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Stream D: Groundwater and Sediment Remediation Case Studies

Technology for the Improvement of the Qualities of Surface Water and Sediments

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In 2002, a filtration vessel was developed and a full-scale demonstration of water purification was performed for three months in an actual small bay in Japan. The filter was made of two layers of marine sand and slag, with some contrivances. As a result, 6000 m3/day of seawater were purified. The level of SS of the filtered water decreased from 25 mg/L to less than 2 mg/L. The average removal rate was higher than 80%.

In many enclosed and semi-enclosed water areas, the accumulation of nutrients and hazardous substances becomes increasingly one of the important problems for sustainable environment, because of potential eutrophication and bioaccumulation. Most of the hazardous materials, such as dioxin, heavy metals, organic compounds, bacteria, etc., which were discharged into water area, are adsorbed or absorbed onto the surfaces of suspended solids, and settled at the bottom. Recent works showed that dangerous materials are usually organic matter and fine inorganic particles, such as clay, because of their active surface interactions. These sediments cause not only a danger of aqueous life, but also contamination of seafood for human consumption.

To reduce energy required and volume to be treated for remediation, the removal of contaminated suspended and resuspended solids can be proposed as a potentially effective technique using processes of resuspension-segregation-filtration. In this paper, the contamination of sediments is reviewed, and a technique for the improvement of sediment quality using the processes is presented.

Filtration is the most fundamental and effective technique to improve water quality. This is because the major impurity in water is suspended solids (SS) which can be removed by the filtration. It is interesting that most of the other impurities can be adsorbed on SS and they can also be removed with SS. It is possible that dissolved substances in water can be removed by repetition of the filtration process, because the physical filter can become a bio-filter with trapped SS. It can even remove dissolved materials such as ions and dissolved chemical oxygen demand (COD).

Sediments can be improved by the combined technique of resuspension and filtration. The technique is being developed for sites in Canada. This work will be presented.

Solidification/Stabilization of Contaminated Sediments at the Sydney Tar Ponds, Sydney, Nova Scotia

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The Sydney Tar Ponds Remediation Project is the result of nearly 100 years of steel production in Sydney, Nova Scotia. When production ceased in 2001, a legacy of contaminated soils, sediments and groundwater remained, bearing such contaminants as PAHs, VOCs, PHCs, PCBs, and heavy metals. The primary mechanism for the clean up is the use of Solidification/Stabilization (S/S) of approximately 700,000 tonnes of sediment in the Tar Ponds. The final design for the Tar Ponds includes a S/S monolith, with a lined channel conveying the incoming surface and cap runoff water through the site and into Sydney Harbour.

The North Tar Pond, which is open to Sydney Harbour, is characterized by high PAH concentrations while the South Tar Pond is characterized by elevated PCB concentrations. The variation in grain size (much finer in the South Tar Pond) required the design to address each pond separately with respect to the S/S design.

Over the past two years, bench and pilot scale testing were conducted at two locations within the Tar Ponds to support the design and to satisfy regulatory conditions of the environmental assessment approval. Most recently favourable results from the pilot-scale work were reported; these are required in order to obtain regulatory approval in advance of S/S treatment. The pilot report detailed the results of testing undertaken on six recipes of cement and other reagents in each of the North and South Tar Pond. Other aspects of reporting included results of air monitoring, laboratory procedures, and scale up factors.

The detailed design for the Tar Ponds remediation is divided into three separate contracts. The first contract includes the enabling works and comprises the diversion of surface water inputs around the work areas where S/S will be conducted. The second contract includes the S/S treatment of the sediments and construction of an engineered and lined channel to convey the surface water inputs through the site post-construction. The third contract includes installation of a complex cap to protect the S/S monolith and manage runoff water at the site in the final condition. With the detailed design complete, the S/S enabling works contract was awarded in the spring of 2009. At that same time, a separate contract for the S/S treatment was being tendered. The surface cap contract is expected to be tendered in the fall of 2009. A fourth contract for the construction of a bridge spanning the engineered channel will be sequenced to strategically enable bridge construction while the other contracts are being executed.

