash out mineral fluorescence, thus fluorescent minerals must be viewed in darkness, usually the darker the better. However, under good viewing conditions, many fluorescent minerals can be visually striking, seeming to blaze with intense colors and sometimes dramatic color combinations. Displays of such minerals can be quite impressive. For this reason, there is a growing subgroup of minerals enthusiasts who specialize in putting together fluorescent mineral collections.

Of the 3600+ different known mineral species, about 15% have been identified as being fluorescent at one time or another. The cause of fluorescence in minerals is often complex, depending on the presence of activators (intrinsic, impurity, or defect), coactivators, crystal structure, and presence or absence of quenchers. Some minerals like willemite and scheelite are fluorescent much or all of the time. Others, such as calcite, frequently fluoresce. Others only fluoresce from certain specific locations -- prehnite is a case in point. In addition, a mineral species that fluoresces with a specific hue and intensity when it comes from one location may fluoresce in a totally different manner if it comes from another location. For example, calcite from different locations has been found to fluoresce blue, red, orange, cream, and green under SW UV. And sometimes the fluorescent intensity of a mineral is so dim that it can be observed only in total darkness after an observer's eyes have become dark-adapted.

Most fluorescent minerals will show up best under a limited band of UV wavelengths. The most popular UV wavelength among fluorescent mineral collectors is UV-C at 253.7 nm, usually just referred to as short wave or SW. These SW lamps are manufactured as germicidal lamps, but are admirably suited for revealing mineral fluorescence when used with a suitable ultraviolet-transmitting visible-absorbing SW filter. The next most popular wavelength is a UV-A (352 or 368 nm depending on a lamp's phosphor coating) which usually is referred to as long wave or LW. The phosphor lamps used for this often are called "BL" or "Blacklight." The "Blacklight Blue" lamps used to illuminate fluorescent posters produce UV-A suitable for viewing some fluorescent minerals, and have the advantage that they come with an integral filter. However, the integral filter in "BLB" type lamps is quite thin and lets substantial deep blue light through, which can alter the apparent color of fluorescent responses. For this reason, most fluorescent mineral collectors prefer to use the "BL" type lamps with an external filter. Finally, some collectors recently have become interested in minerals which fluoresce best under UV-B lamps with phosphors peaking at 306 to 312 nm.

In some cases, minerals will fluoresce one hue under one UV band and other hue under another band. Some calcites, for example, will fluoresce blue under SW and pink under LW. Interestingly, the small difference in UV-A wavelength present in the lamps of different manufacturers can change the hue of a mineral's fluorescence substantially. For example, the same calcite that fluoresces a "straw" color under 352 nm will fluoresce a very distinct "pink" color under 368 nm.

There are various mineral museums that have displays of fluorescent minerals, a few of these are the Franklin Mineral Museum in Franklin, NJ; the Bob Campbell Geology Museum at Clemson University in Clemson, SC; the Carnegie Museum of Natural History in Pittsburgh, PA; and of course, The National History Museum (Smithsonian) in Washington, DC. A number of very noteworthy personal collections also have been assembled.

The Fluorescent Mineral Society, Inc. (FMS) is a 28 year old organization of about 465 members world-wide which is intended to provide a meeting ground for all persons interested in fluorescent minerals, either as a hobby or professionally. Members' expertise varies from professional mineralogists to amateur collectors. There are members in about 45 of the states and 18 other countries. The purposes of the FMS are to:
1. Share knowledge and experience in collecting, identifying, and displaying fluorescent minerals as well as minerals displaying other forms of luminescence such as phosphorescence, triboluminescence, and thermoluminescence.

2. Help organize field trips, seminars, research, displays, and exchanges of luminescent minerals, and to disseminate information about luminescent minerals.

3. Encourage interests related to fluorescent minerals such as photography of fluorescent minerals, the study of other luminescent minerals, and the various uses of ultraviolet lights.

