civil
CANADIAN CIVIL ENGINEER
L'INGÉNIEUR CIVIL CANADIEN
2014 | MAY/MAI

- CSCE Conference | Congrès SCGC 2014 Halifax
- Sustainability: a water practitioner's view
- Impact of hydraulic fracturing on water
- Angus L. Macdonald Bridge

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Les contaminants émergeants dans l'eau

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That underscores the importance of the jobs we all do, day in and day out. Which is why CSPI created *In The Trenches* – an online industry newsmagazine for sharing information and new ideas. For many of us, its title may be a metaphor; but, it also reflects the reality that, regardless of whether we operate a backhoe, analyze water and soil, or sit at a computer creating things, we really are all in this together.

That's why CSPI and its members encourage everyone in the industry to openly share their news, knowledge, successes and insights of how to do things better for less. Sharing knowledge empowers us all to succeed in making a better Canada.

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L'INGÉNIEUR CIVIL CANADIEN

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Engineering in a Communicative Society

Not that long ago, or so it feels, I was working as a project engineer for the government of the Northwest Territories (GNWT). I had a project on Baffin Island in the community of Pangnirtung. I was stationed in Yellowknife. The project consultant was from Toronto. The contractor was from Montreal.

The distance for a direct flight between Yellowknife and Pangnirtung is 2,322 km. There are no roads. Based on the cruising speed of a DC 3 this was a day-long flight at a minimum, when a flight was available, and usually required an overnight somewhere. The option was to fly from Yellowknife to Edmonton and then to Ottawa for a connection to Iqaluit and finally to Pangnirtung… still requiring an overnight somewhere. It was not easy to get to "Pang," no matter how you did it.

I made a small splash when I figured out a way to process payment certificates for the Pangnirtung project with a one- to two-week turnaround time. Fax transmission, the newest communication technology, had come to the Northwest Territories. This was the early 1980s. Normal turnaround time for processing a payment certificate until then was measured in months. The process included sending information from the project site to the consultant's office in Toronto, followed by a certificate being sent to Montreal for the contractor's signature. Then the signed certificate came to Yellowknife to be processed by yours truly before finance cut a cheque. Acceptance of a faxed signature by the GNWT was a hurdle but finally approved.

Why am I telling you this story? Fast forward, 30 short years. I now have instant contact at a moment's notice around the world. The flow of information is not only instantaneous, it is continuous.

I openly confess to being social-media challenged. I do not understand or participate in Facebook, Twitter, blogging, or LinkedIn. I did learn to text but only do this in dark, inconspicuous corners so as to hide my flip phone from public view for fear of ridicule for using this technological dinosaur.

In this current media environment, it is our goal to raise the profile of CSCE and civil engineering in Canada. This requires a strategic communications plan that takes advantage of the multitude of media at our disposal. I have come to realize that social media communications has the potential to be one of the most effective, if not the most effective, means of achieving our goal. And with this I also realize it will be our young civil engineers who will be instrumental to our ability to be successful.

I recently attended an EIC board meeting representing CSCE. The "civils," as we were referred to, were acknowledged as demonstrating significant traction with a social media network (LinkedIn). I had to hide my phobia for a few moments and bask in the good work of our young civil engineers who were getting the credit for the leadership CSCE was demonstrating in this area.

In a recent meeting with our youth coordinator Amy Therrien and Young Professionals Committee chair Nigel Parker, I sat and listened to a flow of ideas about how CSCE needs to use social media to meet our visibility goals. While I may not have understood the entire conversation, I came to the realization that it is our young civil engineers who can and need to take a leadership role in this area. In fact, they already are! I think I need to go out and buy a smart phone. Someone is going to have to help me use it. ■

Young Professionals Committee meeting. Discussing social media perhaps? / Réunion du comité des jeunes professionnels.

Le génie dans une société de communication

Il n'y a pas longtemps, je travaillais comme ingénieur de projet pour le gouvernement des Territoires du Nord-ouest. J'avais un projet sur l'île de Baffin, dans la communauté de Pangnirtung. J'étais basé à Yellowknife. Le conseiller au projet était de Toronto. L'entrepreneur était de Montréal.

La distance, par avion, entre Yellowknife et Pangnirtung, était de 2 322 km. Il n'y avait pas de route. En se basant sur la vitesse de croisière d'un DC 3, il s'agissait d'un vol d'une journée, au minimum, lorsqu'un vol était disponible, et cela exigeait généralement de passer une nuit en route. La seule autre option disponible était de prendre l'avion de Yellowknife vers Edmonton et vers Ottawa, prendre un avion vers Iqaluit, et finalement vers Pangnirtung… ce qui exigeait encore une nuitée quelque part. Peu importe comment vous vous y preniez, il n'était pas facile d'aller à « Pang ».

J'ai attiré l'attention lorsque j'ai trouvé un moyen pour acheminer les certificats de paiement pour le projet de Pangnirtung dans un délai de une à deux semaines. La transmission par fax, la plus récente technologie de communication, est arrivée dans les TNO. C'était au début des années quatre-vingt. À l'époque, le délai normal pour traiter un certificat de paiement se calculait en mois. La procédure prévoyait l'expédition d'information depuis le chantier jusqu'au bureau du consultant, à Toronto, suivie de l'expédition du certificat à Montréal pour la signature de l'entrepreneur. Ensuite, le certificat signé se rendait à Yellowknife pour que j'y donne suite et que le service des finances émette un chèque. L'acceptation d'une signature par fax représentait un obstacle au niveau du gouvernement des TNO, mais tout fut finalement approuvé.

Pourquoi est-ce que je vous raconte cela ? Parce que trente brèves années après, j'ai un contact instantané avec le monde entier. L'information n'est pas seulement instantanée, elle est continue.

Je reconnais mes déficiences en matière de médias sociaux. Je ne participe pas à Facebook, à Twitter, aux blogues ou à LinkedIn, et je n'y connais rien. J'ai appris à texter, mais c'est quelque chose que je fais dans les coins noirs afin que personne ne voit mon vieux téléphone pliant, une antiquité qui ferait rire tout le monde !!! Dans un tel environnement, nous avons comme rôle de faire connaître la SCGC et la profession au pays, ce qui exige un plan stratégique de communication qui exploite la multitude de médias à notre disposition. Je me suis rendu compte que les médias sociaux pouvaient être l'un des moyens les plus efficaces, sinon le plus efficace, pour atteindre notre objectif. Par la même occasion, j'ai découvert que ce sont nos jeunes membres qui seront les instruments de notre succès en la matière.

J'ai récemment participé à une réunion du c.a. de l'ICI à titre de représentant de la SCGC. Les « civils », comme ils disent, sont reconnus comme profitant de façon importante d'un réseau social (LinkedIn). J'ai dû cacher ma phobie pendant quelques instants et jouir des réussites de nos jeunes professionnels qui méritent bien le crédit pour le leadership exercé par la SCGC dans ce domaine.

Lors d'une rencontre récente avec notre coordonnatrice avec les jeunes, Amy Therrien, et le président du comité des jeunes professionnels, Nigel Parker, j'ai pu écouter un flot d'idées sur la façon dont la SCGC doit utiliser les médias sociaux pour atteindre ses objectifs en termes de visibilité. Bien que je n'aie pas suivi toute la conversation, je me suis rendu compte que ce sont nos jeunes ingénieurs civils qui doivent exercer le leadership dans ce domaine. En fait, ils le font déjà ! Je dois sortir et aller acheter un téléphone intelligent. J'aurai besoin que quelqu'un m'aide à l'utiliser. ■

Newfoundland and Labrador Section Celebrates 30th Anniversary

Gordon Jin, P. Eng., FCSCE, FEC
FORMER PRESIDENT
CSCE (2009 – 2010)

Bing Chen, Ph.D., P.Eng., MCSCE
CHAIR, NL SECTION,
CSCE

This year marks the 30th anniversary of the CSCE Newfoundland & Labrador Section. Formed under the leadership of Dr. Jim Sharp, professor emeritus of civil engineering at Memorial University, the CSCE NL Section remains a vibrant presence and provides lifelong learning activities to the civil engineering community.

In August, the Section will hold its 2014 Annual General Meeting (AGM) to celebrate past achievements and develop a future strategy to support the CSCE's Vision 2020 of "Leadership in Sustainable Infrastructure." The Section is collaborating with three other professional societies on the organization of the International Conference on Marine and Freshwater Environments (iMFE) (www.nrpop.org/Web/iMFE2014) from August 6-8, 2014, in St. John's, and so the CSCE NL 2014 AGM will be held during this event. Technical sessions and exhibitions will be presented on topics such as environmental and water resources engineering, coastal engineering, infrastructure sustainability, cold region engineering, and policies and regulations.

This thirtieth year will be a year of change, a year of firsts, and a year of renewal for the Section. We will further strengthen, build and raise the profile of CSCE through promoting the advancement of excellence in civil infrastructure and cultivating the next generation of civil engineers within the province and beyond. It is an exciting and challenging time to be a civil engineer, as we have tremendous opportunities as well as a responsibility to address the needs of a growing world and an expectation to design and maintain civil infrastructure. ■

La section de Terre-Neuve et Labrador fête son 30e anniversaire

Gordon Jin, ing., FSCGC, FEC
ANCIEN PRÉSIDENT SCGC (2009 – 2010)
Bing Chen, Ph.D., ing., MSCGC
PRÉSIDENT, SECTION DE TNL, SCGC

Cette année marque le 30e anniversaire de la section de Terre-Neuve et Labrador de la SCGC. Créée sous leadership du professeur Jim Sharp, professeur émérite de génie civil à l'Université Memorial, la section de TNL de la SCGC demeure une présence vivante et offre des activités de formation permanente à la profession.

En août, la section tiendra son assemblée générale annuelle pour 2014 pour célébrer ses réussites et élaborer une stratégie pour l'avenir afin d'appuyer le plan « Vision 2020 » de la SCGC intitulé « Leadership en matière d'infrastructures durables ». La section collabore avec trois autres sociétés professionnelles à l'organisation du congrès international sur les environnements marins et d'eau douce (iMFE) (www.nrpop.org/Web/iMFE2014), qui aura lieu du 6 au 8 août, 2014, à St. John's. L'assemblée générale annuelle de la section pour 2014 aura donc lieu dans le cadre de cette activité. Des séances techniques et des expositions seront présentées sur des sujets comme le génie de l'environnement et des ressources en eau, le génie côtier, la durabilité des infrastructures, le génie en région froide, et les politiques et règlements.

Cette 30e année en sera une de changement, de premières, et une année de renouvellement pour la section. Nous allons affirmer et consolider la présence de la SCGC en faisant la promotion de l'excellence dans les infrastructures civiles et en cultivant la future génération d'ingénieurs dans la province et au-delà. C'est une ère de défis pour les ingénieurs civils, et nous avons d'énormes occasions ainsi que la responsabilité de combler les besoins d'un monde en croissance. Nous entendons bien maintenir la qualité de la conception et de l'entretien des infrastructures civiles. ■

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Conference Has Vibrant Young Professionals Program

Katelyn Freçon, EIT, B.Sc, AMCSCE

Over the past year we have been hard at work putting together another exciting Young Professionals program for the CSCE Annual Conference, which is being held May 28 - 31 in Halifax. We are looking forward to presenting a program that builds on our previous success and provides high quality programming for our Young Professional members.

The purpose of the Young Professionals program is to build on CSCE's strategic direction, "Growing with Youth," by providing services that target the specific career development needs of Young Professionals. Although this program is targeted at Young Professionals and Student Members, it is open to all conference attendees.

