CLASS OF
3T5
ENGINEERING
AND
ARCHITECTURE

LAST NEWSLETTER

This will be the last regular newsletter for the Class of 3T5. The time has come to mark the end of the era represented by a separate 3T5 Newsletter in the traditional format.

Members are still most welcome to attend the luncheons - only the Newsletter is being discontinued. Notice of luncheon meetings will be provided in the normal way, using the 5T3 Newsletter. Just contact me - by phone, mail, or e-mail - and I will add your name to the mailing list for the 5T3 Newsletter.

Please note that the 5T3 Newsletter has a somewhat different format. It does not include a transcription of the talk from the previous luncheon. You will find it less formal – an easier read.

The UofT will continue to maintain the 3T5 and 3T6 mailing lists, so that special letters can be sent out to our group from time to time. I intend to write to you in the fall regarding the funds remaining in the Class of 3T5 bank account, once the expense of producing a separate newsletter each month has ended.

Bob Ross
June, 2005

<u>May Meeting</u>:

Our speaker in May was Elizabeth A. Edwards, PhD, P. Eng., Associate Professor, Department of Chemical Engineering and Applied Chemistry, University of Toronto. Dr. Edwards has over 15 years of experience in anaerobic biodegradation and groundwater bioremediation processes. Her research involves the characterization of microbial communities that degrade pollutants and the development of molecular tools such as nucleic acid probes and DNA microarray technology to detect gene expression in groundwater or soil samples.

The following is an edited version of Professor Edward's talk:

'I'm really very honoured to be here and share a story about bioremediation. You've probably all heard of bioremediation in the media and elsewhere. What really can we make of bioremediation to improve our environment, is the question. So please if you have questions on anything that I gloss over please interrupt and ask questions because I think it's a very diverse audience and one that I'm not accustomed to speaking to, so I might skip over things that would help clarify the story. So what I'm going to talk about today is a little bit of background on ground water contamination and some definitions of bioremediation, just so that we're all on the same page when I talk about things. I'm going to focus the story on chlorinated solvents and what we can do about those that are ubiquitous contaminants in our environments in the industrialized world, and what can we do about cleaning up that kind of contamination.

Canada's worse contaminated site is probably the Sydney Tar Ponds. Last year the government did actually pledge to put $400 million towards cleaning up the Sydney Tar Ponds, which are those ponds left over from coke ovens and a whole host of a hundred years of industrial operations. The tide would come in and out and flush through these ponds, and PCBs and other chemicals were continually flushed into the ocean, and the sediments and the sludge left in here were not good. Close by is also a landfill and this landfill contributes to the problem. So this is probably our worst site.

There's really not a good inventory of contaminated sites in Canada. In the U.S. there's something called the Superfund program that has tried to identify and prioritize contaminated sites so that one would spend dollars towards cleaning up those that are posing the most risk. In Canada we don't really have such a great inventory, but it's estimated that there are probably over 30,000 sites with contamination in Canada. In the U.S. it's estimated that it would cost over a $1 trillion to clean up all the problems. Needless to say that's not going to happen, but what is needed is a way of prioritizing the sites that are contaminated with those that really need to be addressed and money spent vs. those which maybe nature is kind of taking care of.

Why do we want to clean up contaminated sites? Well, because the ground water becomes contaminated. You might remember a movie starring John Travolta called Civil Action where the people around this particular site were getting sick with cancer and it was caused by trichloroethylene, a chlorinated solvent, probably the number one ground water contaminant. Trichloroethylene is a wonderful degreasing solvent that's used in the automotive industry and other manufacturing industries as a degreaser. It was thought that it was completely harmless and it was just dumped behind the plant. Another very famous movie is Erin Brockovich and this is a story about this woman's crusade, again people were getting sick, particularly children, and this turned out to be chromium contamination. This is a movie based on a real story. About three years ago I was at an international conference on remediation of chlorinated and recalcitrant compounds in California and the real Erin Brockovich, not Julia Roberts, came to speak to an audience of about 700 engineers and scientists. It was a very interesting talk and the audience was quite taken aback by her energy.