This last purpose is the one by which FMS would be interested in collaboration with the International Ultra Violet Association. The FMS sends a newsletter called *UV WAVES* to its members six times a year, and a technology publication, *The Journal of the Fluorescent Mineral Society* about every year or so. The web site of the FMS is: www.uvminerals.org. Contact with the organization also can be made through Dr. Rodney K. Burroughs, the President, at: 71543.3343@compuserve.com.

My company, UV SYSTEMS, manufactures a special line of SW and LW UV lights. Our SuperBright 2000SW is the most powerful SW hand-held UV light available today. Our SuperBright 2010LW is one of the most powerful LW hand-held UV lights available. For specific information about UV lights contact me at: (425) 228-9988, or by e-mail (see article heading) or visit my web site at: www.uvsystems.com

We at FMS welcome the formation of the IUVA and wish it the very best success in the years to come.

**What is UV Dose? How Is It Determined?**

James P. Malley, Ph.D.

UV dose commonly refers to the product (Ixt or IT) of the average UV irradiance (I) and the theoretical contact time or reactor residence time distribution (T). Typical units for UV irradiance are mW/cm² and typical units for contact time are seconds. Thus the typical units for UV dose are mW-sec/cm² or (since 1 mW-sec = 1 milli-Joule) mJ/cm².

In bench-scale studies which often use batch liquid, collimated beam test equipment, the average UV irradiance usually is determined by making several measurements at key locations within the UV beam using a UV radiometer calibrated with NIST standards and the contact time is the time the batch liquid has been irradiated by the beam as measure by stopwatch.

Much of the UV data reported in the literature is based on these batch, bench-scale, collimated beam studies.

The reliable determination of UV dosage for continuous flow pilot or full-scale systems is much more difficult. The UV irradiance often is determined by in-line UV sensors (and/or calibrated portable radiometers) and the contact time usually is calculated based on theoretical hydraulic parameters. Although it would be ideal to measure the true residence time distributions of the flowing UV reactor fluid using something like tracer studies, the short residence times of UV reactors (4 to 12 seconds at design flow) make tracer studies difficult if not impossible to perform.

Several projects have used the inactivation data from biological surrogates with known UV dose-response behavior (e.g., *B. subtilis* spores or MS-2 bacteriophage virus) spiked into the UV reactor to determine UV dosage -- this presently is the method favored by the UV Team. Other projects have used theoretical, mathematical models which combine hydraulic components and UV irradiance estimation components to calculate the UV dose delivered by a given reactor. The complexities of determining and understanding UV dosage increase as polychromatic light sources such as medium pressure and pulsed UV lamps are used. As indicated above, additional research in the area of UV dosage understanding is on-going.
Upcoming Meetings

.............. 1999 Meetings ............

Shanghai WEP '99 Water & Environmental Protection Exhibition, Shanghai, China, June 9-11, 1999. Contact: (USA) Tel: 800-605-2765.


Removal of Humic Substances From Water, Trondheim, Norway, 24-25 June 1999. Contact: Prof. Hallvard Ødegaard, Dept. Hydraulic and Environmental Engineering, NTNU, N-7034 Trondheim, Norway. Tel: +47 73 59 47 59; Fax: +47 73 59 05 44; e-mail: Hallvard.odegaard@byggntnu.no


Institute in Drinking Water Treatment, Hotel Northampton, Northampton, MA (USA), August 2-4, 1999. Contact: Jodi Ozdarski, Institute Secretary, Environmental Engineering Program, Dept. of Civil and Environmental Engineering, Univ. of Massachusetts, Amherst, MA (USA) 01003-5205.

1999 Energy Efficiency Forum, San Diego, CA (USA), August 29-31, 1999. Contact: Laura Boland, 1421 So. Sheridan Road, Tulsa, OK 74112-6119; Ph.: 918-831-9179; Fax: 918-831-9776; lboland@pennwell.com


8th IAWQ Conference on Design, Operation and Economics of Large Wastewater Treatment Plants, Budapest, Hungary, 6-9 September 1999. Contact: TRIVENT Conference Office, Szamócà u. 6/b, H-1125 Budapest, Hungary; Tel/Fax: +36 1356 6240; e-mail: trivent@mail.elender.hu; http://www.elender.hu/trivent


XXII World Water Congress (IWSA AIDE) and Exhibition, Sheraton Buenos Aires, Argentina Sept. 29-23, 1999. Contact: IWSA, 1 Queen Anne’s Gate, GB-London SW1H 9BT, UK. Tel: +44 171 957 4567; Fax: +44 171 222 7243. e-mail: iwsa@dial.pipex.com. Includes a session on Design for Cryptosporidium removal.