This year's program will include the following technical sessions:

- a career panel, including representation of public, private, academic, and entrepreneurial sectors;
- a three-part session on "Bridging the Gap," the growing division between the retiring generation and the younger generation. This will address direct and indirect implications on students and young professionals and society;

Young Professionals Pub Night at the 2013 Annual Conference in Montreal. / Soirée au pub des Jeunes professionnels au congrès annuel de 2013, à Montréal.

- a three-part session on "Designing for Durability," which will discuss what our role as civil engineers should be in designing for durability, and our environmental responsibility to the public versus fiscal responsibility to the client.

In addition to the technical sessions, we will tour the Alexander Keith's brewery, follow a ghost tour in downtown Halifax, and check out several of the local downtown establishments.

Some of these events will require RSVPs. Additional information will be sent to CSCE members and conference registrants via email prior to the conference. If you wish to receive these updates and invites please make sure to select this option when you register for the conference. Information will also be available on the conference website: www.csce2014.ca.

For more information, please contact the Young Professionals program coordinator, Katelyn Freçon (kfrecon@walkerprojects.com).

Excellent programme pour les jeunes professionnels au congrès

Katelyn Freçon, EIT, B.Sc, MASCGC

Au cours de la dernière année, nous avons élaboré un autre excellent programme pour les jeunes professionnels pour le congrès annuel de la SCGC, qui aura lieu à Halifax, du 28 au 31 mai 2014. Le programme repose sur nos succès antérieurs et sera d'une qualité qui plaira à nos jeunes professionnels.

Le but du programme des jeunes professionnels est basé sur l'orientation stratégique de la SCGC (« Croître avec les jeunes ») en offrant des services ciblés sur les besoins précis des jeunes professionnels. Bien que ce programme soit axé sur les jeunes professionnels et les membres étudiants, il est ouvert à tous les congressistes.

Le programme de cette année inclut les séances techniques suivantes :

- un panel sur les carrières, incluant des représentants du public, du privé, de l'université et des entreprises ;
- une séance en trois parties intitulée « Combler l'écart », portant sur l'écart croissant entre la génération sortante et la jeune génération. Cette séance portera sur les implications directes et indirectes sur les étudiants, les jeunes professionnels et la société;
- une séance en trois parties intitulée « Créer pour durer », qui portera sur notre rôle dans la création durable et notre responsabilité environnementale envers le public par opposition à notre responsabilité fiscale face au client.

En plus des séances techniques, nous visiterons la brasserie Alexander Keith's, nous ferons une tournée du centre-ville de Halifax, et nous irons voir plusieurs établissements du centre-ville.

Certaines de ces activités exigent une réponse. D'autres renseignements seront expédiés par courriel aux membres de la SCGC et aux inscrits, avant le congrès. Si vous désirez recevoir ces mises à jour et ces invitations, n'oubliez pas de cocher l'option pertinente lorsque vous vous inscrivez. Ces renseignements seront également disponibles sur le site web du congrès : www.csce2014.ca.

Pour avoir plus d'information, adressez-vous à la coordonnatrice du programme des jeunes professionnels, Katelyn Freçon (kfrecon@walkerprojects.com).

Wilcock Appointed Executive Director of the Corrugated Steel Pipe Institute (CSPI)

The CSPI Board of Directors is pleased to announce the appointment of Raymond Wilcock as its executive director, effective April 1, 2014. Mr. Wilcock replaces David J. Penny, who has assumed the role of Director Emeritus.

Over the past two decades, Mr Wilcock has held progressive, senior executive positions at several corporations, including those of: vice-president, general manager, vice-president operations and CFO at Armtec Limited, a diversified provider of materials and solutions to infrastructure markets.

"From the experience garnered during his various executive roles in our industry, Ray brings to CSPI exceptional knowledge and a deep understanding of all aspects related to the strategic position of our products in the infrastructure, agricultural, forestry and mining markets," says Kenzie MacPherson, president of Atlantic Industries Ltd. (AIL), a CSPI member company.

Mr. Wilcock earned his undergraduate B.Comm degree from Concordia University, followed by post-graduate F.C.M.A. and C.M.A. accounting designations from the Society of Management Accountants of Canada.

"I am extremely excited about tackling this new challenge and I look forward to renewing relationships as well as establishing new ones," says Mr. Wilcock. "As an industry veteran, I've worked closely over the years with CSPI and other industry bodies on a number of major projects, including serving on the MTO Gravity Pipe Design Guidelines Committee and on the Ontario Road Builders Association Board of Directors. One of my strengths is strategic planning and, as CSPI continues to evolve through technical innovation from R&D findings, I hope to channel those developments through aggressive marketing of new CSP products to educate the marketplace regarding their significant cost/benefits to owners," he concludes.

"I've known Ray for more than 30 years, and can assure you he's passionate about corrugated steel pipe and the heavy construction industry, and will bring vast knowledge and continued enthusiasm to CSPI," says David Penny, "and I look forward to working closely with him during our transition period."

The Corrugated Steel Pipe Institute (CSPI) is an impartial association representing Canada's corrugated steel pipe manufacturers that works with engineers, contractors and owners throughout Canada to provide information and technical support related to best practices and innovations for corrugated steel pipe and plate products. CSPI also encourages sustainable engineering practices and provides technical information and other essential resources to help owners reduce environmental impact, while delivering optimal soil/water management solutions for their stakeholders.

For more information about the Corrugated Steel Pipe Institute, visit cspi.ca, call 519-650-8080, or email info@cspi.ca

Student Organizations' Role in Civil Engineering Education

Charles-Darwin Annan, Ph.D., P.Eng., M.CSCE
CHAIR, STUDENT AFFAIRS, CSCE

Two civil engineering students from Laval University participated in the 15th Joint Architectural and Engineering Steel Structures Educators Conference, held on February 28 and March 1, 2014, in Quebec City. The biennial meeting is organized by the Steel Structures Education Foundation (SSEF) to provide a platform for Canadian university educators to brainstorm about teaching excellence in steel construction in Canada. It also aims to foster positive communications between architects and engineers at the academic level, and consequently in professional practice.

Speaking about their involvement and experience in the American ASCE/AISC Steel Bridge Competition, the leaders of the Laval Steel Bridge Team, Francis-Olivier Biron and Gabriel Cyr, impressed the educators with their passion and hard work in applying the steel design principles they learn in the classroom in such a high quality international competition. It quickly became evident that their participation in the competition has equipped them with very important skills which lend themselves to a successful civil engineering professional career. On the technical side, the students learn and engage in precise steel construction techniques such as welding, cutting and assembling.

According to the students, presenting a competitive team was attributed to their attention to the non-technical details, such as paying careful attention to competition rules and construction requirements, good quality control practices, efficient time and money management, effective planning and organisation, and other good project management practices. These are skills that surpass what is typically offered in a classroom setting.

It was encouraging for the educators to hear that the Laval team has consistently performed well over the years. The students were, however, quick to acknowledge as key to their successful participation the immense support from their department and faculty, as well as the steel industry. ■

From left to right: / De gauche à droite : Dr. Charles-Darwin Annan; Gabriel Cyr; Francis-Olivier Biron; Dr. Hellen Christodoulou (Canadian Institute of Steel Construction / l'Institut canadien de la construction en acier).

Le rôle des organismes étudiants dans la formation de l'ingénieur civil

Charles-Darwin Annan, Ph.D, ing., MSCGC
PRÉSIDENT, COMITÉ DES AFFAIRES ÉTUDIANTES DE LA SCGC

Deux étudiants en génie civil de l'Université Laval ont participé au 15e congrès conjoint des formateurs en architecture et en génie des charpentes qui a eu lieu du 29 février au 1er mars 2014, dans la ville de Québec. Cet événement biennal est organisé par la « Steel Structures Education Foundation (SSEF) » dans le but de fournir aux formateurs universitaires canadiens un forum pour échanger sur l'excellence dans la construction en acier au Canada et de favoriser la communication entre architectes et ingénieurs au niveau universitaire, et, par voie de conséquence, dans la pratique professionnelle. À propos de leur expérience au concours américain de ponts en acier de l'ASCE/AISC, les leaders de l'équipe de Laval, Francis-Olivier Biron et Gabriel Cyr, ont impressionné les éducateurs par leur passion et leur travail acharné dans l'application des principes du design pour l'acier appris dans les cours dans le cadre d'un concours international de si haut calibre. Il est rapidement devenu évident que leur participation au concours leur avait donné des compétences cruciales qui leur permettraient de bien faire dans leur carrière. Côté technique, les étudiants apprennent et pratiquent des techniques de construction de l'acier comme la soudure, le découpage et l'assemblage.

Selon les étudiants, ils ont pu présenter une équipe concurrentielle grâce à leur respect pour des détails non-techniques comme le fait que toute l'équipe portait une attention particulière aux règles du concours et aux exigences de la construction, au contrôle de la qualité, à la gestion efficace du temps et de l'argent, à l'efficacité dans la planification et la gestion, et à d'autres pratiques en matière de gestion de projet. Ce sont là des compétences qui dépassent ce qui s'enseigne normalement dans une classe.

Il était encourageant pour les éducateurs d'apprendre que l'équipe de Laval avait toujours bien fait au fil des ans. Les étudiants se sont empressés de souligner qu'un facteur clé de leur succès était l'immense appui de leur département et de leur faculté, ainsi que l'aide de l'industrie de l'acier. ■

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Angus L. Macdonald Bridge, Halifax

Recent view. The bridge's main span is more than 440-metres.

Photographs courtesy Halifax Harbour Bridges

NATIONAL HISTORIC CIVIL ENGINEERING SITES

Each year at the CSCE/SCGC annual conference, the society's National History Committee selects a site or project from the region in which the conference is being held as a national Historic Civil Engineering Site.

Through this program the committee aims to make the general public and engineers themselves more aware of the rich history and heritage of Civil engineering in Canada. A commemoration ceremony is held during the conference, and a plaque is placed on the chosen site. Since the program began in 1983, 63 national, international and regional sites have been designated.

At the conference this year, the Angus L. Macdonald Bridge (1955) and the Robie Street Reservoir (1913) in Halifax, Nova Scotia, (as featured here and on pages 14-15) will be designated, The Halifax Graving Dock and the Acadian Aboiteaux in New Brunswick are two other sites that are being designated this year.

The 1.3-kilometre suspension bridge across Halifax Harbour built in 1955 remains the third longest suspension bridge in Canada.

By Bruce Higgins, P.Eng.

The Angus L. Macdonald Bridge is a suspension bridge crossing Halifax Harbour. Completed in 1955, the bridge was named after the former Nova Scotia premier and federal minister of defence.

The bridge is a "sister" bridge to the Lions Gate Bridge in Vancouver and was also designed by Philip L. Pratley, one of Canada's foremost long-span bridge designers. The bridges have a similar design, which is most notable in the towers. The total length of the Halifax bridge is 1.3 km, including a 441-m main span. At the centre of the span the clearance under the bridge is 47 m, accommodating vessels using the north end of the harbour.

Engineering and historical significance

At the time of its completion, the Angus L. Macdonald Bridge was the second longest suspension bridge in Canada and the British Commonwealth, after the Lions Gate Bridge. After construction of the Pierre Laporte Bridge in Quebec City in 1970, the Macdonald Bridge remains the third longest suspension bridge in Canada.

Along with the bridge's original construc-

tion, advanced engineering is also involved in the major conversion carried out in 1999 and the upcoming deck replacement program.

It is one of two suspension bridges currently linking the Halifax Peninsula to Dartmouth in the Halifax Regional Municipality, after the addition of the A. Murray MacKay Bridge in 1970. The number of vehicles using the Angus L. Macdonald bridge has risen from three million per year in 1955 to about 15 million today, which underscores the tremendous influence it has played in the development of the metropolitan Halifax area.

The structure has come to be an iconic and distinctive landmark of the harbour and the regional municipality. It continues to play an important role in the community and is used for festivities, including bridge walks, road races and fireworks.


