Field site trial of iron-dithionite injection.
Photo courtesy of Ariel Nunez Garcia

INTEGRATE RENEW Newsletter

June 2016

In this issue

We reached half way in Year 5 of the INTEGRATE Project and we have just started Year 3 of the RENEW (NSERC/CREATE) Program. We currently have 6 students/Post-docs in INTEGRATE only, 9 in RENEW only, and 12 that are in both programs.

This issue brings two contributions. The first on field application of iron-dithionite for groundwater remediation, by Ariel Nunez Garcia. The second, on global issues on water, written by Dr. Lesley Herstein, our invited contributor.

At the end of this issue, you will find a list of our latest publications, and updates on what has happened or will happen next.

Enjoy!

Featured Student

This issue features Ariel Nunez Garcia, PhD student working with Professor O'Carroll.

Iron-Dithionite for In-Situ Remediation

by Ariel Nunez Garcia

Field applications of zero valent iron (ZVI) particles have mostly focused on targeting contaminant plumes by intersecting the groundwater flow downgradient of a source zone. This is commonly known as permeable reactive barriers (PRBs). Another approach used for the implementation of ZVI is hydraulic fracturing; high pressure injection to create a permeable conduit for the particles. With the advent of ZVI nanoparticles (nZVI) in the late 1990's, new in situ approaches for the application of ZVI emerged (e.g., gravity feed injections). Though limited mobility was characteristic of the early field scale trials, development of polymer coated nZVI led to successful field implementation of the technology. Polymers (such as carboxymethyl cellulose, CMC) also helps to prevent agglomeration, stabilizing nanoparticles and allowing them to achieve greater mobility in porous media.

Sodium dithionite ($Na_2S_2O_4$) is predominantly used in a technique known as In Situ Redox Manipulation

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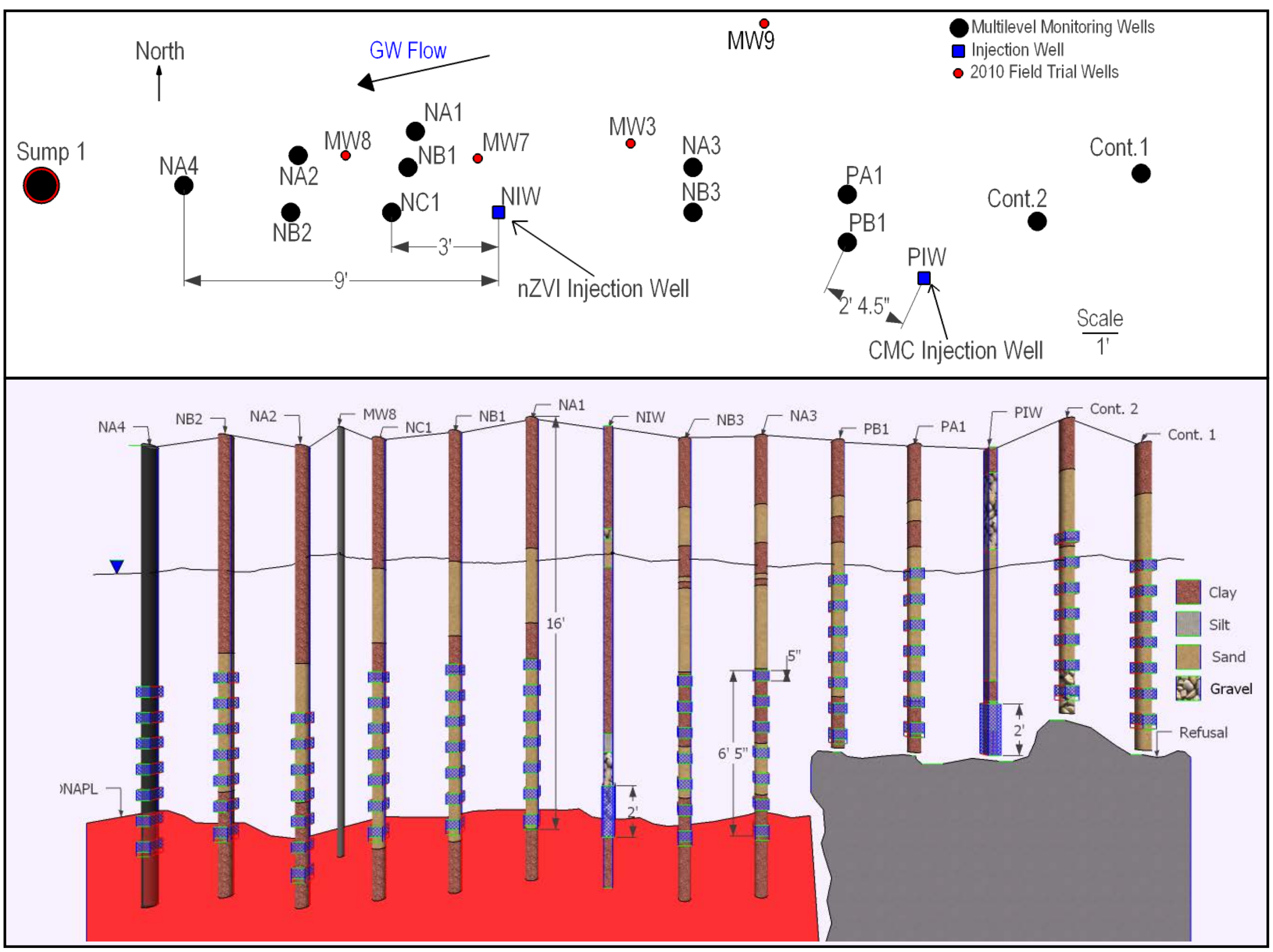
(ISRM). Similar to the creation of a PRB by ZVI, a dithionite solution is added to the subsurface to reduce naturally occurring ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+}). The resulting Fe^{2+} species in soil matrixes then serve as electron donors for redox-sensitive contaminants.