Watertech '99, Microelectronics Water, Portland, OR, USA, Oct. 5-7, 1999. Contact: Miriam Slejko, Tel: 303-973-6700; Fax: 303-973-5327; water@talloaks.com; www.talloaks.com


WEFTEC '99, New Orleans, LA, October 9-13, 1999. Contact: Water Environment Federation: Tel: 1-800-666-0206 (U.S. and Canada) or 703-684-2452; Fax: 703-684-2492; e-mail: confinfo@wef.org


Environ/Watertec India '99, Bombay, India, Nov. 18-22, 1999. Organized by Messe Düsseldorf Int'l. Contact: Tel: (USA) 312-781-5180.

Watermex Asia '99, Suntec Centre, Singapore, Nov. 30-Dec. 3, 1999. Call: (UK) +44 (0) 171-862-2080.

Wattech '99, Power & Petrochemicals Water, Houston, TX (USA), Dec. 1-3, 1999. Contact: Miriam Slejko, Tel: 303-973-6700; Fax: 303-973-5327; water@talloaks.com; www.talloaks.com

............. 2000 Meetings ..........

Technology Expo and Int'l. Symposium on Small Drinking Water and Wastewater Systems, Phoenix, AZ, January 12-15, 2000. Contact: Dr. Joseph Cotruvo, NSF International, Ph. 202-289-2140; Fx 202-289-2149; cotruvo@nsf.org; or H. Diane Snyder, RWREF, Ph. 505-843-9119, Fx 505-224-9119; rwref@nm.net


Xth IWRA World Water Conference, Melbourne, Australia, 11-17 March 2000. Contact: ICMS Pty., 84 Queensbridge Street, Southbank, Victoria, Australia 3006. Tel: +61 3 9682 0244. Fax: +61 3 9682 0288; e-mail: worldwater@icms.com.au


Water 2000, Auckland, New Zealand, 17-25 March 2000. Contact: New Zealand Water & Wastes Assoc., P.O. Box 15-974, New Lynn, Auckland 1232, New Zealand. Tel: +64 9 827 5757; Fax: +64 9 827 2003; e-mail: water@nzwwa.org.nz


9th National Conference on Drinking Water, Regina, Saskatchewan, May 16-18, 2000. Contact: <admin@cwwa.ab.ca> Call for Papers – abstracts due June 30, 1999.

2nd Int'l. Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey Conference Center, Monterey, CA, USA, 22-25 May 2000. Contact: Karl Nehring, Battelle, 505 King Avenue, Columbus, OH 43201-2693; Tel: 614-424-6510; Fax: 614-424-3667; nehring@battelle.com

H₂O AccadueO 2000, Int'l. Exhibition on Water Technology, Ferrara, Italy, 24-27 May 2000. Contact: Paola Cestari, Ferrara Fiere Srl, Via Bologna, 534, 44040 Chiesuol del Fosso (FE), Italy, Tel. +39 (0)532-900713; Fax: +39 (0)532-976007; pcestari@ferrarafiere.it

ECWatech-2000 Water: Ecology and Technology, Moscow, Russia, May 29 - June 2, 2000. Contact: SIBICO Int'l. Ltd., Tel: 7-095-975-5104; Fax: 7-207-6310; e-mail: sibico.int@gb23.relcom.ru


Paris 2000 Conference -- 1st World Congress of the Int'l. Water Association (IWA), Paris, France, 3-7 July 2000. 20th Biennial IAWQ Conference; 8th World Congress of the ISWA; and a Specialized Conf. of the IWSA/AISE. Contact: Paris 2000 Conference, c/o AGHTM / CFRP, 83 Ave Foch, BP 3916, 75761 Paris cedex 16, France; Tel: +33 1 53 70 13 53; Fax: +33 1 53 70 13 40. Call for Papers: Manuscripts (not to exceed 8 pages) are due by July 1, 1999 -- info1@iawq.org.uk Web-site: http://www.iawq.org.uk Poster Proposals (not to exceed 4 pages) due 15 Jan. 2000.


