## Keynote Session

John Veil, Veil Environmental, LLC, Annapolis, MD

John Veil founded Veil Environmental, LLC, a consulting practice specializing in water issues affecting the energy industries, upon his retirement from Argonne National Laboratory in January 2011. Mr. Veil spent more than 20 years as the manager of the Water Policy Program for Argonne National Laboratory in Washington, DC, where he was a senior scientist. He analyzed a variety of energy industry water and waste issues for the Department of Energy.

Mr. Veil has a B.A. in Earth and Planetary Science from Johns Hopkins University, and two M.S. degrees -- in Zoology and Civil Engineering -- from the University of Maryland.

Before joining Argonne, Mr. Veil managed Maryland's programs for industrial water pollution control permitting through the National Pollutant Discharge Elimination System (NPDES) and Underground Injection Control (UIC). Mr. Veil also served as a faculty member of the University of Maryland, Department of Zoology for several years.

Mr. Veil has been recognized by the Society of Petroleum Engineers as a Distinguished Lecturer in 2008-2009, and as the recipient of the 2009 international award for Health, Safety, Security, Environment and Social Responsibility.

Mr. Veil has published many articles and reports and is frequently invited to make presentations on environmental and energy issues.

## Principles of a Liquid Desiccant Dehumidification System (LDDS) for Water Extraction from Combustion Gases.

Bruce Folkedahl, Energy & Environmental Research Center, Grand Forks, ND

It is clear that fossil fueled power plants and combustion systems consume vast quantities of water while the demand for water resources increase faster than replenishment technologies can match. This paper describes a novel technology that enables the recovery of water vapor contained in combustion flue gas streams. The Energy & Environmental Research Center (EERC) has successfully completed a U.S. Department of Energy (DOE) supported pilot-scale program firing natural gas and coal to produce a flue gas for dehumidification. The testing has proved the viability of the system to recover a significant portion of the water vapor contained in flue gases. The water recovered by this system is of a quality similar to that of a reverse osmosis system outlet (RO Out). This water can be used for plant needs as recovered or can receive minimal treatment so it can be used as direct cycle makeup. This paper provides a detailed description of the pilot-scale system and process conditions, presents the reportable results of the recent pilot-scale test program, and discusses the expected commercial characteristics.

## Recovery and Recycling of Industrial Side-Stream Wastewater

Michael Chan, Duraflow, LLC, Tewksbury, MA

For most industrial water and wastewater treatment operations, a substantial quantity of "side-stream" wastes as by-products is generated from the treatment processes. These side streams may include RO reject (brine) from treatment of plant process water and wastewater, backwash from UF or multi-media filtration, regeneration wastes from deionization, and blow-down from cooling tower water treatment. These streams are characterized by their high concentrations in dissolved solids, suspended particles, difficult-to-treat chemicals and organic substances. Recent studies have identified side streams as one of the major causes of performance problem when not properly managed in a treatment operation. As the national water scarcity crisis is escalating to the next level, industries have started looking into recycling of the secondary or less desirable water sources, such as the side-stream wastewater, as a long-term sustainable solution to the problem. This presentation shall explore the various side-stream wastewater sources and illustrate the associated technical challenges that need to be recognized and overcome by the industries. The discussion will outline the role of tubular membrane microfiltration and its

viability as a technology for recovering and recycling the secondary water sources to complement the existing treatment operations and maximize the overall water recycling goal. Case studies are presented for selected pilot studies and full scale side-stream recycling systems

## Municipal Wastewater as an Alternative Feed Source for Industrial Water Needs

Katariina Majamaa, Dow Chemical Ibérica, S.L., Tarragona, Spain

Gregg Poppe, The Dow Chemical Company Edina, MN

Industrial processes consume large quantities of water and lack of fresh water sources in many places drives the search for alternatives. Reuse of treated municipal wastewater offers an attractive and cost-efficient option for those seeking an alternative source. Typical treatment schemes to produce high-quality industrial water involve membrane technologies including ultrafiltration (UF), membrane bioreactors (MBR), and reverse osmosis (RO). Compared to conventional brackish water sources, the concentration of certain species like NH4+, NO3-, and total organic carbon (TOC) can be much higher in municipal water effluent and, thus, they can become the most stringent quality limit. The applicable membrane technologies are discussed, including certain features that help them operate successfully despite the challenges presented by purifying wastewater. Due to the high fouling potential of membranes with wastewater, strategies to control biofouling are integrally important for successful long-term operation with membranes and selected strategies are also discussed. A reference list of at least ten recent wastewater reuse installations spanning the globe is presented. These plants not only range in geographic location, but also in size, industry segment, type of pretreatment, and the purpose for which the recovered water is used. In particular, successful performance of two plants is provided, demonstrating consistent product flow and quality from integrated membrane systems treating wastewater for industrial use. Experience from these plants, especially regarding topics of disinfection and preventative cleaning, has contributed to the knowledge base of the wastewater treatment industry.