The bridge in context.

Rehabilitation in 1999

The superstructure was converted in 1999 from two lanes to three lanes with a pedestrian walkway and bicycle lane. To achieve the new cross section, the concrete bridge deck was replaced by a much lighter orthotropic steel plate deck, and the pedestrian and bike lanes were added to the exterior of the original deck width.

Other weight-saving measures included a lighter pavement design and lighter utilities such as a water main and fibre optic cables. As well, the bridge has a weight restriction of 3,200 kg, meaning that large trucks crossing the harbour must use the newer MacKay Bridge.

The 1999 work was essentially carried out at night such that daytime traffic could be accommodated throughout the 2-1/2 year construction period. The added third lane has reversible traffic, which facilitates traffic to Halifax in the morning hours and to Dartmouth in the afternoon. This modification increased the capacity of the bridge by 1,000 vehicles per hour. Other bridge improvements incorporated in the third lane project were upgrades to the approaches, the addition of an access structure, toll plaza modifications, and new equipment such as electronic tolling, variable message signage and surveillance cameras.

Prime consultant for the third lane project was O'Halloran Campbell Consultants Limited, in association with Hugh Pratley. The latter had collaborated with his father, Philip Pratley, on the original design.


Bridge tower detail.

Future changes

The bridge presently carries approximately 50,000 vehicles per weekday across Halifax Harbour, as well as accommodating pedestrians and cyclists. Plans are now under way for a complete replacement of the bridge deck system, extending the service life of the crossing. The project will include replacing the road deck, floor beams, stiffening trusses and suspender ropes on the suspended spans of the bridge, leaving only the original towers and main cables. The project will be completed mainly with evening bridge closures and several weekend bridge closures. The bridge will be open for the travelling public during weekdays.

Prime consultant for this project is Buckland & Taylor Ltd. ■

Robie Street Reservoir, Halifax

Engineering innovation has been used twice to replace the massive roof on a 1913 structure that survived the Halifax explosion.

By Bruce Higgins, P.Eng. and Carl Yates, P.Eng.

The Robie Street Reservoir in Halifax is a century old and remains in full service today. The prominent north-end Halifax landmark is owned and operated by Halifax Water, and is accessible from Robie Street.

The original reservoir was built in 1913 as a massive structure, albeit of rather conventional construction. It was one of the few structures in the area to survive the Halifax Explosion that occurred in 1917 less than one kilometre away.

However, the engineering and historical significance of the reservoir is largely due to the innovative rehabilitation methods carried out — twice. The roof replacement in 1946 was considered to be the largest of its type in the world at the time. Also, at that time, prestressed concrete was still a relatively new form of construction. The design, as well as the removal and construction methods and materials used, were specialized in nature and specifically adapted to the site conditions. The combination of the design, the construction, and the fact that it was design-build construction, made for a creative engineering solution.

The reservoir was designated as a landmark by the American Water Works Association in 1983.

Original 1913 structure

The 48-m diameter x 7.5-m deep reservoir was originally built in 1913. The 100-mm thick concrete roof was supported on a series

Historical photograph of the original reservoir under construction. Halifax Water

The Robie Street Reservoir in the north end of Halifax today, with its new geodesic lightweight roof installed in 2000. Halifax Water

of beams, which in turn were held up by 53 interior columns and the circular walls. The heavily reinforced walls varied in thickness from 450 mm to 900 mm.

Very little maintenance work was carried out, and by 1946 there was extensive deterioration. The roof slab and supporting beams were near complete failure. The sides were severely spalled both inside and outside, although there was no significant leakage. Replacement or major repairs were required.

The Water Commission had taken over operational control of water assets from the City of Halifax in 1945, including the reservoir, and it issued general specifications for the design and construction of an appropriate repair or replacement.

1946 rehabilitation

The methodology selected for the 1946 rehabilitation was to replace the roof with a prestressed concrete shell, together with extensive repairs on the walls. Both the roof shell and wall repairs were carried out with gunite. This method was well suited to the irregular shape of the wall repairs. For the dome, gunite provided higher compressive strength than conventional concrete and better shrinkage properties.

The walls were repaired in multiple layers from both sides, and in places the full wall thickness was replaced. The first phase of the roof construction included more than five days of round-the-clock continuous gunite operation to construct the dome, which was initially supported on falsework.

Subsequently, the prestressing ring was installed around the dome perimeter, which included five layers of prestressing wire. This was wrapped in a continuous spiral fashion around the dome perimeter, with a total length of nearly 70 km. The prestressed dome required less than half the quantity of concrete and reinforcing steel as the original reinforced concrete roof.

Roof replacement in 2000

The roof was replaced again in 2000 due to concrete deterioration. This required an intricate removal of the 500-tonne concrete dome. Controlled blasting was used to demolish the concrete roof in conjunction with the release of the post-tensioned concrete ring beam. The walls and floor were undamaged and were re-used to support the innovative new roof, a geodesic dome using aluminum panels and framing. This lightweight roof structure, which was designed by Bill Slater, P.Eng., again illustrates an unconventional and resourceful solution for the challenging site conditions. The project was believed to be the largest dome replacement in Canada. ■

CONFERENCE ORGANIZATION

The annual general conference is being held in conjunction with three specialty conferences; each reinforcing the conference theme of Sustainable Municipalities. The conference will provide researchers and practitioners with a wide variety of topics.

GENERAL CONFERENCE

For the general conference, papers have been submitted relevant to the following subject areas:

- cold regions engineering
- construction engineering
- engineering education
- engineering history
- engineering mechanics
- engineering materials
- hydrotechnical engineering
- sustainability
- sustainable infrastructure
- emerging technologies and innovation
- alternative project delivery

SPECIALTY CONFERENCES

For the three specialty conferences, papers have been submitted with relevance to municipal infrastructure in the following subject areas:

The 4th International Structural Specialty Conference:

- structural analysis and design
- structural materials
- durability and sustainability
- asset management
- construction case studies
- inspection, rehabilitation and evaluation

The 10th International Transportation Specialty Conference:

- design, construction and operation of highway facilities
- highway construction and management
- highway capacity analysis
- traffic control and devices
- intelligent transportation systems (ITS) applications in Canadian cities
- transportation planning and administration in Canadian large metropolitan areas
- sustainable municipal transit
- bituminous and concrete materials
- design model calibration and validation
- preservation and financing of municipal transportation infrastructure
- safety and safety audits
- pavement design and analysis techniques
- pavement and asset management
- pavement maintenance and rehabilitation
- low volume roads
- urban freight transportation
- effectiveness of the Canadian transportation industry
- energy, sustainability, and environment issues within Canadian municipalities
- transportation systems and changing climates

The 13th International Environmental Specialty Conference:

- water and wastewater treatment
- water pollution control engineering
- landfills and solid waste management
- environmental modeling
- contaminated soils remediation
- air pollution and control
- innovative environmental technologies
- contaminants of emerging concern
- storm water quality and management
- recycle, reuse and other sustainable environmental practices
- water distribution and wastewater collection

ORGANISATION DU CONGRÈS

Le congrès annuel se déroulera conjointement avec trois conférences spécialisées, chacune d'entre elles renforçant le thème de Municipalités durables du congrès. Le congrès offrira aux chercheurs et aux praticiens une grande variété de sujets.

CONGRÈS GÉNÉRAL

Pour le congrès général des communications ont été soumises sur les sujets suivants :

- Ingénierie des régions froides
- génie de la construction
- enseignement du génie civil
- histoire du génie civil
- génie de la mécanique technique
- génie des matériaux
- génie hydrotechnique
- durabilité
- infrastructures durables
- technologies émergeantes et innovation
- livraison de projet alternative

CONFÉRENCES SPÉCIALISÉES

Pour les trois conférences spécialisées, des communications présentant de l'intérêt pour l'infrastructure municipale ont été soumises sur les domaines suivants :

4e Conférence internationale spécialisée sur les structures:

- analyse et conception structurales
- matériaux de structures
- solidité et durabilité
- gestion des actifs
- études de cas en construction
- inspection, réhabilitation et évaluation

10e Conférence internationale spécialisée sur les transports:

- conception, construction et exploitation des installations routières
- construction et gestion des routes
- analyse de capacité des routes
- sécurité et vérifications sécuritaires
- signalisation routière
- systèmes de transport intelligents (STI) dans les villes canadiennes
- planification et administration des transports dans les grandes métropoles canadiennes
- transport en commun municipal
- matériaux bitumineux et de béton
- calibrage et validation des modèles de conception
- conception des chaussées et techniques d'analyse
- préservation et financement des infrastructures de transport municipales
- gestion des chaussées et des actifs
- maintenance et réhabilitation des chaussées
- routes à faible volume
- transport du frêt urbain
- efficacité de l'industrie canadienne des transports
- questions d'énergie, de durabilité et de l'environnement dans les municipalités canadiennes
- systèmes de transport et changements climatiques

13e Conférence internationale spécialisée sur l'environnement:

- traitement de l'eau et des eaux usées
- ingénierie du contrôle de la pollution de l'eau
- gestion des sites d'enfouissement et des déchets solides
- modélisation environnementale
- assainissement des sols contaminés
- pollution et contrôle de l'air
- technologies environnementales innovantes
- nouveaux contaminants préoccupants
- qualité et gestion des eaux pluviales
- recyclage, réutilisation et autres pratiques environnementales durables
- distribution de l'eau et collecte des eaux usées

Sustainable Infrastructure: A Water Practitioner's Perspective

Carl D. Yates, M.A.Sc., P.Eng.
GENERAL MANAGER, HALIFAX WATER

The term "sustainable infrastructure" invokes many different responses from the civil engineering practitioner depending on their technical knowledge or practical experience. In its simplest form, I consider sustainable infrastructure to be infrastructure that reflects full cost recovery. Many professional organizations and regulators have waxed eloquently on the definition of full cost recovery but one of my favourites stems from an InfraGuide[1] publication. The InfraGuide publication states that "full cost recovery supports a business plan and funding approach that suits local conditions, sustains water and sewage systems in perpetuity and maintains acceptable service levels for the users of the system." I especially like the word perpetuity as it recognizes infrastructure as a going concern and that it is designed to serve the users with a specific level of service. It recognizes that just as you retire some assets, more come on board to replace existing ones, in addition to bringing on new assets to accommodate growth and comply with the latest standards.

As a practitioner in the water, wastewater and stormwater field, I will attempt to describe this concept by outlining Halifax Water's approach to sustainable infrastructure as it relates to its stewardship responsibility to deliver services to customers within the Halifax Regional Municipality (HRM).

Halifax Water is the first regulated and integrated water, wastewater and stormwater utility in Canada (regulated in this context pertains to business operations: rates, rules and regulations). It is a body corporate municipal utility, generating approximately $130 million in annual revenue with assets of more than $2 billion.

Halifax Water was initially incorporated in 1944 as the Public Service Commission (PSC) of Halifax to look after the water system in the former City of Halifax after it was ravaged by two World Wars and the Great Depression. As the Halifax Regional Municpality grew, Halifax Water took on more and varied water and wastewater systems.

The piecemeal history of Halifax Water gives context to its development of a holistic and integrated plan for sustainable infrastructure. To ensure sustainable infrastructure, three questions need to be answered: What investments need to be made? How are the investments to be financed? Who is going to pay?

In 2008, with wastewater and stormwater assets now regulated pursuant to the Public Utilities Act of Nova Scotia, the Nova Scotia Utility and Review Board (NSUARB) ordered Halifax Water to conduct a formal cost of service study as the basis for the establishment of rates and charges to cover all three services delivered by the utility. Concurrent with this was the utility's desire to develop a long term plan to address the infrastructure deficit inherited with the 2007 asset transfer from HRM. As it turned out, the NSUARB felt a long term plan was also appropriate, and in 2010 ordered the utility to conduct an integrated resource plan (IRP). Recognizing the capital intensive nature of the IRP, the NSUARB also ordered the utility to conduct a review of an efficient capital funding mechanism (debt strategy) to ensure investments would be financed in the most cost effective way.