Recent Research Items

AWWARF/EPRI Crypto Report Available

The final report for an AWWARF/EPRI funded project on "Innovative Electrotechnologies for Cryptosporidium Inactivation" has been published. Key researchers on the project were Clancy Environmental Consultants' John Dyksen (formerly of Malcolm Pirnie, now with United Water) and Marilyn Marshall (University of Arizona). The researchers have presented and published several papers related to the project. The final report can be obtained through EPRI/CEC (Keith Carns or John Murphy - jmurphy@epri.com) or AWWARF (Elizabeth Kawczynski - ekawczynski@awwarf.com). This report indicates that the Safe Water Solutions Cryptosporidium Inactivation Device (SWS-CID) and a pulsed UV unit produced by Innovatech, Inc. were the most promising technologies for Cryptosporidium inactivation. Another important outcome of the work was the finding that the effectiveness of UV irradiation for inactivation of protozoan cysts cannot be determined accurately through excystation or vital dye studies. It appears that these techniques grossly underestimate the degree of inactivation which is produced by UV. As a result, animal infectivity or perhaps emerging cell culture techniques must be used to evaluate UV inactivation effectiveness.

EPA/NSF ETV UV Project Reported

A U.S. EPA/NSF International, ETV Program project "Performance Evaluation of Sentinel™ Ultraviolet Tower for Inactivation of Giardia and Cryptosporidium" has been reported on at several conferences by Clancy Environmental Consultants and/or by Calgon Carbon Corporation (maker of the Sentinel). This study shows promising results -- that continuous wave medium pressure UV can inactivate Cryptosporidium oocysts at cost-effective UV dosages. The study did not show that the same device was effective for Giardia lamblia cysts, but only excystation and vital dyes were used to evaluate cyst viability, making it difficult to determine effectiveness of UV for Giardia. The final report for this project is undergoing peer review by third party researchers and by U.S. EPA and should be available soon. Contact Bruce Bartley (bartley@nsf.org) at NSF International for more information.

AWWARF/EPRI UV Project Progress

An AWWARF/EPRI project (1997-1999) "Full-Scale Implementation of UV in Groundwater Disinfection Systems" is being performed by the Univ. of New Hampshire’s UV Team (Malley-PI), Indianapolis Water Company, South Berwick (ME) Water District, Black and Veatch (consulting engineers) and Trojan Technologies. This project is the third in a series of projects performed by the UV Team addressing key issues of UV implementation in drinking water treatment. Several presentations are planned for the AWWA Annual and AWWA WQTC Conferences in 1999. Current project information as well as final project reports from the previous two UV Team projects can be obtained from Albert Ilges (ailges@awwarf.com) at AWWARF.

MP and Pulsed UV Disinfection Systems Status

An AWWARF project (1998-2000) "Disinfection Efficiency and Dose Measurement for Medium Pressure and Pulsed UV Disinfection Systems" is being performed by UNC-Charlotte (Linden, Co-PI) and MWDSC (Mofidi, Co-PI). The goals of the project are to develop better UV dose determination methodologies, especially for polychromatic light sources such as medium pressure UV and pulsed UV, as well as to examine the effectiveness of UV for inactivating pathogens. The project researchers recently have prepared their first progress report and information can be obtained from Kim Hout Garrity (khgarrity@aol.com) at AWWARF.

EPRI Pulsed UV Project

Part of a large multi-component EPRI project at the MWDSC is examining pulsed UV for drinking water disinfection using Innovatech, Inc. pulsed UV equipment. Further information on this project can be obtained from John Murphy (jmurphy@epri.com) at EPRI.