## Amine Chemistry – Update on Impact to Resin

Gregory Bachman, Technology and Lab Services, Rockford, IL

Doug Kellogg, Siemens Industry Inc. – Water Technology Division Rockford, IL

Marty Wilkes, Siemens Industry Inc. – Water Technology Division Rockford, IL

Impurity removal in the Steam Cycle and the associated prevention of corrosion and/or fouling of system components is the goal of ion exchange resins. However, in many instances (such as a switch to amine chemistry or a change in product specifications), resins do not remove, and in fact, contribute impurities to the steam cycle. This paper will review recent data compiled to determine the effects of amines on ion exchange resins used in the Power Industry.

## Molybdate removal by ion exchange

Andrew Bishop, ResinTech, West Berlin, NJ

Peter Meyers, ResinTech West Berlin, NJ

Use of molybdate in cooling tower treatment can be problematic due to skyrocketing costs and limits on discharge to sanitary sewers. Closed loop cooling systems that once depended on molybdate chemistry are switching to other types of chemical treatment. Prior to making a switch it may be necessary to remove molybdate from the system. Ion exchange is in many cases the best available technology for molybdate removal. This paper discusses the requirements for a successful molybdate removal system and disposal or regeneration options for various ion exchange resins, and systems that are used to remove molybdate.

## Seawater Regeneration of PUROLITE® SST80™ shallow shell SAC resin

Donald Downey, Purolite Company, Paris, ON, Canada

Efficiently using seawater to regenerate strong acid cation resins used in softening applications has been a long sought after alternative vs. using excessive and costly amounts of concentrated sodium chloride (NaCl) brine to drive the regeneration reaction. The limitations for using sea water have been isolated to the inefficiencies of the ion exchange bead matrix. Early studies show that upwards of 150 USG/ft3-R could provide 22 Kgr/ft3-R of operating capacity (OC) to a 2 PPM leakage end point1. Normal softening requires 50 USG/ft3-R for the same OC and leakage. In present day operations the need for higher regeneration efficiency not only drives the economics of the ion exchange process but also increasingly, has become a limitation on new ion exchange considerations because of restrictions on regenerant waste disposal. Recent developments in the resin bead functionalisation technique have lead to a new family of resins with improved regenerant utilization and reduced waste volume discharge. This paper presents a combined lab and field study carried out at a remote oil facility in 2008. The study used seawater ranging from 1.9% to 3.6% to regenerate Purolite SST80, a shell and inert core resin. The study showed a 40 Kgr/ft3-R of operating capacity (OC) to an endpoint of < 10% leakage using 48 USG/ft3-R.

## NORM Removal from Hydrofracturing Water

James Silva, General Electric Global Research, Niskayuna, NY

Hope Matis, GE Global Research Center Niskayuna, NY

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Vicki Watkins, GE Global Research Center Niskayuna, NY

Naturally occurring radioactive material (NORM), particularly 226Ra, is often found in hydro fracturing flow back water and produced water (both referred to as “frac” water) from shale gas wells. A key frac water disposal option is to thermally recover clean water by evaporation and a salable salt product by crystallization. In order to avoid radium contamination of the salt product and to minimize worker exposure to radium, it is desirable to remove radium from the frac water. Commercially available radium-specific complexing (RSC) ion exchange resins are effective for removing radium from well water and softener regeneration brines. However, frac water typically contains very high levels of dissolved salts, including barium, which interferes with radium removal by such resins. Using RSC resin as a benchmark, we screened a variety of adsorbents and ion exchange resins for their effectiveness in radium removal from frac water. This paper describes both equilibrium and column breakthrough test results for several promising adsorbents under a variety of conditions. Barium sulfate, montmorillonite, and manganese oxide (adsorbents) as well as strong acid cation exchange resins were found to be effective at removing radium from certain frac waters. Both ionic strength and barium concentration were found to be key factors in determining radium sorption or exchange capacity for a given material.