This presentation will provide details of the pilot scale testing and provide an update on the full-scale implementation of S/S treatment. Details with respect to air monitoring, environmental controls, and contract implementation will be provided. In addition, given the multiple contracts being executed simultaneously at this site, the presentation will provide an overview of challenges and strategy for their implementation.

Industrial Effluent Impact Assessment of the Major River System and Agriculture Soil in Hanoi City, Vietnam

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Vietnam has a wealth of fertile agricultural land for food production. However, it is challenging to maintain the land quality and to enforce land-use planning and environmental regulations in the face of rapid economic and industrial development. Many villages have been partially transformed into industrial areas, and industrial pollution has had a negative impact on the quality of agricultural soil. This study assessed the environmental impact of urbanization in Hanoi by investigating the extent of metal pollutants such as copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd), chromium (Cr) and nickel (Ni) in Tolich River and Kimnguu River, the two major water sources in Hanoi City. These rivers are the only sources of water for irrigation of the agricultural areas and fish farming. Water, sediments and soil samples were collected and characterized. The results indicated that the stream water has extremely poor quality, with extremely low biochemical oxygen demand (BOD), pH as high as 11 and high metals concentrations exceeding the Vietnamese water standard limits. The metal concentrations in water and sediments are directly related to industrial discharges along the rivers and transportation activities where leaded gasoline is still in use. The agricultural soils also contain high metal concentrations which exceed the soil standard. Biological uptake of heavy metals by the eatable vegetations from the field was also observed. The human health impact by consume the vegetations can be estimated based on the value obtained.

Water Management Strategy during the Solidification/Stabilization of Contaminated Sediments at the Sydney Tar Ponds Remediation Project

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The Sydney Tar Ponds Remediation Project is the result of nearly 100 years of steel production in Sydney, Nova Scotia. At one time, Nova Scotia produced almost 50% of Canada's steel. When production ceased in 2001, a legacy of contaminated soils, sediments and groundwater remained, bearing such contaminants as PAHs, VOCs, PHCs, PCBs, and heavy metals. What remains today is one million tonnes of contaminated soil and sediment spread over two major sites – the North and South Tar Ponds, and the former Coke Ovens site; an area spanning 168 acres. The primary mechanism for the clean up is the use of solidification/stabilization (S/S) of approximately 700,000 tonnes of sediment in the Tar Ponds. The final design for the Tar Ponds includes a S/S monolith, with a lined channel conveying the incoming surface and cap runoff water through the site and into Sydney Harbour.

Detailed design for this remediation project commenced in October 2006 and has an anticipated construction completion date of 2014. AECOM conducted the preliminary design and the detailed design engineering for the remediation project and is overseeing the work including construction oversight, inspection and contract management. Most recently contracts were tendered for the surface water diversion (enabling works for S/S) and for the S/S of the Tar Ponds' sediments. Tendering of two more contracts are expected late in 2009; these are construction of a protective cap over the S/S material and a bridge over the completed channel.

As with many earthwork projects, water is a significant construction issue with impacts on the effectiveness of S/S treatment, the dispersion of contaminants and capital cost. Water sources for the project include tidal waters within the Tar Ponds, surface water from two brooks with an urbanized catchment area (Coke Oven Brook and Wash Brook), groundwater, and precipitation, all of which must be considered in the water management approach during remediation. During the remediation process, the objective is to restrict the flow of contaminated water from reaching Sydney Harbour in order to mitigate impacts to aquatic life, which in Cape Breton is a local resource. The water management strategy of the project includes vertical cut-off walls, by-pass pumping systems, diversion ditches, water treatment, sedimentation control, water dissipation structures, and extensive monitoring in an effort to mitigate the impacts noted above.

This presentation will provide a description and update related to the water management strategy and challenges to Canada's largest remediation project. In particular, the presentation will provide details of the strategy and its implementation across four separate contracts within the site limits.