Full-Scale UV Equipment Evaluations

AWWARF recently has approved a Tailored Collaboration to examine the SWS-CID and Sentinel equipment in full-scale at the North Shore Water District (WI). The project team includes: NSWD, Carollo Engineers, Clancy Environmental Consultants, the UNH UV Team, University of Wisconsin, Rice University, Safe Water Solutions and Calgon. The project has not begun officially (as of March 1999), but information related to objectives and planned scope can be obtained from Elizabeth Kawczynski (ekawczynski@awwarf.com) at AWWARF.

(Excerpted from UNH UV Mail, March 1999)
Abstract -- Decomposition of 2-chlorobiphenyl (2-CB) in the systems of UV/TiO₂, UV/oxidant and UV/TiO₂/oxidant (i.e., H₂O₂, S₂O₅₂⁻ and IO₃⁻), were investigated. The addition of inorganic oxidants to the UV/TiO₂ system showed no rate-enhancing effects for the degradation of 2-CB with oxidant concentration of 10⁻³ and 10⁻² M and TiO₂ concentration of 25 mg/L. The negative effect of oxidants on the heterogeneous oxidation was demonstrated. Homogeneous photooxidation seems to dominate over the parallel heterogeneous process when both TiO₂ and oxidants are present.

Tertiary Treatment Using Microfiltration and UV Disinfection for Water Reclamation

Domène Jolis, Robin Hirano, Paul Pitt


Abstract: Microfiltration and UV disinfection are two alternative technologies for water reclamation. The results of a pilot study combining these two processes are presented. In addition to producing filtrate turbidities averaging 0.06 nephelometric turbidity units, microfiltration was an effective barrier to pathogens, demonstrating average log reductions of 4.5 for total coliforms and 2.9 for MS2 bacteriophage. Ultraviolet disinfection following microfiltration reliably met the California Wastewater Reclamation Criteria (Title 22) total coliform standard of 2.2 colony-forming units/100 mL at a UV dose of 450 J/m². The MS2 bacteriophage standard, which requires a 5-log reduction, was achieved by microfiltration and a UV dose of 880 J/m². A model of the kinetics of inactivation of MS2 bacteriophage was used in further analysis of disinfection data. The model indicated that considerable backmixing occurred in the pilot UV disinfection unit, and observed UV doses could be reduced with improved hydraulics.

Treatment of Gas-Phase Volatile Organic Compounds (VOCs) by the UV/O³ Process

Shen, Y.S. and Young, Ku


Abstract: The decomposition of several gas-phase volatile organic compounds (dichloromethane, chloroform, carbon tetrachloride, 1,2-dichloroethane, 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane, benzene, toluene, and o-xylene) in air streams by the UV/O³ process was studied. The addition of ozone apparently improved the removal of VOCs by the UV/O³ process, and excessive ozone reduces the treatment efficiency of VOCs. The enhancement of UV light intensity promotes the decomposition of VOCs more effectively than the supplement of ozone. The mineralization and dechlorination of chloromethanes and chloroethanes by UV photolysis can be effectively achieved in the presence of ozone and were affected by the number of chlorine atoms substituted on the molecules. The hydrogen abstraction from the VOC molecules by hydroxyl radicals was inferred to be the major degradation pathway for the decomposition of VOCs.