## Evaluation of Brackish Groundwater Treatment for Use in Hydraulic Fracturing of the Bakken Formation, North Dakota

Bethany Kurz, Energy & Environmental Research Center, Grand Forks, ND

Daniel Stepan, Energy & Environmental Research Center Grand Forks, ND

John Harju, Energy & Environmental Research Center Grand Forks, ND

Brad Stevens, Energy & Environmental Research Center Grand Forks, ND

Robert Cowan, Energy & Environmental Research Center Grand Forks, ND

The Northern Great Plains Water Consortium® (NGPWC) is a partnership between the Energy & Environmental Research Center (EERC), the U.S. Department of Energy, and key stakeholders in the north-central region of the United States. The overall goal of the NGPWC is to assess, develop, and demonstrate technologies and methodologies that minimize water use and reduce impacted water discharges from a range of energy technologies. One of the NGPWC’s current activities is to evaluate potential sources of water for use in

hydraulically fracturing the Bakken Formation of North Dakota. Because of the current high costs ! for acquisition and transportation of existing water resources in western North Dakota, treatment of nontraditional water supply sources may be economically feasible. To evaluate the feasibility of treating nonpotable groundwater as a means of providing freshwater supply for hydraulic fracturing of the Bakken Formation, the EERC teamed with a major oil producer in the state to conduct a pilot treatment project using reverse osmosis (RO) to treat brackish groundwater. The success of the pilot has led to plans to build a full-scale, 1-million-gallon-per-day RO treatment plant. This paper will discuss the RO system performance, economic comparability to alternate water supply sources, and applications for other industries with water supply issues.

## The Real Cost of ZLD for Shale Gas Frac Water in the Marcellus Shale Play

William Shaw, P.E.,HPD, LLC, a Veolia Water Solutions & Technologies company, Plainfield, IL

In the Marcellus Shale play in particular, both surface and underground disposal of the frac water are not options, and re-use of the brine in further fracturing operations is limited. Zero liquid discharge is the apparent long-term solution to the problem, using evaporators and crystallizers to concentrate the brine, crystallize out the salts and recover clean distilled water for re-use or direct discharge to the environment. Evaporation is a very energy-intensive process, but the energy consumption can be made less onerous by the use of such techniques as mechanical vapor recompression (MVR). Some companies have designed mobile evaporators to deploy at the drilling sites. These machines, we are told, can recover and recycle up to 75% of the frac water at a total cost, including energy, which is less than the of transportation and tipping fees to a POTW, an option that used to be available in Pennsylvania, but no longer. Crystallizers are proposed to recover the remaining water and produce a solid waste for landfill disposal from the concentrated brine, at least 25% of the total frac water volume. But crystallization is even more energy intensive than evaporation, and MVR is often not possible. Extensive chemical pretreatment of the brine may be necessary to keep the energy consumption reasonable and to remove constituents which may make the solids a hazardous waste. Because of these limitations, crystallization is not practical to do at the drill site with mobile units. By focusing on the chemistry of frac water and the physics required to transport, treat, evaporate, crystallize, and dispose of the solids, this paper will calculate the true costs of a complete ZLD solution for Marcellus Shale frac water.

## Mine Waste Clean-Up with Novel Hybrid Organic-Inorganic Materials

Edward Rosenberg, University of Montana (UM)/Purity Systems Inc(PSI), Missoula, MT

Carolyn Hart, University of Montana (UM)/Purity Systems Inc(PSI) Missoula, MT

In the past 10 years the University of Montana in collaboration with Purity Systems Inc, both located in Missoula, MT have been developing a new class of chelator composite materials that have some specific advantages over conventional polymer and silica based ion exchange materials. Previous presentations at IWC focused on the synthesis, characterization and bench scale applications. Since that time the technology has been successfully commercialized and is being used in the mining industry to recover copper, nickel and cobalt from acid mine drainages and solvent extraction raffinates. A description of the industrial scale circuits in which these materials have been employed and the problems encountered in these projects will be presented. Future directions in the manufacture of these materials and other potential applications will also be discussed.

## Sulfate Removal from Acid Mine Drainage for Potential Water Re-use

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Alex West, BioteQ Environmental Technologies Inc Vancouver BC, Canada

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Sulfate is a common by-product of the mining process. Coal and most metals are won from ore bodies containing sulfur-based minerals that oxidize to sulfate during mining, metal extraction or from natural oxidation in waste

rock, tailings and rock surfaces exposed to elements in open pits. Sulfate is easily mobilized and reports to wastewater streams such as mine drainage. Once considered harmless and a non-regulated substance, sulfate in treated or untreated mine drainage released into the environment is now subject to discharge limits ranging from 250 to 1000 mg/L depending on the receiving environment and/or applicable Total Dissolved Solids (TDS) limits. Furthermore, the presence of sulfate in mine drainage often limits the potential re-use of water by agriculture or industries that require make-up water with low sulfate content to prevent scaling. An innovative ion exchange based technology has been developed to reduce sulfate levels in mine drainage to meet regulations and allow for effective water re-use by a number of industries. This water treatment solution is a two-stage process using commercially available cationic and anionic resins to remove calcium or magnesium in the cationic stage and sulfate in a subsequent anionic stage. The products of the process are treated water with compliant levels of sulfate and TDS, and clean solid gypsum. This process consumes little energy and delivers water recovery rates up to 99%, reducing the impact on fresh water supplies. This paper will profile the ion exchange process and provide case studies of the technology applied at mining operations.