Developing a Comprehensive Understanding of Groundwater Flow and Petroleum Hydrocarbon Migration in a Complex Permafrost Fractured Bedrock Environment at Colomac Mine, NWT

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The former Colomac open pit gold mine is located approximately 220 kilometres north of Yellowknife, Northwest Territories. The mine operated from 1989 to 1997 and has had documented uncontrolled releases of diesel and gasoline products throughout the mine's operational history. Indian and Northern Affairs Canada (INAC) is undertaking the remediation of environmental impacts and assessment of ecological and human health risks at the site. Previous work performed at the mine site has included collection of a significant amount of information on the subsurface structure and has shown the behaviour of groundwater to be highly variable, heavily influenced by seasonal changes, precipitation and melt cycles and irregular permafrost, however a consistent conceptual and observational model of groundwater flow and product migration within the complex, fractured bedrock has not been developed.

In order to improve this situation, a supplementary hydrogeological investigation is being undertaken in 2009. The first step in improving the hydrogeological assessment of the site is to produce a 3D subsurface model of the area of interest, by compiling all historical drilling results into a single dataset, from which a current bedrock composite is being prepared. The 3D subsurface model is being used to plan a physical investigation to characterize groundwater movement, through completion of a dye-testing (tracer) program. The objective of the dye-tracer testing program is to evaluate the hydraulic connection or communication between wells under passive, non-pumping conditions. The dye tracer testing program involves the injection of several conservative tracer chemicals (sodium chloride, sodium fluorescein, sodium bromide) at selected up-gradient points, followed by regular monitoring of down-gradient wells for collection of multi-level groundwater samples. The dye tracer chemicals chosen are ones that offer the least likelihood of chemical interaction (i.e., are conservative), while satisfying the practical requirement of allowing for analysis in the field at sufficiently low concentrations to provide accurate results.

In this paper, the planning, execution and results of the supplementary hydrogeological investigation are outlined, with particular attention paid to how production of the 3D subsurface model and the dye tracer testing program contributed to developing an improved understanding of groundwater flow and petroleum hydrocarbon migration through this complex permafrost fractured bedrock setting.

Federal Interim Groundwater Quality Guidelines

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Groundwater contamination is present at many federal contaminated sites, particularly those with relatively soluble contaminants and soil contamination extending to or near the water table. While the collection of groundwater samples and analyses for potential contaminants of concern is standard practice at contaminated sites, historically there have not been any federal groundwater quality guidelines to compare the results of groundwater analyses to. As a result, a mix of different approaches has been applied for groundwater at federal contaminated sites, including the use of surface water guidelines, drinking water guidelines, and provincial guidelines.

In order to promote the consistent management of groundwater contamination at federal contaminated sites, Federal Interim Groundwater Quality Guidelines have been developed. The interim guidelines were developed based on a review of existing approaches applied both in Canada and internationally. Key features of the interim guidelines include a multi-tiered framework and the protection of a wide variety of receptors and exposure pathways. The paper provides the rationale and basis for the interim guidelines, as well as discussing the intended application of the guidelines at federal contaminated sites.

Sediment Liability Estimation Toolkit

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Canada includes 20% of the world’s freshwater resources and the longest marine coastline of any country. Human settlements have historically congregated on coasts and rivers. Sediment contamination is now a widespread and significant environmental issue. Many sites under Federal ownership and/or jurisdiction include marine or freshwater sediments, and it is expected that the number of sediment remediation projects will increase significantly in the coming years as the Federal Contaminated Sites Action Plan (FCSAP) continues to be implemented. Project management and budgeting require early-stage cost estimates, yet sediment project cost estimates are notorious for inaccuracy and high variability.

By combining expert guidance, Microsoft Excel™, Visual Basic programming and the off-the-shelf Monte Carlo simulation program Crystal Ball™, Public Works and Government Services Canada (PWGSC) demonstrated that user-friendly packages for the initial estimation of sediment liability requiring no previous experience with Monte Carlo methods or programming can be developed. An example toolkit has been assembled using three levels of excel sheets that work together to produce systematic, reproducible, documented liability estimates where dredging remains the default or baseline remedial strategy. Visual Basic programming is used to guide the user through a Class D/Indicative Estimate, including a preliminary feasibility screen and an overview of both design status and the major design components left to complete. Visual Basic is also used to pre-process data for Crystal Ball and to trigger a Crystal Ball simulation.