Photo: Halifax Water

An upgrade and an expansion of the wastewater treatment facility at Eastern Passage were undertaken to renew aging infrastructure, comply with new federal regulations and provide service to areas of growth.

The "Holy Trinity" drives the business

For Halifax Water, these three initiatives (IRP, debt strategy and cost of service study) became affectionately known as the Holy Trinity for their inherent connection to one another and their importance in making the utility a sound operation (see Figure 1). The IRP[2] answers the question of what investments have to be made; the debt strategy[3] answers the question of how to finance these investments and the cost of service study[4] determines who pays.

The IRP incorporated three primary strategic drivers: asset renewal, regulatory compliance and growth over a 30-year time frame. The 30-year period was chosen as it matched the time frame set out by the Canadian Council of the Ministers of the Environment (CCME) for the Municipal Wastewater Effluent Strategy which was entrenched in regulations under the federal Fisheries Act in 2012. Amongst other things, these regulations set national performance standards for municipal wastewater effluent and are arguably the biggest regulatory change since the Walkerton incident. The IRP projected that the util-

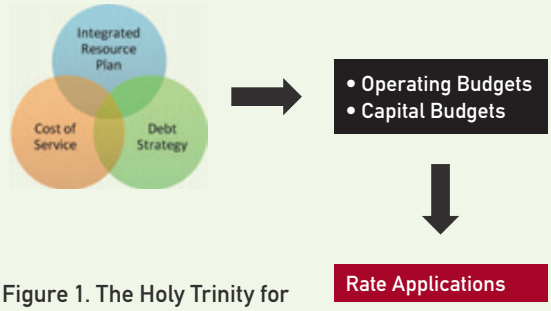

Figure 1. The Holy Trinity for sustainable infrastructure.

ity would have to spend $2.6 billion in net present value (NPV) from 2012 to 2042, with corresponding expenditure tied to the three strategic drivers, as indicated in Figure 2.

Concurrent with the development of the IRP, Halifax Water developed a debt strategy to ensure there was a financial framework for sustainable infrastructure. The debt strategy used the findings of the IRP as the backbone to determine the preferred approach to finance capital investments. Alternatives were developed taking into consideration different debt servicing ratios, project timing, interest rates, depreciation assumptions, external grant funding, development charges, rate assumptions and rate affordability. In the end, the preferred approach recognized a maximum debt servicing ratio (debt service charges to annual operating revenue) of 35% and a 60/40 debt-to-equity ratio. The preferred approach is indicated in Figure 3 and it can be seen that depreciation contributes the lion's share to infrastructure investments.

A word on depreciation, which, from a business and social perspective, is a wonderful thing. From a business perspective, it follows a pay-as-you-go philosophy to ensure asset renewal is funded directly from operating revenues and is a cornerstone for rate-regulated utilities. From a social perspective, it promotes intergenerational equity, which means we won't take unfair advantage of the customers who came before us and we won't burden future customers with more than their fair share. Intergenerational equity is crucial for utilities to understand as it forces long-term thinking, which is what sustainable infrastructure is all about.

And now the final question: who pays? The cost of service study developed by Halifax Water followed best practice manuals developed by the American Waterworks Association[5] and by the Water Environment Federation[6]. In addition to a cost of service for water and wastewater, Halifax Water also developed a cost of service for stormwater as a hybrid from the AWWA and WEF best practices.

The biggest revelation from the study was the recognition that stormwater charges should be based on runoff and not water consumption, with impervious surface used as the prime billing determinant.

At the heart of a cost of service study is the premise that those who derive the benefit should pay, with no cross subsidization between customer classes.

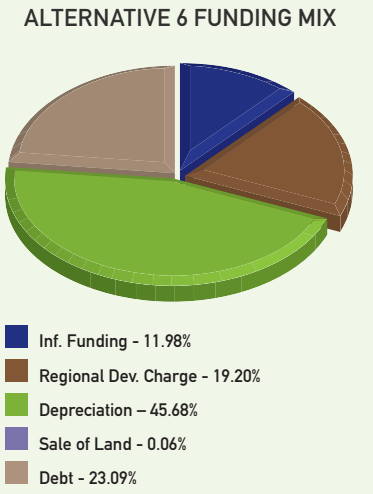

Figure 3. Debt strategy preferred funding scenario. This is the base scenario, plus full depreciation on assets, including donated and grant funded assets, federal/provincial funding for CCME compliance projects to upgrade WWTFs and reduce combined sewer overflows, and a Regional Development Charge that fully pays for growth. The average residential bill grows from 0.8% of median household income to 1.39% of median household income at the end of 30 years.

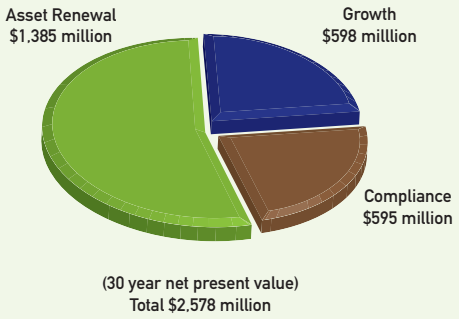

Figure 2. IRP expenditures by strategic driver

An important distinction about a cost of service study is that it is not a rate structure design. A rate structure design goes beyond the cost of service with many factors taken into account, as elaborated by James Bonbright et al[7]. These principles, amongst other things, include revenue adequacy, revenue stability, rate continuity, simplicity, and fairness by class.

In addition to maintaining the life of assets, there are many practices that can optimize performance while assets are in service. Two practices that reflect this notion are water loss control for water distribution systems, and inflow and infiltration reduction for wastewater collection systems. The former practice keeps the water in the pipes, while the latter keeps the water out. Ironically, in poorly maintained systems, the water leaking out of distribution mains often finds its way into collection pipes, as they are buried in the same trench. This culminates in increased operating costs as more energy and chemicals are wasted in this scenario than need be.

Halifax Water has had tremendous success with reducing leakage in its water distribution system. It was the first utility in North America to adopt the IWA best practice methodology in 1999. Since then, the utility has recaptured approximately 40 million litres per day of leakage which represents marginal cost savings of $600,000 per year[8]. The utility is now positioned to tackle the inflow and infiltration problem associated

Continues on page 29

Emerging Contaminants in Water Causing Challenges

Removal technologies will be required for these new contaminants.

Gopal Achari, PhD, P.Eng
CHAIR, CSCE, ENVIRONMENTAL DIVISION

Most of our water and wastewater treatment plants are designed to treat conventional pollutants. These treatments encompass turbidity removal and disinfection for water treatment, and grit and organic removal along with disinfection for wastewaters. Some plants go further, with units for softening, ammonia removal, phosphorus removal, and other processes.

Over the past decade or so, two relatively new issues have come to the forefront and are causing concerns for plant operators. These are: contaminants of emerging concern (CECs) and disinfection by-products (DBPs).

CECs are a loose group of contaminants that comprise pharmaceuticals and personal care products (PPCPs), household chemicals, pesticides, fire retardants, medicines used for animals, and many others. These are not completely removed in wastewater treatment plants and make their way into water bodies. Many CECs behave as endocrine-disrupting compounds and have known ecological impacts.

DBPs are a group of chlorinated and brominated compounds that are formed when chlorine is used for disinfection of waters that have high organic matter. DBPs include trihalomethanes and haloacetic acids, for which limits have been imposed by Health Canada, as well as other emerging DBPs such as halonitromethane and haloacetonitrile.

These different contaminants, although present at very low concentrations in our water bodies, are having an effect on the ecology and therefore provide challenges that will soon require development of removal technologies. ■

Gopal Achari is a professor in the Department of Civil Engineering, University of Calgary.

Les contaminants émergeants dans l'eau créent des défis

Il faudra des technologies d'élimination pour ces nouveaux contaminants.

Gopal Achari, Ph.D.
PRÉSIDENT, DIVISION DE L'ENVIRONNEMENT, SCGC

La plupart des nos usines de traitement pour l'eau et pour les eaux usées sont conçues pour traiter les polluants conventionnels. Ceci regroupe l'élimination de la turbidité et la désinfection pour le traitement de l'eau, le dessablage et l'élimination des éléments organiques, ainsi que la désinfection des eaux usées. Certaines usines vont plus loin, avec des unités pour l'adoucissement, l'élimination de l'ammoniaque, l'élimination du phosphore et d'autres procédés.

Au cours de la dernière décennie, deux questions relativement nouvelles sont apparues et ont causé quelques maux de tête aux opérateurs d'usines. Il s'agit des contaminants émergents et des sous-produits de désinfection.

Les contaminants émergeants sont un groupe indéfini de contaminants comprenant les produits pharmaceutiques et les produits d'hygiène personnel, les produits chimiques pour la maison, les pesticides, les produits ignifuges, les remèdes pour les animaux, etc. Ces éléments ne sont pas complètement éliminés par les usines de traitement des eaux usées et se retrouvent dans les plans d'eau. Nombre de contaminants émergeants se comportent comme des perturbateurs endocriniens et ont des impacts écologiques connus.

Les sous-produits de la désinfection sont un groupe de composés bromés et chlorés formés lorsque le chlore est utilisé pour désinfecter des eaux comportant beaucoup de matière organique. Ces sous-produits comprennent les trihalométhanes et les acides haloacétiques, pour lesquels Santé Canada n'a pas encore imposé de limites, ainsi que d'autres contaminants émergeants comme l'halonitrométhane et le haloacetonitrile.

Ces différents contaminants, même s'ils sont présents en très faibles concentrations dans nos plans d'eau, ont un impact sur l'écologie et présentent par conséquent des défis qui vont bientôt exiger l'élaboration de technologies d'élimination. ■

Gopal Achari est professeur au département de génie civil de l'Université de Calgary.

Environmental Contaminants with Hormone-like Activity: Screening and Risk Characterization

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An increasing global population demands better waste disposal systems to improve living conditions. There is a clear link between sanitation and public health. Most industrialized countries have adequate municipal and industrial waste facilities in place, and possess technologies that help them to better manage biochemical oxygen demand (BOD) and suspended solids, as well as provide the ability to remove fats and most pathogens. Advanced wastewater treatment plants (WWTPs) are currently aiming to improve their ability to reduce nutrients from wastewater (nitrogen and phosphorus) as well as metals, chemicals (organic and inorganic), and toxic substances.

An area that requires significant research is the development of methods to remove contaminants of emerging concern (CEC), including those of microbiological origin, pharmaceuticals, personal care products, pesticides, herbicides, fungicides, surfactants, organic solvents, and fire retardants. Sources of these contaminants range from municipal households, hospitals and industrial operations, to agriculture and forestry (Hontela and Habibi, 2014; Annett et al., 2014; Lapworth et al., 2012; Grassi et al., 2013; Aguera, et al., 2013; Li 2014).

Almost all material produced by society is found in wastes and most of these contaminants can be detected at various quantities in the water system. Multiple lines of evidence indicate that CECs, even at low concentrations, can disrupt human and animal health and may adversely affect populations. Contaminants present in municipal waste are of particular importance as more than 13 trillion litres of wastewater is discharged annually into natural ecosystems in Canada alone. The amount of wastewater discharged in the ecosystem is considerably greater in the United States and other OECD countries. A large number of contaminants in the wastewater effluents exhibit biological activity with potential to disrupt health if concentrations exceed the lowest observed adverse effects level (LOAEC) (Wibbertmann, et al., 2011; Lapworth et al., 2012; Grassi et al., 2013).