## AMD Reuse and Other Sustainable Technologies

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Allison McCurdy, GAI Consultants Pittsburgh, PA

Gary Van Balen, P.E., Sci-Tek Consultants, Inc. Penn Hills, PA

Joseph Fedor, P.E., ALCOSAN Pittsburgh, PA

At the Grandview Golf Course located in North Braddock Borough, Pennsylvania, Acid Mine Discharge (AMD) has been combining with local runoff and entering the Allegheny County Sanitary Authority (ALCOSAN) sewer system in North Braddock. A program was developed for removing the AMD from the combined sewer system and remediating the AMD for reuse as irrigation water for the golf course. When irrigation water is not needed, the treated AMD will be piped to a newly constructed municipal storm sewer and discharged to Turtle Creek. As part of this project, the team is designing an alternative energy supply source for the golf course. Field data is currently being collected for evaluating the installation of a wind-driven generator to power the facility. Additionally, a micro-hydroelectric generator driven by AMD is being evaluated for feasibility. This project is being partially funded through a Pennsylvania Department of Environmental Protection Growing Greener Watershed Protection Grant.

## Forward osmosis applied to desalination and evaporative cooling make-up water

Peter Nicoll, Modern Water plc, Guildford, Surrey, UK

Modern Water is one of the few companies that have developed and deployed forward osmosis processes on a commercial scale, for a variety of different applications. This paper outlines the progress made to date on the development and commercial deployment of two of these processes applied to desalination and evaporative cooling tower make-up water. Operational results taken from a commercial scale forward osmosis desalination plant operating alongside a seawater reverse osmosis plant, located in Oman, utilizing a common pre-treatment system are outlined. The forward osmosis plant demonstrated significant advantages in performance, both in energy consumption and in particular very low fouling. The plant operated over a year long period without any chemical cleans, whereas the conventional plant had numerous chemical cleans, a change of membranes and showed a marked decline in productivity over the same period. The manipulated / forward osmosis plant also demonstrated the inherent capability for higher boron rejection than conventional membrane plant. Manipulated osmosis may also be applied directly to provide make-up water for evaporative cooling towers. Modern Water has successful developed and demonstrated this new process. This new technology shows significant promise in allowing various raw water sources, such as seawater or treated sewage effluent, to be used directly in the manipulated osmosis step, thus releasing the use of scarce and valuable potable water for other more important uses. The paper presents theoretical and operational results for the process, where it is shown that the process

can produce make-up water at considerably lower opex than conventional processes. Manipulated osmosis may also be applied directly to provide make-up water for.

## Monochloramine Removal by Activated Carbon – Design, Operating and Maintenance Considerations

William Collentro, Worcester Polytechnic Institute, Plymouth, MA

Over the last several years, municipal water treatment systems with feed water from a surface source or ground water source influenced by surface water have attempted to minimize production of carcinogenic disinfection byproducts such as trihalomethanes. Addition of ammonia to chlorinated water for secondary microbial control in distribution systems is frequently employed, producing monchloramines. Activated carbon removal of monochloramine in industrial water purification presents unique challenges. Design, operating, and maintenance consideration will be discussed. The impact of feed water temperature, pH, Total Organic Carbon concentration, activated carbon media selection, and multivalent caption concentration on empty bed contact time will be presented.

## Achieving Complete Lime Softening in a Deep Well Saline Water Source via Solids Contact Process Treatment in the Presence of Natural Organic Matter

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Deep, non-potable aquifers containing significant concentrations of salinity, total hardness, and silica, though unsuitable for drinking water supplies, are considered viable water sources for use in various industrial applications such as boiler feed make-up in Steam Assisted Gravity Drainage (SAGD) facilities. Pre-treatment is typically required due to the scaling potentials associated with both total hardness and silica, which is detrimental to boiler operations. Cold lime softening (CLS) was evaluated using solids contact process treatment in laboratory batch tests to demonstrate the advantage of high-efficiency solids contact clarification by introducing previously precipitated calcium carbonate solids back into the reaction zone that act as a “seed” due to the existing calcium carbonate crystal surface (solids contact effect) that can stimulate additional calcium hardness removal while providing increased surface area adsorption for Total Organic Carbon removal. Initial test results demonstrated that a lime dosage slightly above the calculated stoichiometric dosage was able to yield effluent total hardness concentrations below 40 mg/L as CaCO3 under cold weather conditions near 5° C. Further tests spiking natural organic matter (NOM) up to 33.5 mg/L were found to initially exert inhibitory affects on complete total hardness removal. Implementing solids contact process treatment demonstrated that the inhibitory affects from the spiked NOM could be overcome and reach effluent total hardness concentrations below 40 mg/L as CaCO3 under cold weather conditions. Experience has shown that high salinity and NOM play an important role in achieving efficient calcium carbonate precipitation and crystal growth. The laboratory evaluation demonstrated NOM can exert varying degrees of inhibitory affects on calcium carbonate precipitation. The physical and chemical properties associated with the multitude of molecular configurations that constitute NOM will greatly dictate the ability to treat and limit its affects on calcium crystal inhibition, particularly at low temperatures. High-efficiency solids contact process treatment is considered a viable treatment approach to limit these effects and yield total hardness removal below theoretical expectations (25 – 50 mg/L as CaCO3) when under the influence of certain NOM and saline conditions via CLS. This pre-treatment approach continues to provide reliable