Both nZVI and sodium dithionite belong to a broader category of remediation technologies known as In Situ Chemical Reduction (ISCR). In ISCR technologies, remediation occurs mainly by the reduction of target contaminants. In most cases, the target contaminants are chlorinated solvents, in particular chlorinated ethanes and ethenes, which are amongst the most common contaminants treated by ISCR technologies. Though research combining both reductants has been conducted in recent years, their combined ability for dechlorination of recalcitrant chlorinated compounds has not been widely studied. My current research consists of combining both technologies at the field scale to target a free phase chlorinated solvent pool. It is expected that their combination will help overcome some of the limitations associated with each individual technology, such as short reactive lifespan for nZVI and dependability on the iron content in the soil matrix for sodium dithionite. To prevent agglomeration and improve transport, iron nanoparticles will be polymer coated with CMC. As stated in the previous Newsletter (Issue 6), an added advantage of the CMC-nanoiron is the possibility of stimulating the microbial community, which could contribute to the overall degradation of chlorinated compounds.

In 2010 a field trial was conducted next to the study area where former PhD student Chris Kocur had done his trial with a 1 g L^{-1} of nZVI slurry injected into the subsurface. Having previous experience at the site allowed for informed decision making when installing monitoring and injection wells. Our study area was divided in two zones: a "nanoiron zone" where 1 g L^{-1} nanoiron in 0.8 %wt CMC and 22 mM dithionite were injected, and a "CMC zone" where a solution of 0.8 %wt CMC was injected. A total of 12 multilevel monitoring wells and two injection wells were installed. These multilevel wells were custom made at Western University and consist of 7 intervals, with a screen of 5 inches each, 1 foot apart. Below is a plan view with the relative location of each well, and a cross-sectional view with the stratigraphy of the site as well as screen depths. Field work for this research, including installation of wells, borehole loggings, sampling and nanoiron synthesis, was completed with collaboration with CH2M HILL.

The nanoiron-dithionite slurry was synthesized on-site and injected overnight on November 25 2014. Following injection, it was visually confirmed that iron nanoparticles traveled to several of the downstream wells, and even to upstream wells. The performance of the treatment has been monitored by conducting multiple post-injection sampling rounds. Samples are collected for the analysis of volatile organic compounds (VOCs), total organic carbon (TOC), sulfides, anions and total metals. Complementary diagnostic tools, such as compound specific isotope analysis (CSIA) and molecular biological tools (MBTs), are being employed.