Contaminants can exert different types and levels of toxicity leading to death (lethal) at one extreme, or to disruption of normal physiological function (sublethal). The period of exposure can also influence the outcome and severity of the harmful effects. Acute toxicity can result from a single or short-term exposure, while chronic toxicity is caused by an extended period of contact with contaminants. The type and scope of chronic toxicity will depend on repeated or continuous exposure, sometimes lasting for the entire duration of life. The mechanisms of toxicity range from extreme poisoning causing organ failure and death to disruption of growth, development, metabolism and reproduction, which is usually the result of chronic stress, oxidative stress, and immune or endocrine disruption (Wibbertmann et al., 2011).

The term "endocrine disrupting chemicals" (EDCs) describes a variety of synthetic chemicals and natural plant compounds that have hormone-like activities (Bergman, et al., 2013; Testai, et al.,2013; Anway et al., 2005). There is evidence that these environmentally persistent compounds can mimic or block the effects of natural estrogens, androgens, and thyroid hormones, and are suspected of causing health defects in both humans and wildlife through disruption of the endocrine system (Tyler and Jobling, 2008). Direct exposure to EDCs may be through diet, and industrial or household products including detergents, drugs, lubricants, cosmetics, pesticides and plastics. Indirect exposure occurs when chemicals are released into the air and water, such as airborne ash from industrial or hazardous waste incinerators, contaminating agricultural products and livestock, which are then are passed along to humans (Bergman, et al., 2013; Grassi, et al., 2013; Ponzo, et al, 2013; Sun, et al., 2013; Zawatski, et al., 2013).

In more populated countries, drinking water may also be contaminated by chemicals and their breakdown products found in industrial discharge and sewage effluent. Among the more abundant known EDCs are plant-derived estrogens, organochlorine pesticides, herbicides and insecticides (such as o,p'-DDT, endosulfan, dieldrin, methoxychlor, kepone, dicofol, toxaphene and chordane); products associated with plastics (bisphenol A); pharmaceuticals (drug estrogens - birth control pills); ordinary household products (breakdowns products of detergents and associated surfactants, including nonylphenol and octylphenol); and industrial chemicals (polychlorinated biphenyls (PCBs), and dioxins). A number of proven EDCs used as pesticides, such as o,p'-DDT, toxaphene and dicofol, have been banned from use in most western industrial countries, but are still used in many developing nations. However, other proven estrogenic compounds, such as nonylphenol and endosulfan, are still being used worldwide in plastics manufacturing and to combat "pest" plants and insects. In the OECD countries, although a number of harmful substances have been banned, people and other organisms are still vulnerable to their effects because their breakdown products remain in our environment and are stored in animal fat and tissues

for a long time, and can be passed along to humans (Bergman, et al., 2013).

Various academics as well as government and non-government organizations in the past two decades have highlighted the need for improved methods of risk assessment and new approaches for determination of the adverse health impact of environmental contaminants. Since the passage of the Food Quality Protection Act and the Safe Drinking Water Act amendments in the United States in 1996, other OECD countries have initiated similar programs to develop effective screening and testing of EDCs (Bergman, et al., 2013). An important principle is that concentrations of chemical contaminants can be measured with sensitive instruments currently in place in advanced analytical labs. However, only living material can be used to measure toxicity and no instrument has yet been invented that can measure toxicity. Therefore chemical analysis alone in the absence of appropriate biological monitoring will not be sufficient for meaningful risk and hazard assessment. Accurate biological data on toxicity level will be essential in order to come up with strategies for mitigation and risk management (Fig. 1).

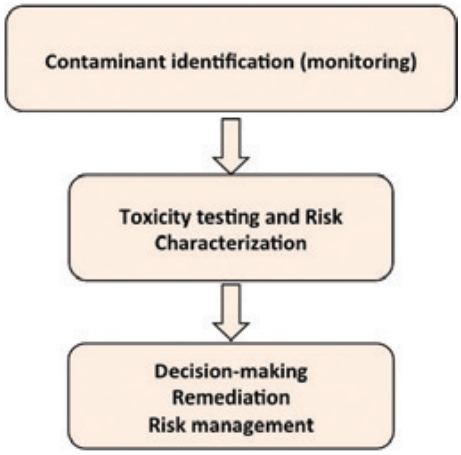

Figure 1. Strategies for risk characterization, mitigation and management.

A wide variety of environmental contaminants found in the rivers and surface waters around the world are known to be endocrine disruptors. Many of these EDCs have been demonstrated to have estrogen-like activity and can impact normal male and female physiology by disrupting estrogen-mediated response, reproduction, gonadal development and hormone-dependent cancers (Soto, et al., 2013). A key mechanism by which chemicals influence the endocrine system is by interacting with the appropriate hormone receptors. There is substantial evidence to support this statement for estrogen and androgen receptors. However, since these are synthetic chemicals, their specificity and potency can change depending on their concentration and interaction with other contaminants. A number of investigators have used transcriptional activation and receptor binding assays for assessing estrogen-like activity using high throughput methods as an initial indication of the presence of hormone-like activity in environmental samples (Bergman, et al., 2013). However, the use of a receptor reporter system alone cannot provide accurate information on the potency, nature of toxicity and harmful effects of contaminants when present in complex mixtures. Use of whole animal models to assess biological response would be the best approach to obtain accurate information on the potency and nature of biological response. Fish would be a very suitable model to assess the presence of toxins in the aquatic environment and to mechanistically link environmental contaminants to the health of field-based populations.

In 2005, Alberta Environment (AE) released a report that contained results of water analyses due to concerns about the potential impacts of environmental contaminants on humans, livestock, aquatic organisms, and wildlife in Southern Alberta (Sosiak et al., 2005). Subsequent studies demonstrated the presence of a number of other contaminants in water collected from rivers in southern Alberta (Jeffries, et al., 2008, 2010; Evans, et al., 2012). A number of contaminants (natural and synthetic steroids, organic compounds and pharmaceuticals) were

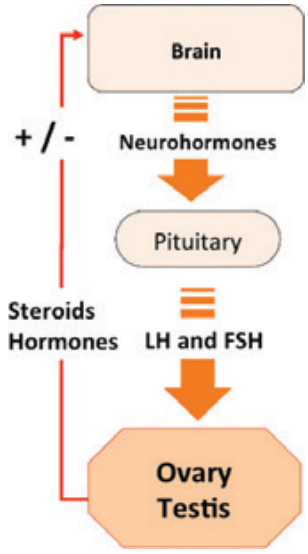

Figure 2. Brain-pituitary-gonadal axis, and hormonal control of reproduction. LH, Luteinizing hormone; FSH, Follicle-stimulating hormone. LH and FSH stimulate hormone production and production of eggs and sperm in the gonads.

detected at all sites sampled along the Oldman River, Bow River and Red Deer River (Sosiak et al., 2005; Jeffries, et al., 2008, 2010; Evans, et al., 2012). The compounds detected include synthetic estrogens and industrial chemicals downstream of municipal wastewater effluents, as well as natural hormones in the agricultural areas. Greater concentrations of pollutants were measured at sites downstream of wastewater treatment plants and agricultural areas, which indicate cumulative inputs of such compounds in these rivers.

We used longnose dace as an indigenous model species to investigate a link between exposures to environmental contaminants and adverse biological response. A significant increase in female to male adult ratio from approximately 55% to 90% was observed in longnose dace caught downstream of certain municipalities and Lethbridge WWTP (Jeffries, et al., 2008, 2010; Evans, et al., 2012). The observed results are consistent with the hypothesis that the presence of compounds with estrogen-like activity caused the sex reversal of male fish and their development into female fish. This is biologically possible in fish and other species exposed to abnormal levels of male and female reproductive hormones (Habibi and Andreu-Vieyra, 2007).

Sexual development in fish, in particular, is plastic and can be influenced by various genes that are in turn influenced by factors such as estrogen, temperature, and environmental stimuli (Kikuchi and Hamaguchi, 2013; Nakamura, 2010). Reproduction in fish and other vertebrates is controlled by gonadotropin hormones (luteinizing hormone, LH and follicle stimulating hormone, FSH) secreted from the pituitary gland under the influence of brain neurohormones (Habibi and Andreu-Vieyra, 2007). Increasing levels of LH and FSH stimulates gonadal functions that include gametogenesis (production of sperm in male and egg in female) and secretion of gonadal steroids (testosterone in male and estrogen in female) (Fig. 2). Ovarian development in female fish is stimulated by estrogen, which in turn stimulates production of an egg yolk protein known as vitellogenin (Vtg) (Polzonetti-Magni et al., 2004). Once synthesized in the liver as a result of increasing estrogen level, Vtg is carried in the blood to the ovaries and is taken up by the growing ovarian follicles. This process, driven by estrogen, is essential for normal growth of ovaries and production of eggs by female fish (Fig. 3) (Polzonetti-Magni et al., 2004). Both male and female fish have the genes for Vtg, but its expression and concentration is very low to undetectable in male fish. The reason is that male fish do not normally have high circulating levels of estrogen required for Vtg synthesis.

An increased level of Vtg in male fish is an important indicator of exposure to EDCs with estrogen-like activity (Polzonetti-Magni et al., 2004) (Fig. 3). In the Oldman River, we observed higher than normal levels of Vtg in male longnose dace in correlation with increased female bias in the downstream locations (Jeffries, et al., 2008, 2010; Evans, et al., 2012). The observed results suggests a link between the observed female bias in the fish and various contaminants detected in the Oldman River suspected to have estrogen-like activity such as

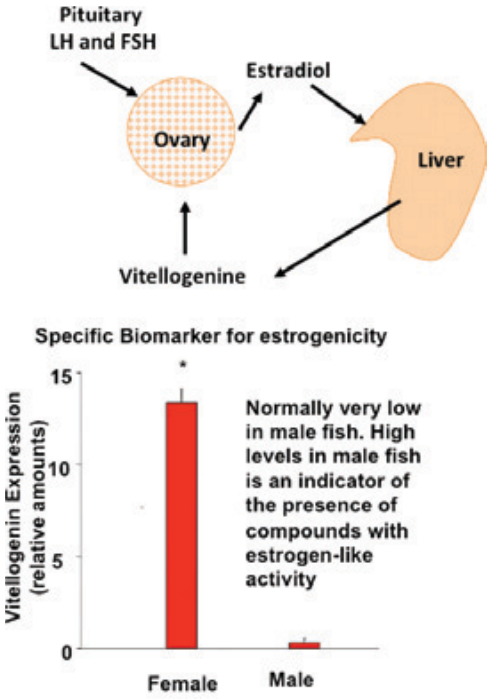

Figure 3. Vitellogenin (Vtg) expression in male and female fish. Under normal conditions, Vtg level is very low in male fish. In female fish Vtg level is significantly greater due to normal circulating levels of estrogen in the blood.

bispheol-A, phthalates, nonylphenol, pharmaceuticals and possibly various pesticides and herbicides. The presence of compounds such as plastic derivatives and organic solvents in the receiving rivers strongly indicates the failure of WWTPs to break down and remove these contaminants under current conditions.

Studies are in progress to test the effects of contaminants detected in the Oldman River on fish and cultured cells under controlled laboratory conditions (Hatef et al., 2012), individually and in mixture (Jordan et al., 2012), to assess the nature of adverse biological response and potency. The next logical step would be to apply treatment approaches such as advanced oxidative processes and photolysis to treat the pollutants. The proof that a new treatment process is suitable will have to be based on subsequent bioassay data to prove that the byproducts do not retain toxic effects. Such a multidisciplinary approach would be essential in

all cases to assess and characterize the risk, and to develop effective and meaningful remedial solutions. Finally, it would be essential to exploit advanced treatment techniques and employ novel bioassay approaches to address one of the most urgent needs globally to ensure availability of water that is free of harmful chemicals. ■

References

Aguera, A., Martínez Bueno, M.J., Fernández-Alba, A.R. (2013) "New trends in the analytical determination of emerging contaminants and their transformation products in environmental waters," *Environ Sci Pollut Res Int.* 2013 Jun; 20(6):3496-515.