## Study of the scaling process by the Fast Controlled Precipitation method: application to raw river water

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Scaling phenomenon is a major concern which can reduce efficiency in condenser cooling circuits of power plants fed with raw river water. In order to ensure an optimum, safe and sustainable process, it is of vital importance to study the mechanisms of the scaling phenomenon and to find effective ways to prevent or fight it. In a water circuit, scaling is essentially related to the formation of calcium carbonate. The Fast Controlled Precipitation method (FCP), developed by the Ecole Nationale Supérieure des Arts et Métiers (ENSAM Paris), is among the newest techniques to study the scaling process and allows to characterize the heterogeneous nucleation of CaCO3 via the measurement of conductivity and pH under continuous degassing of CO2. The variation of dissolved carbon dioxide concentration is the driving force of the system evolution, generating scaling. The FCP method was chosen to study the scaling process of raw river waters with the ambition to recreate faster the scaling phenomenon in industrial circuits supplied with river waters. It was applied to raw river waters from the Seine, the Rhone and the Moselle (France) over a large period of time. This gave some insight into the scaling potential of these waters, depending on the season. The possible correlations with the quality water (e.g. suspended matter) were explored. The possibility to use these data to optimize the acid injections as anti-scaling agent will be discussed.

## Monitoring of trace levels of ions in the steam cycle by microchip capillary electrophoresis

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Jonathan Vickers, Advanced MicroLabs, LLC Fort Collins, CO

Matthew Heim, Advanced MicroLabs, LLC Fort Collins, CO

EPRI has shown that monitoring trace levels of selected ions in the water is essential for the efficient and safe operation of thermoelectric generation plants. Furthermore, on-line monitoring is strongly recommended wherever feasible. Sensitive on-line monitors exist for very few of these ions, so ion chromatography (IC) systems have been adapted to operate in on-line modes, with mixed success. We report on an alternative approach to on-line monitoring of trace levels of key ions, based on microchip capillary electrophoresis (MCE). Rather than using a fused-silica capillary as in conventional CE analytical systems, the capillary channel is embossed in a plastic microchip, thus providing a more rugged element, in a smaller footprint, as well as a lower replacement cost. This system offers rapid assays (on the order of 10 minutes), minimal reagent use and waste stream, yet with detection limits comparable to ion chromatography, or better. Our initial application of this MCE system has been to tracking the chemistry in various process streams in the steam cycle, monitoring a suite of ions, including sodium, potassium, magnesium, calcium, chloride, sulfate and nitrate.

## Operating Experience with Amine Form Condensate Polishing

Lewis Crone, Dominion Nuclear Connecticut, Inc., Waterford, CT

Millstone Power Station seeks to update its experience with full flow operation of deep bed condensate polisher resins chemically configured in the amine form. The operating experience will address areas such as the effects of elevated hydrazine and its decomposition product ammonia on resin kinetics and steam generator and balance of plant chemical compositions; resin stationary phase and secondary cycle ethanolamine behavior as a function of time; effects on iron transport and polisher iron removal efficiency; mechanical resin cleaning and contamination control; behavior during a condenser tube ingress; and the effect on steam generator non-volatile impurities. These attributes will be discussed from the perspectives of open cycle blow down, which is employed at Millstone 2, and closed cycle blow down, utilized at Millstone 3.