Typically, estimators fill in the line items on an estimate using their understanding of the project and of current market prices. However, they know that each number is prone to variance. Many estimators therefore sum and re-sum their breakdowns using “best case” (low), “worst case” (high) and “most likely” (criteria not defined) numbers, often presenting the results to decision makers as a form of sensitivity analysis.

The Sediment Liability Toolkit takes over the task of summing and re-summing the model, and does so thousands of times using probability to vary input values. If a given parameter has a 15% probability of being value “X”, the software, in the process of re-summing over and over again, will use the value “X” for that parameter in about 15% of the runs.

Of the thousands of total costs calculated, most cluster around a “most probable cost”. The software provides the most probable cost, as well as measures of the variance of total cost given the input uncertainty (risk) for each component line item.

Use of the Sediment Liability Estimation Toolkit for typical projects indicates that (a) a relatively small number of project components, particularly those related to materials handling/disposal, are responsible for the vast majority of project cost variability and (b) because of the compounding effect of “worst case” scenarios, the cost distribution function is skewed to the right (to -higher values). Use of the tool as a planning, cost-estimating, and communication aid focuses remediation projects on the aspects that have the largest influence on total cost. Additionally, uncertainty is quantifiably and reproducibly incorporated into costing, minimizing early-stage under-estimation.

Surfactant Enhanced Remediation of DNAPL Contaminated Soil and Groundwater Refinery Site Case Study

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This paper will focus on the in-situ application of surfactant technology at an active refinery site near Montreal, Canada. The surfactant was applied to improve the mass recovery of chlorinated contaminants resulting from an historical DNAPL spill that impacted local soil and groundwater. The client had attempted several remediation technologies at significant cost, without success, before attempting site remediation with surfactants. In brief, the surfactants increased the rate of contaminant mass recovery by greater than 800% – 1200% from the designated soil and groundwater DNAPL plume contamination that was posing a significant risk to a nearby municipal groundwater aquifer.

The case study provides an overview of site conditions, sources and extents of contaminant plumes, in-situ surfactant system designs, installation, detailed mass recovery data, and the application process design resulting in significant time and cost savings for the client.

A brief overview of the surfactant technology, along with several graphical surfactant injection and contaminant recovery plots, with the associated mass recovery for individual chlorinated compounds, are also detailed within the paper.

Use of Cement to Fill in Underground Mines: General Information, Developments in Practice and use of Industrial By-products as a Complement to Cement

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Filling underground mines, especially using mining waste (sterile rocks, concentrator waste), has become a widespread practice throughout the world. Starting in the 1960s, the addition of cement to fill material made it possible, by improving the mechanical strength of the fill, to develop new mining techniques. Three main types of fill exist: rock fill, hydraulic fill and cement paste fill (CPF). CPF (a mixture of concentrator waste, mixing water and cement) emerged in the early 1990 and quickly became common practice in most modern mines.

Apart from playing a field support role by allowing for increased ore development, CPF allows an alternative to the surface storage of mining residue (up to 60% can be returned underground). Since sulphide reactivity is dramatically decreased by incorporating mining residue into a cement matrix that remains saturated with water, CPF significantly reduces the risk of environmental pollution caused by mining acid drainage.

Although it has undeniable benefits, the cost of cement (up to 80% of fill operation costs) can sometimes prohibit the use of CPF. In unfavourable technological/economic situations, the costs of fill can be reduced by replacing a portion of the cement traditionally used (Portland GU and HS and blast furnace slag cement) with industrial by-products that have pozzolanic or hydraulic properties: post-consumption glass, copper molten slag, biomass ash, CAlSiFrit and fluorgypsum. Apart from the economic appeal, this re-purposing of industrial by-products has undeniable environmental benefits: reduction in the use of natural resources (raw material for the cement and fossil

fuel), lower greenhouse gas emissions (fossil fuel consumption and limestone decarbonatation) and reduced surface areas used for storing reconditioned residue. The results show that strong performance can be realized with substitution rates for costly binding agents (Portland and slag cement) of up to 50%. In terms of future perspectives, these alternative binding agents could be used to mitigate surface-stored concentrator waste.