Annett, R., Habibi, H.R., Hontela, A. (2014) "Impact of glyphosate and glyphosate-based herbicides on the freshwater environment," *Journal of Applied Toxicology*, in press.

Anway, M.D., Cupp, A.S., Uzumcu, M., Skinner, M.K. (2005) "Epigenetic transgenerational actions of endocrine disruptors and male fertility," *Science 308*, 1466–1469.

Bergman, A., Heindel, J.J., Jobling, S., Kidd, K.A., Zoeller, R.T. (2013) "The State-of-the-Science of Endocrine Disrupting Chemicals," World Health Organization and United Nations Environment Programme Report - 2012, Geneva:UNEP/WHO, www.who.int/ceh/publications/endocrine/en/index.html

Evans, J.S., Jackson, L.J., Habibi, H.R., Ikonomou, M.G. (2012) "Feminization of longnose dace (Rhinichthys cataractae) in the Oldman River, Alberta (Canada) provides evidence of widespread endocrine disruption in an agricultural basin," *Scientifica*, Volume 2012, Article ID 521931, 11 pages, http://dx.doi.org/10.6064/2012/521931

Grassi, M., Rizzo, L., Farina, A. (2013) "Endocrine disruptors compounds, pharmaceuticals and personal care products in urban wastewater: implications for agricultural reuse and their removal by adsorption process," *Environ Sci Pollut Res Int.* 2013 Jun; 20(6):3616-28.

Habibi, H.R., Andreu-Vieyra, C.V. (2007) "Hormonal Regulation of Follicular atresia in the teleost fish," In: *The Fish Oocyte: From Basic Studies to Biotechnological Applications*. (Babin, P.J., Cerda, J., and Lubzens E., eds.), Springer Pub Co., pp 231-250.

Hatef, A., Zare, A., Hadi Alavi, S.M., Habibi, H.R., Linhart, O. (2012) "Modulations in androgen and estrogen mediating genes and testicular response in male goldfish exposed to Bisphenol A," *Environmental Toxicology and Chemistry* 31(9):2069-2077.

Hontela, A., Habibi, H.R. (2014) "Personal care products in the aquatic environment: a case study on the effects of Triclosan in fish," *Fish Physiology*, Vol 33: Organic Chemical Toxicology of Fishes, In Press.

Jeffries, K.M., Nelson, E.R., Jackson, L.J., Habibi, H.R. (2008) "Basin-wide impacts of compounds with estrogen-like activity on longnose dace (Rhinichthys cataractae) in two prairie rivers of Alberta, Canada," *Environmental Toxicology and Chemistry* 27, 2042-2052.

Jeffries, K.M., Jackson, L.J., Ikonomou, M.G., Habibi, H.R. (2010) "Presence of natural and anthropogenic organic contaminants and potential fish health impacts along two river gradients in Alberta, Canada," *Environmental Toxicology & Chemistry* 29(10):2379-8.

Jordan, J., Zare, A., Jackson, L.J., Habibi, H.R., Weljie, A.M. (2012) "Exposure to low concentrations of waterborne contaminants, individually and in a mixture, causes disruption in metabolism in fish," *Journal of Proteome Research* 11(2):1133-1143.

Kikuchi, K., Hamaguchi, S. (2013) "Novel sex-determining genes in fish and sex chromosome evolution," *Dev Dyn.* 2013 Apr; 242(4):339-53.

Lapworth, D.J., Baran, N., Stuart, M.E., Ward, R.S. (2012) "Emerging organic contaminants in groundwater: A review of sources, fate and occurrence," *Environ Pollut.* 2012 Apr; 163:287-303.

Li, W.C. (2014) "Occurrence, sources, and fate of pharmaceuticals in aquatic environment and soil," *Environ Pollut.* 2014 Apr; 187C:193-201.

Nakamura, M. (2010) "The mechanism of sex determination in vertebrates - Are sex steroids the key-factor?" *J Exp Zool A Ecol Genet Physiol*. 2010 Aug 1; 313(7):381-98.

Polzonetti-Magni, A.M., Mosconi, G., Soverchia, L., Kikuyama, S., Carnevali, O. (2004) "Multihormonal control of vitellogenesis in lower vertebrates," *Int Rev Cytol*. 2004; 239:1-46

Ponzo, O.J., Silvia, C. (2013) "Evidence of reproductive disruption associated with neuroendocrine changes induced by UV-B filters, phthalates and nonylphenol during sexual maturation in rats of both gender," *Toxicology*. 2013 Sep 6; 311(1-2):41-51.

Sosiak, A., and Hebben, T. (2005). *"A Preliminary Survey of Pharmaceuticals and Endocrine Disrupting Compounds in Treated Municipal Wastewaters and Receiving Rivers of Alberta,"* Alberta Environment, 1-64.

Soto, A.M., Brisken, C., Schaeberle, C., Sonnenschein, C. (2013) "Does cancer start in the womb? Altered mammary gland development and predisposition to breast cancer due to in utero exposure to endocrine disruptors," *J Mammary Gland Biol Neoplasia*. 2013 Jun; 18(2):199-208.

Sun Y, Huang H, Sun Y, Wang C, Shi XL, Hu HY, Kameya T, Fujie K. (2013) "Ecological risk of estrogenic endocrine disrupting chemicals in sewage plant effluent and reclaimed water," *Environ Pollut*. 2013 Sep; 180:339-44.

Testai, E., Galli, C.L., Dekant, W., Marinovich, M., Piersma, A.H., Sharpe, R.M. (2013) "A plea for risk assessment of endocrine disrupting chemicals," *Toxicology*. 2013 Dec 6; 314(1):51-9.

Tyler, C.R., Jobling, S. (2008) "Roach sex and gender bending chemicals: the feminization of wild fish in English rivers," *BioScience* 58, 1051-1059.

Wibbertmann, A., Mangelsdorf, I., Gamon, K., Sedlak, R. (2011) "Toxicological properties and risk assessment of the anionic surfactants category: Alkyl sulfates, primary alkane sulfonates, and α-olefin sulfonates," *Ecotoxicol Environ Saf.* 2011 Jul; 74(5):1089-106.

Zawatski, W., Lee, M.M. (2013) "Male pubertal development: are endocrine-disrupting compounds shifting the norms?" *J Endocrinol*. 2013 Jul 11; 218(2):R1-12.

Potential Impacts of Hydraulic Fracturing on Water Environment

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Over the past 20 years, global energy use – largely from fossil fuels – has increased by 45% (Tollefson and Monastersky 2012) and is predicted to increase by 56% by 2040 (EIA 2013). Recently, the extraction of unconventional energy from deep formations (in the form of shale gas and oil) has emerged as an opportunity to meet the ever-increasing energy demand (Tollefson and Monastersky 2012; Vidic et al. 2013).

Shale formations are quite impermeable and to extract this unconventional resource, a special technique known as hydraulic fracturing, or fracking, is used. Large volumes of water augmented with special chemicals are used for fracking. This has led to growing concerns of possible contamination of the aquifer resulting from contact with frack water, flowback water or gases released from the formation.

Composition of frack fluids

Frack fluids are prepared to transport a proppant (typically sand) that keeps fractures open. The main composition of hydraulic frack fluids is water, sand and chemical admixtures. Typically, frack fluids comprise 90% water, about 8-9.5% sand or proppants and between 0.5-2% additives or chemicals (Maule et al. 2013). The chemical additives can be friction reducers, scale inhibitors, surfactants (Kaufman et al. 2008), gelling agents, corrosion inhibitors and chemicals that prevent microbes from forming biogeochemical by-products (Arthur and Coughlin 2008). While these additives are used to enhance the fracking process, their impact can lead to groundwater and surface water contamination. Additionally, flowback waters may contain hydrocarbons from the target formation, naturally occurring radioactive materials (NORMs) and inorganics. To reuse these waters, a certain level of treatment prior to reuse may be required (Kargbo et al. 2010).

Reported impacts of hydraulic fracturing

Table 1 provides the potential effects of hydraulic fracturing on water quality, as reported in literature. The impacts on water systems can either be on water quantity or quality (see Figure 1). The water quantity issue arises from the volume of water used, whereas quality is impacted due to ground stimulation activities, use of chemical admixture in frack fluid and the presence of chemicals in flowback waters. It is reported that hydraulic fracturing requires large amounts (as high as 13 million gallons) of water and can significantly deplete local water resources (Cooley and Donnelly 2012).

Underground methane can migrate to the water system from natural or anthropogenic ground stimulation activities, such as hydraulic fracturing. The most common causes of methane release are faulty seals in casings and connectivity between the deep shale formation and groundwater aquifer. Osborn et al. (2011) reported that they found elevated levels of methane in wells within 1 km of a drilling site compared to wells located farther than 1

TABLE 1: EFFECTS OF HYDRAULIC FRACTURING

No.	Effects	Potential effects reported	References
1	Gas contamination of shallow ground water aquifer	GW	Entrekin et al. 2011; Vengosh et al. 2013; Vidic et al. 2013
2	Improper disposal of produced and flowback waters	GW & SW	Vengosh et al. 2013
3	Connectivity of deep and shallow aquifer	GW	Vengosh et al. 2013
4	Water stress / water depletion	GW & SW	Nicot and Scanlon 2012
5	Elevated sediment runoff from pipelines and roads	SW	Entrekin et al. 2011
6	Alternation of stream flow	SW	Entrekin et al. 2011
7	Contamination of surface water from fracture fluids chemicals	SW	Entrekin et al. 2011; Vidic et al. 2013
8	Accidental spills	SW	Vidic et al. 2013
9	Air pollution from heavy and frequent traffic movement	Air	Kargbo et al. 2010; Rahm 2011
10	Sound and noise pollution from heavy frequent traffic, well construction and drilling	Sound	Rahm 2011
11	Greenhouse gas from methane	GHG	Howarth et al. 2011
12	Human health risk from BTEX	Cancer risk	Maule et al. 2013
13	Induced seismicity from fracking stimulation and fracking fluid injections	Earthquake	Clark et al. 2012

GW: ground water, SW: surface water; GHG: greenhouse gas.

km from drilling sites in Pennsylvania (Vengosh et al. 2013). Release of methane creates a favorable environment to release other hazardous materials like arsenic. Due to microbial activities, methane can be oxidized and creates oxygen depletion. The low levels of oxygen lead to increased solubility of arsenic and iron in groundwater. Anaerobic microbial activities also convert sulfates to sulfides (Vidic et al. 2013).

The main concerns of flowback water are high turbidity, chemical admixtures and other chemicals, including heavy metals, volatile organic compounds, and radioactive materials (Finkel et al. 2013). The flowback water with chemical admixtures and other compounds can come in contact with water systems due to well leaks and above ground accidents during transportation, storage and handling of flowback water and chemicals (Gordalla et al. 2013). There is observational evidence of groundwater contamination at Dimock, Pennsylvania, and Pavillion, Wyoming, associated with well integrity and wastewater storage (Cooley and Donnelly 2012). Fontenot et al. (2013) reported that in some wells located within 3 km of the drilling site, the amount of arsenic, selenium, strontium and total dissolved solids (TDS) exceeded the Environmental Protection Agency's Drinking Water Maximum Contaminant Limit (MCL), whereas levels of these chemicals were less than MCL in wells located beyond 3 km from the drilling site. Colborn et al. (2011) reported that many of the chemicals used in hydraulic fracturing may have negative human health impacts. Warner et al. (2013) found the concentration of ^{226}Ra to be 200 times in the stream sediments (544–8759 Bq/kg) at the flowback water discharge point compared to upstream background sediments (22–44 Bq/kg).