## Upgrade of condensate water filtration system with high efficiency disposable filters

Khalid Farooq, Pall Corp., Port Washington, NY

A 1,000 MW power plant in North Italy was using back-washable metal filter cartridges with a cellulose based filter-aid for the filtration of condensate water. The filtration system, consisting of 403 metal filter cartridges, treated 760 tons / hr (3000 GPM) of the condensate. There were a number of operational problems with the filtration system including inconsistent particulate removal efficiency, frequent, labor intensive and time consuming back-wash cycles that generated a waste stream and consumed water and energy. Following the testing during the plant start-up and normal operation using a side stream of the condensate, a filtration system using disposable filter cartridges was proposed and accepted by the plant. The back-wash filtration system was replaced with a compact, high surface area, disposable cartridge filtration system. The 60" long, polypropylene made filter cartridges engineered for high flow capacity and high particle removal efficiency (99.98% efficient for particles 4.5µm and larger) were installed in a horizontally oriented filter housing that contained 34 cartridges. Experience with the new filtration system over a period of 30 months since installation on one system and for 27 months on a second system, has shown a consistent and improved contamination removal and substantial cost savings for the plant. The presentation discusses the experience of the plant with the two filtration systems.

## Use of Mobile Technologies in the Design of Liquid and Solid Radwaste Treatment Systems For Nuclear Power Plants

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New generation nuclear power plants are incorporating the use of mobile (trailer-mounted or skid-mounted) processing systems to treat and package low-level radioactive liquid and solid waste. In contrast to the permanently installed radwaste treatment systems originally included in the design of the majority of the current operating fleet of nuclear plants, the radwaste treatment systems proposed for the new generation of nuclear reactors serve to reduce the complexity and size of the radwaste treatment system through the use of vendor supplied and optimized mobile systems. Benefits of this strategy include lower capital and operating costs resulting from the use of standardized and compact hardware designs and increased efficiency of current waste processing technologies. As further advancements in waste treatment technologies become available, these new generation plants will also have the flexibility to upgrade their current mobile systems to newer methods for waste treatment. Liquid and solid radwaste system designs in existing nuclear plants will be compared with the systems and technologies planned for use in new reactor designs. Mobile treatment options currently available or considered for liquid and solid radioactive waste processing will be discussed, including ion exchange, reverse osmosis, precoat filtration, sludge dewatering and waste solidification. An overview of emerging treatment technologies for application in radwaste systems such as electrodeionization (EDI) and nanofiltration will be provided. Emphasis will also be placed on the advantages of incorporating mobile treatment systems in the early stages of engineering design of new nuclear facilities. A discussion of issues such as interfaces with permanently installed equipment, plant layout and shielding considerations, and allocation of design and operational responsibilities between equipment suppliers, design engineers and plant operators, among others, will be provided with the objective of highlighting the design aspects that are considered in the development of mobile radwaste processing systems.

## Piloting Conventional and Emerging Industrial Wastewater Treatment Technologies for the Treatment of Oil Sands Process-Affected Water

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Piloting is a key stage in the design process for water and wastewater treatment systems, especially for unconventional wastewaters such as those generated by oil sands mining and extraction operations. The nature of the constituents in process-affected tailings water and the scale of operations provide some challenges for conventional industrial wastewater treatment technologies. The organic constituents found in tailings water differ from typical refinery wastewaters, and gaining insight on fouling characteristics, removal efficiencies, and toxicity of the water is important in determining potential end-uses for tailings water. A close examination of the potential end-uses for treated water, required treatment objectives, and real-world unit-process performance is required in order to select suitable treatment technologies for tailings water. In 2010-2011, Suncor Energy (on behalf of the Oil Sands Leadership Initiative) piloted several conventional and emerging industrial wastewater treatment technologies on tailings water. Among the technologies examined were Dissolved Air Floatation, Ultrafiltration, and Reverse-Osmosis, Advanced Oxidation (Ozone-Peroxide based), suspended-growth biological systems and attached-growth biological systems. This paper reviews the challenges and performance observed over the course of this pilot.

## Ceramic membranes, commercially available alternatives, operating performance, successes and failures

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The ceramic tubular membranes demonstrate de-oiling efficiencies better than conventional polymeric oil removing filters because of their superior physical integrity, chemical resistance, tolerance to moderate pressures and high operating temperatures, regeneration ability and long service life. This paper provides an overview of select commercially available ceramic membranes, materials, pore sizes, and reviews the performance of the membranes comparatively under a variety of operating conditions for de-oiling produced water. It also addresses the success in separating oil, crudes, solids and Naphthenic acids, and challenges related to flux recovery, cleaning efficiency and membrane regeneration.