Ariel Nunez Garcia is a PhD Student at Western.



Plan view and monitoring well cross section at the fied site. Courtesy of Ariel Nunez Garcia.

Ariel Garcia Nunez - PhD Student at Western

Ariel is a Ph.D. student under the supervision of Dr. Denis O'Carroll and Dr. Jose Herrera in the Department of Civil and Environmental Engineering at Western University. He completed his B.Sc. in 2012 from Utah State University (USU) and M.E.Sc. in 2014 from Western University, both in Environmental Engineering. During his undergraduate he was a member of Engineers Without Borders (EWB) and completed a sanitary project in Uganda in the summer of 2010. He also worked as a research assistant and as a field technician for air quality consulting companies in Logan, UT. After his third year, he worked as an environmental technician for Falcondo Xstrata Nickel and as an intern for Barrick Gold Pueblo Viejo, two mining companies in the Dominican Republic. After being exposed to various fields in environmental engineering through classes and work experience, he decided to focus on contaminant remediation for his graduate studies.

For his current research, he is leading a field study where nZVI was injected into the subsurface to target a DNAPL pool. His responsibilities include logistics, field sampling, lab analysis and data processing. He is also performing experimental work at Western to study the reactivity and transport of different nZVI treatments

See more on Ariel's research in the article he wrote for this newsletter.

Course at UofT Aims to Address Complex Water Challenges

by Lesley Herstein

Water challenges span multiple disciplines and their resulting complexity requires collaboration. Often the challenge is the focus; however, the nature of the collaboration will also play a role in determining the extent to which solutions adequately address what are often complex, systemic water issues.

The question of how to collaborate across disciplines is difficult to answer. Disciplines have their own cultures, which are instilled as students go through higher education. As students take courses in their own disciplines and spend more time with their disciplinary peers and mentors, they slowly acquire a shared disciplinary language, as well as a shared way of learning, approaching problems, interacting and communicating. This is important, as it ensures that students that graduate with a specific disciplinary degree are able to easily migrate to the working world with enough of a foundation to integrate and build their disciplinary expertise and experience.

Although beneficial in terms of working within one's own discipline, deeply entrenched disciplinary cultures, such as engineering, pose a challenge to collaboration across disciplines. When collaborating across disciplines, we are trying to solve a problem with individuals who speak completely different disciplinary languages. Therefore, in these collaborations, an important element for success is to recognize that a common language must be developed in working through a specific challenge toward solutions that are truly multidisciplinary in nature.

This past winter, a new course was offered at the University of Toronto that applied highly interactive and project-based learning to teach students how to develop common language when working in multi-disciplinary groups. Water as a Global Challenge: Science, Economics and the Politics of Policy-Making, GLA2091, exposed students to methods that can be used to collaborate across disciplines to collectively frame water issues, explore solutions and build strategies toward comprehensive solutions.

The course brought together instructors and graduate students from the University of Toronto's Department of Economics, the Faculty of Engineering & Applied Science, and the Munk School of Global Affairs. The instructors designed the course to be highly interactive and project-based. There were some formal lectures that provided the class with some base knowledge from each discipline. The remaining time in the course was spent guiding multidisciplinary student project groups through a structured interactive process. Through this process, they were able to define and scope a grand water challenge of their choosing and work towards a solution.

As students began to work together on their water challenges, they were asked to think about their chosen challenge from a systems perspective (e.g., systemic causes, stakeholders interactions). For example, they were introduced to the technique of conceptual system mapping, which allowed them to visually communicate complex stakeholder and issue interactions associated with their challenges (see example map in the next page). This collective and explicit tool for creating a shared system view ensured that all members of the group were thinking about the problem in the same way. It also was used as a tool to identify leverage points within their problem systems and to design their solutions to take advantage of these.