So what I'm going to be talking about today is bioremediation, as opposed to some other kinds of remediation or clean up, and the real driver for this is cost. If you have ground water contamination the easiest thing to do is to install wells at the downgrade and pump the ground water out. You treat it with activated carbon or by air-stripping or something like that, and maybe you re-inject the ground water afterwards, and that's called 'Pump and Treat'. And that is something that works, no question, you can intercept the water so the water doesn't flow off your property and become a liability but you have to keep doing this forever because if you have an infinite source of contamination on your site it will continuously bleed off. So 'Pump and Treat' usually has to be done indefinitely and 30 years is usually the cost projection that is made and you have to pay millions of dollars a year in operations and maintenance costs to keep these things running.

Another alternative is called a 'Bio-Barrier'. Instead of a series of wells you install a barrier that is biologically active; that is there are micro-organisms there destroying contaminants as they flow through. This would be a lot cheaper because you haven't got the operation of pumping every day and so on.

MNA stands for Monitored Natural Attenuation and it turns out that at a lot of contaminated sites, the indigenous bacteria that live in the soil, in the subsurface, can bring about a lot of degradation without anyone doing any engineering on the site. So, if you can monitor these kinds of processes and make sure they are occurring fast enough – ground water you know moves pretty slowly – you can have a pretty slow transformation process and still bring about a significant reduction in the amount of the contaminant fluid that's leaving your property. So that's an interesting option; that's almost your do nothing option, but you still have to monitor and meet your regulatory requirements.

And you can combine bioremediation and MNA, or you can also use other catalysts such as rusty nails. Iron turns out to be a wonderful reactant or catalyst for de-chlorinating some of these solvents. So you can dig a trench and dump in a whole bunch of rusty iron and have the ground water flow through that and it will actually remove the chlorines off some of these organic compounds. Some of these more passive technologies will definitely be more cost-effective, they just need to be as reliable as 'Pump and Treat'. You can't go wrong with 'Pump and Treat' because you put in your wells, you pump the water out, and you're intercepting it all. In terms of reliability it's what the industry prefers if there's a lawsuit pending.

So let's look at a little historical perspective on bioremediation. I looked and I think the earliest commercial application of bioremediation was probably in the 1970s when there was a pipeline rupture. The crude oil was spilled onto the soil, so the first commercial application was just applying fertilizer to that soil with a nitrogen and phosphorous kind of mixture, and stimulating the degradation of the crude oil. And that worked reasonably well, especially if you got there pretty quickly before it sunk down into the ground.

In the 1970s and 1980s, especially toward the late '70s and early '80s, people started realizing that some of these chemicals that we were dealing with in the industrial process were potential carcinogens. Things like trichloroethylene, for example, was not known before the late ‘70s that it really was a carcinogen, so people were handling this much like we handle water. So new legislation was developed and new technology - it was just an increased awareness of ground water technologies. Then enter into the ‘80s and this was when biology is having a bit of a revolution and people were able to move genes around from one microorganism to another. The thought was, you know what, we’re going to be able to make a microorganism, a bacterium, that can degrade anything. We’ll just move the genes from this organism into the other one and presto we’ll have magic bacterium. A lot of companies started developing proprietary micro-formulations that they would claim could do anything. It really was oversold, you can track journal publications over time and they went up during the ‘80s and then they kind of collapsed because it wasn’t the magical solution for all of these contamination problems. Bacteria can do very interesting things but they still have to obey the laws of physics. Moving genes from one organism that you might have purified in a laboratory into another organism and then injecting that organism into the ground to try and stimulate degradation didn’t really work very well. There were quite a few failures and people became very cynical about this.