## Enzymatic Removal Of Selenocyanate From Sour Water Stripper Bottoms

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Yakup Nurdogan, PhD, PE, Bechtel Pueblo, CO

Sour water stripper bottom streams of oil refineries processing seleniferous crudes contain high concentrations of soluble selenium present primarily as selenocyanate (SeCN-), but relatively low flow rates. The current biological and physicochemical selenium removal technologies are not effective in reducing SeCN- concentrations in these source streams without effective pretreatment processes. Specific enzymes engineered to maintain optimal activity in the presence of toxic compounds found in sour water stripper bottoms may offer a cost-effective alternative to the existing selenium treatment technologies. Unlike biological processes, this technology is not affected from toxicity of wastewater and does not require nutrient addition. In laboratory trials, a monocomponent recombinant enzyme was added to refinery stripped sour water samples to ascertain the effectiveness of enzymatic reactions on selenium species. Selenium speciation and dissolved selenium concentration were determined by ion chromatography inductively coupled plasma dynamic reaction cell mass spectrometry (IC-ICP-DRC-MS) and inductively coupled plasma dynamic reaction cell mass spectrometry (ICP-DRC-MS), respectively. Soluble SeCN- concentrations were reduced from 1,000-1,500 ppb to 30 ppb with 98% removal efficiency. The removal efficiencies for total selenium were greater than 90%. During the bench-scale testing, parameters such as type and quantity of enzyme, treatment time, pH, and temperature were varied. Ideally, the enzymatically-treated sour water stream bottom streams will be diluted by other refinery process effluents with

much higher flow rates and low or no selenium content. The combined refinery wastewater stream should easily comply with increasingly stringent selenium discharge limits imposed on oil refineries.

## Nutrient Control - The Key to a Low Environmental Impact Cooling Water Program

John Richardson Ph.D., ChemTreat, Ashland, VA

Helen Cerra, ChemTreat Ashland, VA

Richard Tribble, ChemTreat Ashland, VA

Nutrients in surface water sources are coming under increasing scrutiny from an environmental standpoint. High levels of phosphorus and nitrogen in water can lead to eutrophication resulting in low oxygen levels which can impact both fresh and sea water organisms. Cooling tower operation can exacerbate the issue since evaporation leads to increased concentrations of nutrients. This increase in nutrients causes problems for the operation of the tower and can have an adverse impact on resulting waste streams. This paper discusses methods to improve the environmental profile of evaporative cooling systems and introduces new corrosion and scale inhibitor technologies which are designed to contribute minimum additional nutrient value to the recirculating water.

## Filtration of Soluble Metals and Organic Contaminants by Nanoalumina Fiber Filters

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At the last IWC meeting, a nano alumina non-woven media was described that is capable of retaining sub-micron particles including metal oxides. The filtration mechanism relies on the high positive zeta potential that attracts and retains particles in water and polar fluids. The filter was benchmarked against many non-woven as well as membrane filters, exceeding other filter media in virtually all attributes. This paper focuses on filtering soluble contaminants by chemisorption and physical absorption. Metal contaminants are often toxic even at ppt concentrations (e.g- Cr VI). Breakthrough curves (ppm challenges) will be presented showing the retention of several soluble metals including copper, lead, tin, and silver, Fe++, Cr+++ and Cr VI on a single layer of the nano alumina media. A version of the nano alumina media embodies powdered activated carbon (“PAC”), capable of a high efficiency in both particle adsorption and physical absorption. This media was challenged by organic pollutants representative of endocrine disruptors including trace pharmaceuticals and phenolic monomers. Dynamic absorption data will be presented for Penicillin G, Bisphenol A and Flumequine, showing that a single layer of PAC is an effective absorber of such organics while in the ppm to low ppb billion range. The filter was challenged by a mixture containing 209 PCB’s (a known carcinogen) and tested in accordance with EPA Method 1668A (detection limit 0.25-0.75 ng/L). At a challenge of 20,797 ng/L, the filter retained eight of the ten cogener PCB groups to less than detectable, with a total retention of 3.21 ng/L for all groups combined. (Beta coefficient ~ 6400).

## Thirty Years of Successful Nitrogen Removal Using Deep Bed Denitrification Filters in Florida

David Pickard, David Pickard Consulting, Tampa, FL

Florida requires Advanced Wastewater Treatment for discharges to coastal waters on the West Coast of Florida. The permitted discharge limits for surface water discharge in the Tampa Bay area are 5 mg/l Biochemical Oxygen Demand (BOD5), 5 mg/l Total Suspended Solids (TSS), 3 mg/l. Total Nitrogen (TN), and 1 mg./l. Total Phosphorus (TP). Deep Bed Denitrification Filters have been used successfully to meet the TN standard since 1979 at Tampa

and many other plants in Florida and nationwide. Data will be presented demonstrating thirty years of successful denitrification at the City of Tampa Howard F. Curren AWT Pl! ant and other facilities in the state. Total nitrogen discharge levels have averaged 2.2 mg/l consistently. The methanol to NO3-N ratios has averaged slightly below the published standard s for the denitrification process. Since coastal and estuarine waters in Florida are largely nitrogen limited, deep bed filter denitrification is largely responsible for greatly improved water quality in the bays and estuaries of the West Coast of Florida. Locations in the state that have chosen to meet the stringent discharge limits by utilizing a total reuse scheme have also used the deep bed filters to achieve the stringent standard for TSS required in the reclaimed water regulations. Forty percent of all reuse water produced in the state of Florida has been treated using a deep bed monomedia filter.