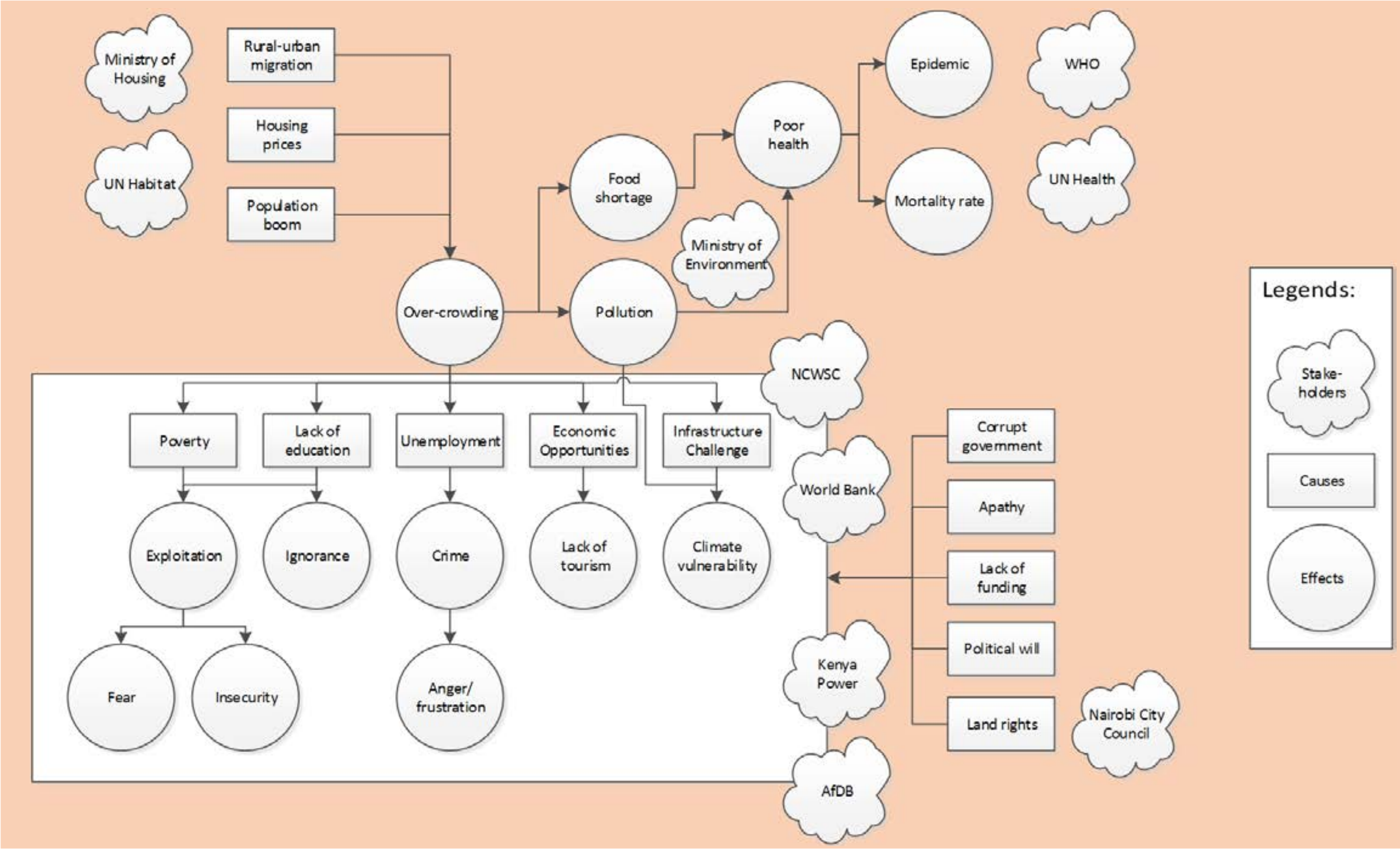
Lesley Herstein got her PhD at UofT with Professor Barry Adams and is now the lead Instructor for GLA2091 and Manager of Policy at WaterTAP (the Water Technology Acceleration Project)

Updated Publications

From Years 1 to 4, our contribution to the science and engineering of groundwater remediation has included 46 articles in international refereed journals, 2 book chapters, and 129 conference presentations (28 of these in Year 5).

These are our latest journal publications:

Garcia, A.N.; Boparai, H.; O'Carroll, D. (2016)



Conceptual system mapping, an example of how to visually communicate complex stakeholder and issue interactions associated with multidisciplinary work groups. Courtesy of Lesley Herstein.