There has been a reversal now in the last decade or so. What we’re realizing is that if you just go out to a contaminated site, and I’m sure there’s one just out here by the 401, and drill some wells, you can measure the concentration of petroleum products. You also measure things like oxygen or sulfate or methane and you get an idea of not just what chemicals are there, but also what processes are occurring in the subsurface. There’s an idea that we can prioritize sites based on those that are self-cleaning, and maybe if we wait thirty years maybe this will be cleaned up. Or we can gently enhance what processes are already occurring, as opposed to aggressively coming in there with something new, adding in some super bugs that actually can’t compete with the native organisms that are there anyway.

So what is the current status of biodegradation and bioremediation? The most common use is still back to using it for compounds like alkenes and aromatics and things that are found in petroleum hydrocarbons. The reason is because petroleum hydrocarbons have been around on earth since the dawn of time, and there are microorganisms that have evolved the genetic capability. Microorganisms have developed to exploit any potential niche, any potential difference between an electron donor or electron receptor that they can exploit, they will develop the machinery to tap into that potential difference and grow. And so petroleum hydrocarbons are readily degraded. In any teaspoon of soil you get from the garden or anywhere, you will find plenty of microorganisms that can degrade hydrocarbons under aerobic conditions.

The compounds that I've been focussing a lot of my work on are trichloroethylene (TCE) and perchloroethylene (PCE). PCE is your dry-cleaning solvent - 95% of all the drycleaners still use this as a solvent. TCE is an industrial degreaser that's used very widely. Of the super fund sites that mentioned, one out of three are contaminated with PCE and one out of four with TCE. So these are very prevalent contaminants. And because they're toxic, there are health risks involved. Because these are probably human carcinogens and also there are other liver and kidney issues, the drinking water limits are very low. The reason there's a range depends on the jurisdiction - U.S., Canada, or wherever you're looking. Canada tends to be on the higher end of these ranges.

What happens is that you have an industry that's been using trichloroethylene for years and years and nobody really knows how much was released and nobody knows exactly where it was released. If you come along thirty years after the plant was closed and you drill some wells here, you might hit something, and then you figure this is where the source is. And then you drill some wells over here and you hit something and so it's very hard to piece it all together as to where the contamination is. So the big question is how do you clean something like this up? And the true answer is that nobody knows.

The mass that's in there is so much greater than what you can dissolve out of the ground that you have an infinite source of contamination that just bleeds out into the ground water over years and years. So how do you clean it up? Well the way to do it is to put wells down here and just contain the contamination to your property so you don't have that liability. Containment measures are what are used right now to deal with it. Wouldn't it be nice to be able to get at the source and remove the source? Often the depth here can be hundreds of metres so you can't go in there and excavate it. You can dig it out if it's shallow, but often it's just spread out over miles of area and down several hundred feet, so it's very difficult to get at.

Here is an example of what we do in the lab. In these boxes we put a one inch slab of soil and flow water through it. We injected 10 millimetres of PCE in the middle and then we inject nutrients and bacteria culture and we just flow and analyse. What we've found is that you can enhance the dissolution and the removal of the PCE from the system by having close proximity, having the bacteria very close to the source of the solvent. So we're also doing this on a highly instrumented field site, at Dover Air Force Base. We've put a tent over it so we don't have rain, and all of these are wells in the sand so we can monitor what's going on. A paper that just came out this January in the Journal of Science describing the whole genome. It seems to have is a very small genome, and it seems to be very specialized, so they are definitely born to dechlorinate.

To end then, I just want to say that this project is a wonderful blend of very applied resources and fundamental science. These organisms are a fascinating new life form that we're studying. How do they evolve? Certainly PCE has only been around for the last 60 years, so what did these organisms dechlorinate before we provided them with such a young substrate, and how did they evolve? Certainly there are a lot of chlorinated organics that are naturally synthesized. Why does bio-augmentation work for these kinds of compounds? The reason is there's a unique niche for these organisms, so when you add these organisms into the subsurface the only thing they can do is dechlorinate - they don't compete with other organisms.