Conclusions

Hydraulic fracturing requires large volumes of water. The water is augmented with a number of chemical additives that if released into a receiving environment may have potential adverse effects. Due to limited understanding and potential harmful impacts on the water environment, the development and operation of shale wells using fracking should receive further attention. The accidental releases of frack fluid and flowback fluid from wells or ground operations can lead to adverse impacts to the water environment. ■

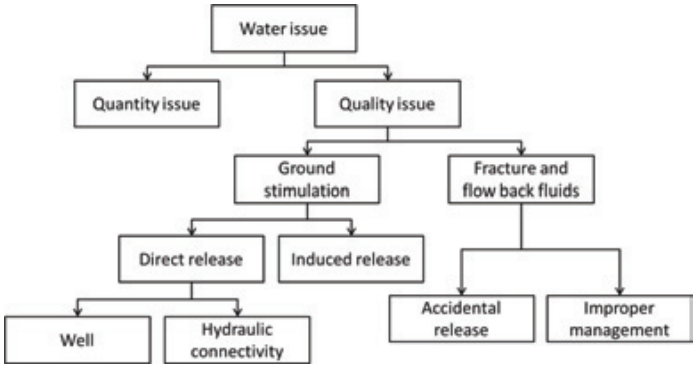

Figure 1: Water issue topology from hydraulic fracturing

References

Arthur, D. J., and Coughlin, B. J. (2008). *Evaluating the Environmental Implications of Hydraulic Fracturing in Shale Gas Reservoirs*. Tulsa, OK, USA, 21.

Clark, C., Burnham, A., Harto, C., and Horner, R. (2012). *Hydraulic Fracturing and Shale Gas Production: Technology, Impacts, and Policy, Argonne National Laboratory, 2012*.

Colborn, T., Kwiatkowski, C., Schultz, K., and Bachran, M. (2011). "Natural Gas Operations from a Public Health Perspective." *Human and Ecological Risk Assessment: An International Journal*, Taylor & Francis, 17(5), 1039–1056.

Cooley, H., and Donnelly, K. (2012). *Hydraulic Fracturing and Water Resources: Separating the Frack from the Fiction*.

EIA. (2013). *International Energy Outlook 2013, U.S. Department of Energy Washington, DC , http://www.eia.gov/forecasts/ieo/pdf/0484(2013).pdf*.

Entrekin, S., Evans-White, M., Johnson, B., and Hagenbuch, E. (2011). "Rapid expansion of natural gas development poses a threat to surface waters." *Frontiers in Ecology and the Environment*, Ecological Society of America, 9(9), 503–511.

Finkel, M., Hays, J., and Law, A. (2013). "The shale gas boom and the need for rational policy." *American Journal of Public Health*, American Public Health Association, 103(7), 1161–3.

Fontenot, B. E., Hunt, L. R., Hildenbrand, Z. L., Carlton, D. D., Oka, H., Walton, J. L., Hopkins, D., Osorio, A., Bjorndal, B., Hu, Q. H., and Schug, K. A. (2013). "An evaluation of water quality in private drinking water wells near natural gas extraction sites in the barnett shale formation." *Environmental Science & Technology*, American Chemical Society, 47(17), 10032–40.

Gordalla, B. C., Ewers, U., and Frimmel, F. H. (2013). "Hydraulic fracturing: a toxicological threat for groundwater and drinking-water?" *Environmental Earth Sciences*, 70(8), 3875–3893.

Howarth, R. W., Santoro, R., and Ingraffea, A. (2011). "Methane and the greenhouse-gas footprint of natural gas from shale formations." *Climatic Change*, 106(4), 679–690.

Kargbo, D. M., Wilhelm, R. G., and Campbell, D. J. (2010). "Natural gas plays in the Marcellus Shale: challenges and potential opportunities." *Environmental Science & Technology*, American Chemical Society, 44(15), 5679–84.

Kaufman, P., Penny, G. S., and Paktinat, J. (2008). "Critical Evaluations of Additives Used in Shale Slickwater Fracs, 16-18 November, Irving, TX." *SPE Shale Gas Production Conference*.

Maule, A. L., Makey, C. M., Benson, E. B., Burrows, I. J., and Scammell, M. K. (2013). "Disclosure of Hydraulic Fracturing Fluid Chemical Additives: Analysis of Regulations." *New Solutions*, 23(1), 167–187.

Nicot, J.-P., and Scanlon, B. R. (2012). "Water use for Shale-gas production in Texas, U.S." *Environmental Science & Technology*, American Chemical Society, 46(6), 3580–6.

Osborn, S. G., Vengosh, A., Warner, N. R., and Jackson, R. B. (2011). "Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing." *Proceedings of the National Academy of Sciences of the United States of America*, 108(20), 8172–6.

Rahm, D. (2011). "Regulating hydraulic fracturing in shale gas plays: The case of Texas." *Energy Policy*, 39(5), 2974–2981.

Tollefson, J., and Monastersky, R. (2012). "The global energy challenge: Awash with carbon." *Nature*, 491(7426), 654–5.

Vengosh, A., Warner, N., Jackson, R., and Darrah, T. (2013). "The Effects of Shale Gas Exploration and Hydraulic Fracturing on the Quality of Water Resources in the United States." *Procedia Earth and Planetary…*, 7, 863–866.

Vidic, R. D., Brantley, S. L., Vandenbossche, J. M., Yoxtheimer, D., and Abad, J. D. (2013). "Impact of shale gas development on regional water quality." *Science (New York, N.Y.)*, 340(6134), 1235009(1–8).

Warner, N. R., Christie, C. A., Jackson, R. B., and Vengosh, A. (2013). "Impacts of shale gas wastewater disposal on water quality in western Pennsylvania." *Environmental Science & Technology*, American Chemical Society, 47(20), 11849–57.

Emerging Contaminants and Their Treatment in Water

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Over the past decades a great deal of interest and concern has arisen regarding the source, occurrence, environmental fate and potential toxicity of trace contaminants in the aquatic environment (Synder 2008; Lapworth et al. 2012). Of particular concern are emerging contaminants (ECs), also known as contaminants of emerging concern. According to Cunniff and Asiello (2009), emerging contaminants are defined as "chemicals or materials that have evolving science (e.g. beryllium); new or unknown exposure pathways (e.g. trichloroethylene and nano-materials); and new detection capabilities (e.g. perchlorate) that can be reasonably anticipated to lead to regulatory changes" (Lindsey, Meyer and Thurman 2001; Richardson 2014). Compounds possibly known for a long time but recently categorized as potential contaminants are also included in this classification.

ECs comprise a wide spectrum of different compounds including pesticides, pharmaceuticals, personal care products (PPCPs), veterinary medicines, industrial compounds/byproducts, household chemicals, fire retardants, food additives, nano-materials and many others (Lapworth et al. 2012). ECs are released into the environment as a consequence of human activities and through a variety of pathways such as municipal sewage, industrial wastewaters, landfills, agricultural run-off and wash water from roadways (Bolong et al. 2009).

The issues associated with ECs are (Bolong et al. 2009):

- ECs may have adverse effects on aquatic ecosystems and human health (Huang et al. 2003; Pal et al. 2010). They can be persistent, bioaccumulative, cotoxic, carcinogenic and repro-toxic. Some of the ECs are classified as endocrine disrupting chemicals (EDCs), which are chemicals with estrogenic effects. Chemicals such as DDT, polychlorinated biphenyls (PCBs), bisphenol A, polybrominated diphenyl ethers (PBDE's), and a variety of phthalates are considered as EDCs (Purdom et al. 1994; Desbrow and Routledge 1998a,b; Guillette 1994).
- ECs have different forms and mechanisms of action and there is no standard or common method for monitoring them.

Each compound is required to be identified and quantified by specific analytical techniques.

- ECs are present in water at very low concentrations (µg/L or even ng/L) therefore the removal of these compounds by conventional waste water treatment processes is not necessarily effective; there is also difficulty in the analysis of these compounds because of low concentrations.

Treatment of ECs in water using AOPs

Considering the issues associated with ECs, research on a number of different areas is required. These include development of analytical methods for ECs at trace levels, determination of environmental occurrence, characterization of the sources and pathways, identification of transport and fate (e.g. biodegradation, photodegradation in natural environments) and determination of ecological effects (USGS 2014).

Advanced oxidation processes (AOPs) to treat ECs in water and wastewater have indicated promise (Figure 1). Many AOPs are based on the generation of hydroxyl radicals (with an oxidation potential of 2.80 V) and other strong oxidant species that are able to degrade chemically stable compounds (Parsons 2004).

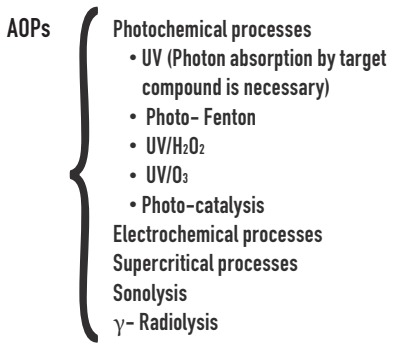


Figure 1. Advanced oxidation processes

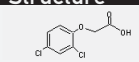
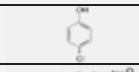
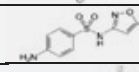
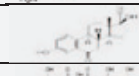
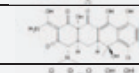
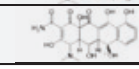
Our research is focused on the application of photochemical processes for the effective treatment of ECs in municipal and industrial waters. The method of choice depends on effectiveness, economics and operation and maintenance issues. Here we only report on the application of light emitting diodes (LEDs) and TiO_2-based photocatalysis (PC) for drinking water treatment. While photocatalysis for environmental applications is quite established, with more than 1,100 papers being published over the past five years (2008-2013), these papers pertain only to conventional mercury (Hg) lamps. Rapidly evolving LEDs have advantages such as near-monochromatic light, long life, higher electric-light conversion efficiency, pulsing, absence of Hg, higher durability, faster start-up time (can be pulsed), low power requirements and DC operation for solar-PV or remote use (Crawford et al. 2005). Table 1 presents a comparison between visible LEDs, incandescent lamps and fluorescent lamps.

TABLE 1. PROPERTIES OF INCANDESCENT LIGHT BULBS, FLUORESCENT LAMPS AND LEDS (modified from http://www.thelightauthority.com/compare.html).

Properties	Incandescent Light Bulbs	Fluorescent (CFL)	LEDs
Average life span	1,200 hours	8,000 hours	50,000 hours
Watts of electricity used to generate 800 lumens	60 watts	13-15 watt	6 - 8 watts
Sensitivity to low temperatures	Some	Yes	None
Sensitive to humidity	Some	Yes	No
On/off cycling.	Some effect	Some effect	No effect
Turns on instantly	Yes	No	Yes
Durability	Not very durable	Not very durable	Very durable
Possibility of mechanical failure	Some	Yes	Not typical

Since intense near-UVA LEDs are commercially available, their lifespan is comparable to mercury discharge lamps and they support TiO_2 photocatalysis for degradation of ECs in lab-scale, economically viable LED-based reactors for small water systems are of interest (Kneissl 2011). Table 2 provides some of the ECs whose degradation we have investigated using LED-based photocatalysis. These include pesticides (2.4-D, chlorophenol) and pharmaceuticals (agricultural antibiotics like sulfomethoxazole).