Enhanced Dechlorination of 1,2-Dichloroethane by Coupled Nano Iron-Dithionite Treatment. *Environ. Sci. Technol.* Article ASAP. DOI: 10.1021/acs.est.6b00734. Date (Web): April 29, 2016.

Koenig, J., H.K. Boparai, M. Lee, D.M. O'Carroll, R.J. Barnes and M. J. Manefield, 2016. Particles and enzymes: Combining nanoscale zero valent iron and organochlorine respiring bacteria for the detoxification of chloroethane mixtures. *J. Hazardous Materials*. Volume 308, 106–112.

Rashwan, T.L., JI Gerhard, G. Grant. 2015. Application of Self-sustaining Smouldering Combustion for the Destruction of Wastewater Biosolids. *Waste Management,* pp. 201-212. doi:10.1016/j.wasman.2016.01.037.

Xu B.S., Sherwood Lollar B., Passeport E., Sleep B.E. 2016. Diffusion related isotopic fractionation effects with one-dimensional advective-dispersive transport. *Science of the Total Environment*, 550: 200-208

Mondal, P.K., Lima, G.P., Zhang, D., Lomheim, L., Tossell, R.W., Patel, P., Sleep, B.E. 2016. Evaluation of Peat and Sawdust as Permeable Reactive Barrier Materials for Stimulating In Situ Biodegradation of Chlorinated Solvents. *J. of Hazardous Materials*. 03/2016; 313. DOI:10.1016/j.jhazmat.2016.03.049.

From the 28 new additions to the list of conference presentations, 8 were presented at Battelle's Tenth International Conference on Remediation of Chlorinated Solvents and Recalcitrant Compounds, this past May 22-26.

Other Updates

Congratulations to Fan Yang, Master's student supervised by Professor Kent Novakowski. Fan successfully defended his thesis on May 5th 2016 and will start his career on June 1st as a consultant. Fan had very kind words to say after his graduation: "my professional and personal skills are greatly benefited from the CREATE/RENEW program". Good luck, Fan, and we wish you the best in your new life.

Our Fifth Integrate and Second Renew Annual meetings will take place at the Seeley Hall, Trinity College of the University of Toronto, on September 29th and 30th 2016. We have two workshops programed for the morning of September 29th, one on Groundwater gadgets with Solinst, and another on Oral Presentation Skills both at Trinity College (details will be sent to all via email).

The afternoon will start with a keynote address from David Reynolds on the application of electrokinetics to groundwater remediation. This talk will be followed by presentations from students and post-docs from the 4 institutions involved in the two programs.

The second day will start with a keynote address from Professor Lesley Warren from UofT . Professor Warren is the Claudette MacKay-Lassonde Chair in Mineral Engineering, and she will present her research on microbial processes associated with mining activities. September 30th will also have students and post-doc presenting results from their work.

This year's annual meeting will also have a 3 Minute Thesis (3MT) competition. So, all students should get ready to impress the judging panel, which will be have representatives from our industrial sponsors. Details will be posted on the RENEW and Integrate Websites.

Our Outreach Program continues to associate high school and graduate students, both at UofT and Western University. We will again host 2 or 3 high school students for Summer internships, we hold sessions at Engineering Summer Camps Western and UofT. Recently Professor Barbara Sherwood-Lollar spoke to over 400 children visiting the UofT campus at the latest Take our Children to Work Day.

We would like to congratulate three Professors who are part of the RENEW/Integrate Programs and who recently won prestigious awards:

Professor Barbara Sherwood-Lollar received the John Polanyi Award,
Professor Elizabeth Edwards received the Killam Award, and
Professor Jason Gerhard received the Faculty Scholar Award from Western.

On April 1st 2016, over 40 of our graduate students went to the Geosyntec headquarters at Research Lane in Guelph for a full day workshop with their engineers and scientists. They will go back in the fall for a second workshop.

FAST FACTS

46
number of scientific publications

129
number of conference participations

40
HQP (+ 19 undergrads + 3 technical staff)

Acknowledgements

We would like to thank Ariel Garcia and Lesley Herstein for their contribution to this issue.

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