Water Treatment of Sterilizers in the Food Industry

P. Scheidel, and H.P. Tost


Treatment of process water for sterilization equipment in food canneries is discussed with reference to: types of sterilizer (batch, continuous, rotary and spray types); the importance of process water quality in sterilizers; aims of water treatment; recycling of water; prevention of growth of microorganisms in process water for sterilizers (use of chlorine, chlorine/bromine combinations, ClO₂, ozone or UV irradiation); softening of process water; decarbonation; degassing; removal of salts; and chemical treatments for improvement of process water quality.
Abstract: Three advanced oxidation processes involving hydrogen peroxide, ozone, and ultraviolet (UV)/visible light were investigated for their relative effectiveness in removing refractory organics from biotreated leachate collected at the municipal landfill site of the city of Stuttgart, Germany. The efficiency of each system was compared with respect to the total reduction and the rate of degradation observed in chemical oxygen demand (COD), total dissolved organic carbon (TOC/DOC), and total organic halogens (TOX/AOX) during eight hours of treatment at acidic pH. The effect of irradiation was investigated by operation of the systems under two different light sources, namely a low-pressure mercury UV lamp with a maximum emission at 253.7 nm, and a high-pressure mercury UV-visible lamp, emitting light from 200 nm to 470 nm, respectively. Hydrogen peroxide (H2O2)-added systems with or without ozone (O3) and used with high-pressure lamps were found adequate for reducing the TOX levels of the tested leachate to desirable limits. The greatest COD reduction was obtained with the H2O2-O3 system irradiated by low-pressure lamps. Ozonation without the addition of H2O2 proved inadequate for the tested leachate even under high irradiation intensity.

Advanced Wastewater Disinfection Technologies: Short and Long Term Efficiency.

Lazarova, V; Janex, M.L.; Fiksdal, L.; Oberg, C.; Barcia, I.; Pompepu, M.; Morris, R., editors

Health-Related Water Microbiology. International Symposium, Vancouver, BC CANADA 1998-06-21


Abstract: Advanced disinfection processes (peracetic acid, UV irradiation and ozonation) have been tested and evaluated through bench and pilot scale studies. 3 Log removals of total coliforms, fecal coliforms and fecal streptococci were achieved by 10 mg/L peracetic acid at a 10min contact time, by UV radiation at 35 mWsec/cm² and by ozone at 5 mg/L for 10 min contact time. Higher doses are required for virus removal by UV and PAA and especially for highly resistant viruses such as F-specific bacteriophage MS2. Ozonation has the advantage of having a strong effect on all types of bacteriophages and protozoa cysts even when low treatment doses and short contact times are applied. The results of this study demonstrated that evaluation of disinfection efficiency of ozone, UV and PAA depends on the criteria and methods employed. Standard method (plate count) results showed an important disinfection effect on culturability, while results from non-standard methods (respiratory activity and β-galactosidase activity assay) indicated less reduction of viable cell levels. Moreover, the results confirm that disinfectants act on bacteria in different ways. It has been clearly demonstrated that β-galactosidase activity is affected by PAA, while UV treatment has no or very limited effect on the enzyme activity. Even without sunlight reactivation, bacterial regrowth in seawater was observed after disinfection of sewage effluents. This study also shows that the biodegradability of sewage effluent for an E. coli strain was affected differently by the oxidative disinfectants ozone and PAA. Biodegradability therefore should be considered when evaluating the total disinfection efficiency.

Ultraviolet Disinfection: A Basic Primer

James R. Bolton and Larry Henke


Abstract: In a world of increasing concern for microbiological safety of our food and water, new microbes and diseases require new disinfection technologies. Contributing to the concern is the discovery that proven disinfection techniques, such as chlorination, may have side effects that interfere with the process, or generate new health concerns. Here we discuss the possibilities ultraviolet light offers in assuaging those worries as they relate to drinking water.

Deadly Pulses

Tom Marshall


Abstract: Research indicates that pulsed ultraviolet light systems may destroy waterborne pathogens more effectively than traditional disinfection systems.
Abstract: The kinetics of the decomposition of 2,4,6-trichlorophenol by ozonation, by Fenton's reagent reaction, and by a polychromatic UV radiation is investigated from experiments performed in a batch reactor. In each oxidation system, the degree of removal of the organic compound from water is evaluated and the influence of the operating variables is established. The ozonation process is conducted at pH=2 and in the presence of radical scavengers. Under these conditions the kinetic constants and reaction orders for the direct reaction between ozone and that organic compound are deduced by using a model based on the film theory. The oxidation by Fenton’s reagent (Fe²⁺ ion and H₂O₂), a generating system of hydroxyl radicals, leads to the evaluation of pseudo-first-order rate constants for the overall reaction and to the determination of the kinetic constant for the direct radical reaction. Finally, the quantum yields in the photodecomposition process are determined from the rate equation, with the radiation flow rates absorbed previously calculated by means of a radiation source emission model.