When you do the same thing for hydrocarbons it doesn't do any good to add organisms, because the organisms that are there already are already best suited to degrade the gas leak, so it's a very different problem. The big challenge around right now is mixing. The point being you have to get the bacteria and the electron donor down to where the DNAPL is and if you don't even know where that is then it's a huge problem. It's a challenge facing all remediation. You need to deal with this mixing. So there's a lot of work done on trying to promote mixing in the subsurface.

So with that I'll just end with future prospects. My big thing is that TCE and PCE are rather benign molecules in the grand scheme of things. Consider dioxins or the whole range of fluorinated compounds that are being synthesized, carpet desticker stuff, stain remover, etc. These long chain fluorinated compounds are now showing up in tissues of polar bears and whales and so on. We all have a certain amount in our blood now resulting from these industrial compounds that are used. How do we manage the synthesis of these new chemicals, how do we appropriately monitor and regulate the use of these, and how do we clean up the spills of these?

I think the answer is to mine the diversity. There are so many microorganisms, and we don't know anything about the microbial diversity of the subsurface. We're just starting; it's a really exciting era now that we can sequence DNA so easily. You can sequence the whole genome of a bacterium in an afternoon, the sequencing machines are so fast now. So we're going to be sequence rich and we're going to have to design algorithms to pick out interesting genes and test them. Although I told you before that making modifications and mutations of genes in the early '80s was a failure, I hope that we're a little bit smarter now. I do hold out that there will be some rational design of new enzymes so that we can improve the catalytic side of enzymes so that they can deal with a fluorinated molecule as well as a chlorinated molecule.

I'd like to acknowledge all the people that have worked with me, specifically David Major and my graduate students. My funding has come from the National Science and Engineering Research Council. And these other acronyms stand for Strategic Environmental Research Defense Program in the U.S., Environmental Certification Technology Program, and Remediation Technology Demonstration Forum. This is a conglomeration of industry and the United States Environmental Protection Agency to try and demonstrate some of these new technologies.

Thank you very much and I hope there are questions.

Q. Professor Edwards, would you say that the lack of sites in Canada is due to a lack of money or a lack of organization?

A. Organization. There are certainly plenty of sites, not a lack of sites. There are plenty of sites proportional to the amount of industry. But in Canada there hasn't been a cohesive, a national policy on what we should do about contaminated sites, it's been very ad hoc. There isn't a national list; there's a little list, but it's not very detailed. A lot of the sites are pretty remote, or we don't use the ground water from there, so it doesn't hit the radar. I think it's going to start to become more of an issue certainly.

Q. Unlike the Tar Ponds in Sydney, Stelco and Defasco have polluted Hamilton Harbour and seem to have gotten around the problem.

A. Well, you know that happens everywhere. Often it's cheaper to pay lawyers to argue the case than it is to do the remediation because we don't have a magic solution. In the Hamilton Harbour, it's kind of hard to know where to start. It's probably better to leave it down there and so the answers aren't obvious. Sydney Tar Ponds for instance, they've been trying to clean them up for 20 years and there just isn't an easy solution that doesn't cost a lot of money. Mind you they should just go in there and aggressively deal with the problem.

Q. What happens when you dig it up, what do you do with it?

A. Good point. You hope you can put it into a secure landfill. One with a good liner and a good drainage ditch so you could monitor it. That's one place to put things. You can also incinerate, if you go hot enough you can incinerate. It's just a money issue. The way I see it is you definitely need to do a risk assessment. In the U.S. and Europe they look like they're going to do a site specific risk assessment in each case and figure out what it is that's in danger. In a lot of cases there isn't a problem. If it's really deep down, no one is drinking the water, it's flowing very slowly, it's not migrating into any sensitive receiving areas, you just put a deed restriction on the land, so there's an indication that it's contaminated and just leave it. That's something that's practical. We need a national list because we need to prioritize. It's easy to find the worst. You need to prioritize and put money or generate incentive to whoever has the liability to clean up their sites.