TABLE 2. LIST OF ECs STUDIED, THEIR STRUCTURE AND CLASSIFICATION

Model compound	Structure	Type of contaminant
2,4-D		Pesticide
4-Chlorophenol		Pesticide
Sulfamethoxazole		Antibiotic
Enthynylestradiol		Hormone
Chlortetracycline		Antibiotic
Oxytetracycline		Antibiotic

Our results show that LEDs (λ_{max}=365nm) are a promising way to photocatalytically treat 2,4-D, sulfamethoxazole (SMX), ethynylestradiol, chlorotetracycline and oxytetracycline in aqueous solutions. Yu et al. (2013) and Malkhasian et al. (2014) provide all the detailed results. It was shown in the case of 2,4-D that 365-nm LEDs are more efficient than mercury lamps (Yu et al. 2013). Figure 2 shows typical results for photocatalytic degradation of sufamethoxazole in a 365-nm LED reactor. The results indicate that photocatalysis can be more efficient if O_2 is bubbled (or if H_2O_2 is added) during the reaction (Fig. 2).

Selective alternative photocatalysts such as

mesoporous TiO_2 with higher surface area (Calleja et al. 2004) and WO_3/TiO_2 nanohybrid with energy storage capability (Zhao et al. 2009) were also tested to find more efficient photocatalysts than Degussa P25 (Izadifard et al. 2013). The results showed that the choices of photocatalysts for different targets are important.

Conclusions

Emerging contaminants are a category of pollutants that have potential adverse environmental effects. AOPs based on LED light sources are promising for the degradation of certain emerging contaminants in water.

Acknowledgements

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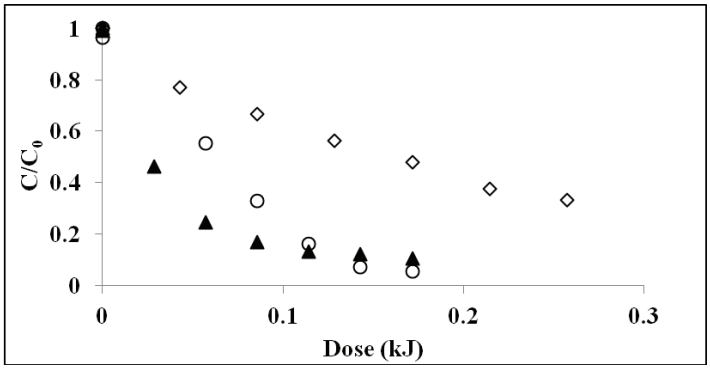

Figure 2. Photocatalytic degradation of SMX using 2.5 g/L of Degussa P25 in 365-nm LED reactor and the effect of O_2 bubbling and adding H_2O_2. The x axis shows the required energy in (kJ) for the corresponding removal of SMX shown on the Y axis. ◊: P25; ▲: P25, air bubbling; ○: P25, 0.1% H_2O_2.

References

Bolong, N., Ismail, A. F., Salim, M. R. Matsuura T. (2009). "A review of the effects of emerging contaminants in wastewater and options for their removal." *Desalination*, 239(1-3), 229–246.

Calleja, G., Serrano, D., Sanz, R., Pizarro, P., García, A. (2004). "Study on the synthesis of high-surface-area mesoporous TiO_2 in the presence of nonionic surfactants." *Ind. Eng. Chem. Res.*, 43(10): 2485–2492.

Crawford, M. H., Banas, M. A., Ross, M.P., Ruby, D. S., Nelson, J. S., Boucher, R., Allerman, A. (2005). Final LDRD report. Sandria National Laboratories, Albuquerque, New Mexico.

Cunniff, S., Asiello, D. (2009). "Controlling acquisition risk via scanning for emerging contaminants." *Defense AT& L*. July-August, 22-27.

Desbrow, C., Routledge, E. J. (1998a). "Identification of estrogenic chemicals in STW effluent. 1. Chemical fractionation and in vitro biological screening." *Environ. Sci. Technol.*, 32 (11), 1549- 1558.

Desbrow, C., Routledge, E. J. (1998b). "Identification of estrogenic chemicals in STW effluent. 2. In vivo responses in trout and roach." *Environ. Toxicol. Chem.*, 32 (11), 1559- 1565.

Ghosh, J. P., Langford, C. H., Achari, G. (2008). "Characterization of an LED based photoreactor to degrade 4-chlorophenol in an aqueous medium using coumarin (C-343) sensitized TiO2." *J. Phys. Chem. A*, 112(41), 10310–10314.

Guillette, L. J., Gross, T. S., Masson, G. R., Matter, J. M., Percival, H. F. Woodward, A. R. (1994). "Developmental abnormalities of the gonad and abnormal sex hormone concentrations in juvenile alligators from contaminated and control lakes in Florida." *Environ. Health Prospect.*, 102(8), 680-688.

Huang, Y., Twidwell, D. L., Elrod, J. C. (2003). "Occurrence and effects of endocrine disrupting chemicals in the environment." *ASCE*, 7(4), 241- 252.

Izadifard, M., Achari G., Langford C. H. (2013). "Application of photocatalysts and LED light sources in drinking water treatment catalysts." *Catalysts, 3*, 726-743, doi, 10.3390/ catal3030.

Izadifard, M., Achari G., Langford C. H. (2014). "Photocatalysts with energy storage capability and LED light sources, an opportunity to reduce energy consumption." *In preparation*.

Kneissl, M., Kolbe1, T., Chua, C., Kueller, V., Lobo, N., Stellmach, J., Knauer, A., Rodriguez, H., Einfeldt, S., Yang, Z., Johnson, N. M., Weyers, M. "Advances in group III-nitride-based deep UV light-emitting diode technology." *Semicond. Sci. Technol.*, 2011, 26, 014036 (6pp).

Lapworth, D. J., Baran N., Stuart, M. E., Ward R. S. (2012). "Emerging organic contaminants in ground water: a review of sources, fate and ocuurance." *Environ. Pllut.*, 163, 287-303.

Lindsey, M. E., Meyer, M., Thurman, E. M. (2001). "Analysis of trace levels of sulfonamide and tetracycline antimicrobials in groundwater and surface water using solid phase extraction and liquid chromatography mass spectroscopy." *Anal. Chem.*, 73 (19), 4640-4646.

Malkhasian, A. Y. S., Izadifard, M., Achari G., Langford, C. H. (2014). "Photocatalytic degradation of agricultural antibiotics using a UV-LED light source." *J Environ. Sci., Health B.*, 49(1), 35-40.

Matos, J., Laine, J., Herrmann, J.M. (1998). "Synergy effect in the photocatalytic degradation of phenol on a suspended mixture of titania and activated carbon." *Appl. Catal. B: Environ.*, 1998, 18, 281-291.

Pal, A., Yew-Hoong Gin, K., Yu-Chen Lin, A., Richard, M. (2010). "Impacts of emerging contaminants on freshwater resources: review of recent occurrence, sources, fate and effects." *Sci. Total Environ.*, 408(24), 6062-6069.

Purdom, C.E., Hardiman, P. A., Bye, V. J., Eno, N. C., Tyler, C. R., Sumpter, J. R. (1994). "Estrogenic effects of effluents from

sewage treatment works." *J. Chem. Ecol.*, 8(4), 275-285.

Parsons, S. (2004). *Advanced oxidation process for water and wastewater treatment*. IWA Publishing, London, UK.

Richardson, S. D., Ternes, T. A. (2014). "Water analysis: emerging contaminants and current issues." *Anal. Chem.* 86 (6), 2813–2848.

Synder, A. (2008). "Occurrence and toxicological relevance of EDCs and pharmaceuticals in water," *Ozone Sci. Eng.*, 30 (1), 65-69.

USGS 2014. Emerging contaminants in the environment. <http://toxics.usgs.gov/regional /emc/> [Last accessed: April 10, 2012]

Wang, W., Serp, P., Kalck, P., Faria, J. L. J. (2005). "Visible light photodegradation of phenol on MWNT-TiO_2 composite catalysts prepared by a modified sol-gel method." *Molecul. Catal. A: Chem.*, 235(1-2), 194-199.

Yu, J., Ma, T. Liu, S. (2011). "Enhanced photocatalytic activity of mesoporous TiO_2 aggregates by embedding carbon nanotubes as electron-transfer channel." *Phys. Chem. Chem. Phys.*, 13, 3491–3501.

Zhao, D., Chen, C., Yu, C., Ma, W., Zhao, J. (2009). "Photoinduced electron storage in WO3/TiO2 nano hybrid material in the presence of oxygen and post irradiated reduction of heavy metal ions." *J. Phys. Chem. C,* 113, 13160–13165.

Yu, L., Achari G., Langford C. H. (2013). "LED-based photocatalytic treatment of pesticides and chlorophenols." *J. Environ. Eng.,* 139(9), 1146-1151.

Continued from page 18

with a deteriorated wastewater system. Reflecting back to 1944, we are getting a sense of déjà vu. Wish us well.■

Carl Yates has extensive experience in the water utility profession having served as project engineer, chief engineer and general manager of the Halifax Water Commission. In 2007, Mr. Yates oversaw the transfer of wastewater and stormwater assets from the Halifax Regional Municipality to Halifax Water.

1 *National Guide to Sustainable Municipal Infrastructure*, Water and Sewer Rates: Full Cost Recovery, March, 2006.

2 Halifax Water Integrated Resource Plan - September 2012.

3 Study of an Efficient Funding Mechanism for Halifax Regional Water Commission by Mark Gilbert, PhD., December 2012.

4 Cost of Service and Rate Design Methodology Review and Recommendations by: Galardi Rothstein Group, LLC., G.A. Isenor Consulting Ltd., W.H. Gates Utility Consultants Ltd., May 2011.

5 AWWA, *Principles of Water Rates, Fees, and Charges*: Manual M1-Sixth Edition, 2012.

6 *Financing and Charges for Wastewater Systems:* WEF Manual of Practice No. 27, 2005.

7 Bonbright, J.C., Danielsen, A.L., Kamerschen, D.R. *Principles of Public Utility Rates*, 2nd Edition, Public Utilities Reports, Inc, Alexandria, VA, 1988.

8 *Blue City: The Water Sustainable City of the Near Future,* Econics, Vancouver. January 2014.

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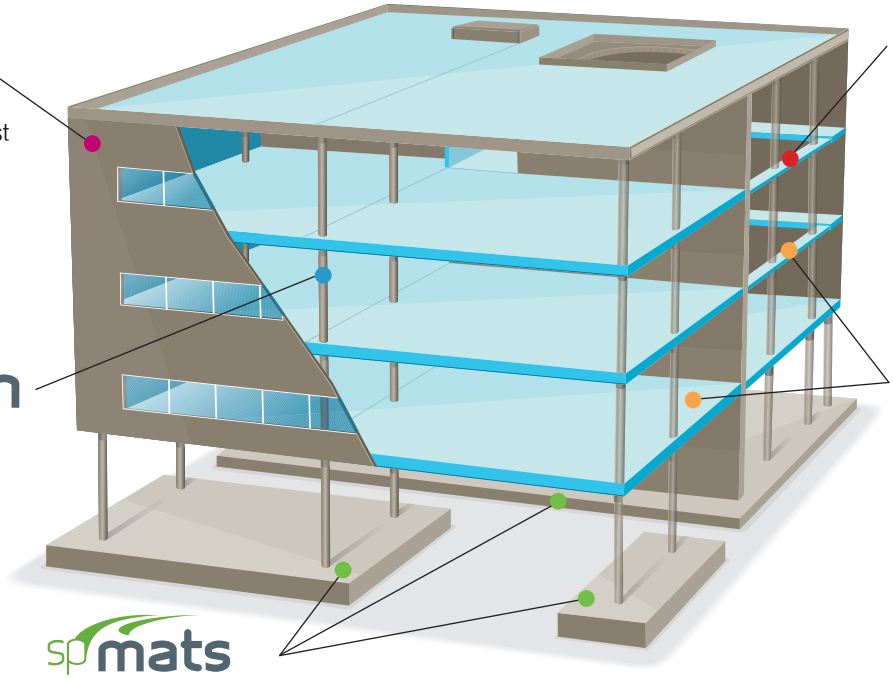

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