Aqueous Degradation of VOCs in the Ozone Combined With Hydrogen Peroxide or UV Radiation Process. 2. Kinetic Modeling

Beltrán, F.J.; Gonzalez, M.; Rivas, J.; Acedo, B.


Abstract: A kinetic model for the removal of trichloroethylene and trichloroethane from natural waters with ozonation processes has been proposed and tested at different conditions implying the presence of hydrogen peroxide or UV radiation. The model is constituted by the mol balance equations of the organochlorine compound, ozone (both in water and gas phases) and hydrogen peroxide and predicts the concentration of these substances with reaction time at different conditions. Main variables that affect the oxidation rate are gas flow rate (volumetric mass transfer and volatility coefficients), concentration of hydrogen peroxide and intensity of UV radiation. The kinetic model predicts reasonably well experimental concentrations of TCA during the ozonation at low gas flow rate (thus minimizing the importance of volatility) but overestimates the experimental concentrations when UV radiation or hydrogen peroxide are applied simultaneously to ozonation of TCE, especially at 20 L/h gas flow rate. The presence of natural substances of different carbonates can be the reason for these deviations because of their hydroxyl free radical scavenging potential character not accounted for in the kinetic model.
A New Dimension in UV Waste Water Disinfection with the TAK 55

- High Efficiency and Low Costs
  The WEDECO open channel UV system (type TAK) is the ultimate solution for waste water disinfection. WEDECO’s latest Spektrotherm UV lamp technology ensures high UV output, low power consumption, a small footprint and a lamp guarantee of 12,000 running hours.

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WEDECO is certified according to DIN ISO 9001/14001
The following electronic documents are presently available:

1. UV Bibliography (1998) - a list of publications on UV in drinking water compiled by Jim Malley.


Several times during the year the list of electronic documents related to UV that UNH-ERG has accumulated will be made available to the readers (of UV Mail) upon request. Authors wishing to add documents to our list should feel free to send electronic files to jim.malley@unh.edu for review and applicability. Copyrighted material cannot be included unless appropriate copyright waivers are provided by the author(s). To use the references, the person requesting a copy must be able to receive and read attached files that are MSWORD or WORDPERFECT compatible or provide a FAX number. Request references by their full citation in an e-mail message to jim.malley@unh.edu.

(Source: UNH UV Mail, March 1999)

Oxidative Treatment of High Explosives Contaminated Wastewater

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Abstract -- The oxidation of high explosives (HE), TNT, RDX and HMX, contaminated water has been studied under different conditions. Catalytic and advanced oxidation employing ultraviolet and hydrogen peroxide were investigated. Catalytic and non-catalytic wet oxidation of HE were carried out over a 4.45 wt% Pt/TiO₂ catalyst with a particle diameter of less than 105 μm in a batch reactor at moderate pressure (<35 atm) and temperature (<200°C). Ultraviolet photolysis in combination with hydrogen peroxide oxidation was carried out in a pyrex glass reactor with a total volume of 310 mL at ambient conditions. The irradiation in the photoreactor was obtained by a low-pressure mercury lamp that emits about 90% of its radiation at 254 nm with a 15 W power input. Catalytic and non-catalytic oxidation results indicate that the reaction rate is very much temperature-dependent, virtually pressure-independent, and mildly dependent on the amount of catalyst. The presence of catalyst resulted in about 20°C advantage in catalytic oxidation when compared to homogeneous wet oxidation. Also RDX/HMX oxidation was relatively easy without the presence of a catalyst at temperatures as low as 85°C and complete oxidation occurs at above 110°C in less than 30 min. Direct photolysis of RDX/HMX was accomplished in about 20 min, whereas TNT was the most stable compound and the presence of hydrogen peroxide was essential to reach total oxidation in a reasonable time.