Q. There are a number of companies that sell bottled water. Are they finding aquifers that are relatively pure or are they using processes of this type?

A. They are finding aquifers that are pure. You have to look carefully at the bottled water. There's bottled water that says pure spring or Perrier, and what they've done is they've used a spring and bought all the land around and nobody has put anything in their water and that's how they preserve that water. For other kinds of water it's reverse osmosis water, so they can take it from anywhere, so they can take it and put it through reverse osmosis and so you've just got water, it's just tasteless, it's just H2O, there are no minerals in it. It doesn't really matter where they take it from as long as it goes through the reverse osmosis process. Sometimes with spring water the regulations are less than what you'd have with tap water.

Q. It seems to me that the tests are done in a laboratory or small site. Are there any of these that are being used to clean up large areas?

A. Well you sort of have to build slowly. But yes, that first demonstration was with 15 litres of culture over a site that was 10 feet deep by 30 feet long. That's pretty small, but it's easy to scale up.

Q. Have you done that?

A. Yes, the biggest is now 250 litres.

Q. How big is that?

A. It's not huge, but it's certainly not considered a demonstration site. There's a lot of work being done on the engineering side to see how best to engineer the mixing of bacteria. Should we make a trench down gradient and circulate bacteria through that trench? That's a very attractive option. If you keep them individually small then you have better control of what you're doing. The hardest problem is determining what's underground. You can't see what's happening to your water. There might be a crack in the bedrock and then your contamination can go zooming off. It's really challenging to have good hydraulic control.'

Attendees:

3T5 and friends: Kay Brobst, Gord Reed

4T9: Maurice Crawford, Doug Forster, Ken Laughlin, John Wilkes

5T0: Doug Dunbar, Vern German, Bob Edmunds, Chris Hinde, Bob McQuillan

5T1: Lang Moffat

5T2: Eric Smythe

5T4: Robbie Rhodes, Bob Hubbs

5T3: Dave Bawden, Barrie Blanshard, Al Bowler, Warren Brown, Bill Chackeris, Don Dowds, Dave Fenwick, Ike Goodfellow, Marv Green, Paul Greenan, Bill Johnson, Bill Kirkpatrick, Derek Little I, Derek Little II, Dusty Miklas, Jack Mollenhauer, David Noble, Dick Pearsall, Ross Raymond, Bruce Taylor, Neville Wesson, George Wildish, Jamie Blanshard (guest).

U of T: Elizabeth Edwards, Márta Ecsedi, Malcolm McGrath

70th Anniversary Event:

The Engineering Alumni Dinner Dance was held on June 3, as one of the UofT Spring Reunion 2005 events. The Class of 3T5 was represented by Wilmot Blackhall with his daughter Mary Lou McDonald, Bob Smallwood and his son Jamie Smallwood, and Kay Brobst accompanied by her daughter Brenda Axon. Also present was second-generation 3T5er Joe Grieco from the Class of 7T0. Members will recall that the Grieco family ran the bar for 3T5 at earlier reunions.

The group was treated royally, as fitting for the oldest class at the Reunion. They sat at the VIP Table with Dean Tas Venetsanopoulos, Márta Ecsedi, Malcolm McGrath, and Alumni Association President John Voss.

Wilmot Blackhall said a few well-chosen words on behalf of the Class. He talked about the camaraderie the Class of 3T5 had always had – initially a result of graduating together during the great depression, and maintained in later years by working together on The Second Mile Award and meeting for regular luncheons. A salute to Wilmot, Bob, and Kay for representing the Class at the 70th Anniversary Event!

Note to Members:

The luncheon meeting on May 11 was the last meeting for this season. The next luncheon meeting will be held on October 12.

It has been a great privilege to edit this Newsletter for the past four years. I have enjoyed every issue, and I hope you have too. However, all good things come to an end, and I think this is the right time for the 3T5 Newsletter. Have a great summer, and please remember to contact me to get your name added to the 5T3 mailing list.

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