## Design of Biotreatment Process for Chemical Agent Hydrolysate by Immobilized Cell Bioreactor

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The Pueblo Chemical Agent Destruction Pilot Plant is being constructed for demilitarization of chemical weapons stored at the Pueblo Chemical Depot, Pueblo, Colorado. The stockpile of munitions at Pueblo contains the vesicants Distilled Mustard (HD) and the mixture HT. The process chosen for demilitarization involves collection of the chemical agent, water hydrolysis of the agent to produce a hydrolysate, biological treatment of the hydrolysate to reduce organic content and treatment to separate salts and recover water for reuse. The biological process selected for hydrolysate treatment is Immobilized Cell Bioreactors. This paper will describe the design of these systems for use at the Pueblo Chemical Agent Destruction Pilot Plant. The design is based on laboratory and pilot testing, which provided determination of organic loading rates, hydraulic retention times, aeration requirements, nutrient requirements, operational parameter ranges and controls (temperature, dissolved oxygen, and especially pH), salinity considerations, and biodegradation mechanisms and biodegradation products. Their incorporation into the design will be presented and discussed.

## Important Considerations for Pre-startup of Cooling Tower Water Systems to Minimize Water Contacted Equipment Deterioration

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Pre-startup considerations of cooling tower water systems are often not performed for various reasons. These various reasons are discussed in detail. If not done this can cause initial corrosion of cooling towers heat exchanger tubes, and circulating water piping that will greatly reduce the life expectancy of this equipment, so who is responsible? Specific case histories are provided as examples of where little or no pre startup occurred. They will be reviewed as to what has happened with the requirements that should have been used. A guide outlining what should have been done for pre-startup water treatment provided for each of the cooling tower, the heat exchangers, and for the piping.

## Novel Biocide Delivery for Improved Control of Biofilm Organisms

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A variety of disinfectants, biocides and dispersants are used to control microbial populations in cooling systems. Sessile microbes - those attached to wetted and submerged surfaces - form biofilms that, if uncontrolled, result in biofouling. Biofouling impedes heat transfer, promotes corrosion and increases the potential for illness associated with water-borne pathogens such as Legionella. Biofouling reduces productivity, increases operating and capital costs and adversely affects profitability. The safety of the cooling tower work environment is also compromised. Controlling biofilm organisms with traditional disinfectants usually requires higher concentrations than for control of planktonic (free floating, bulk water) organisms. This is partly because slower diffusion, as opposed to rapid, turbulent transport in the bulk water, plays a major role determining the rate at which disinfectants move into the biofilm and the residuals to which biofilm organisms are exposed. To effectively drive traditional disinfectants into the biofilm, a sufficient concentration gradient must first be established by applying a high concentration of disinfectant to the bulk water. In effect, the bulk water must be “over-treated” to control organisms in the biofilm. Development and evaluation of a novel biocide delivery material are described. This material enhances delivery of biocide to biofilms and achieves a high concentration of active biocide in the film without resorting to similar levels in the bulk water. Lab studies show the new material allows a significant reduction in applied biocide levels compared to a traditional biocide. At the same time, a higher degree of control over biofilm organisms is achieved.

## Innovative Monitoring and Control System Optimizes Cooling Water Treatment Effectiveness

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Efforts to optimize water treatment performance in preventing fouling have often been limited to laboratory or empirical approximation of scale and corrosion conditions. The system presented in this paper uses an accurate deposit monitoring device, corrosion inserts, and microprocessor controls which adjust inhibitor feed in response to elevated deposition or corrosion in an operating industrial cooling system. This “smart” control enables cost performance of water treatment programs to be fine tuned. Inhibitor feed adjustments are made not on the basis of chemical residual tests, but instead are auto-controlled based on results related to key performance indicators. This technology was used in laboratory simulations to validate and compare performance of cooling water inhibitors under extreme conditions for deposition control, and used in actual field situations to determine optimum dose-response and control inhibitor application. The end users were able with this data to maximize performance and reduce cost of their chemical treatment programs. Laboratory and user data are presented which demonstrate the application of the system algorithms.

## Evaluation of Carbon Sources for the Anaerobic Treatment of Flue Gas Desulfurization (FGD) Wastewaters for Heavy Metals Removal

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An evaluation of carbon sources was conducted to find a suitable compound that could be used in the anaerobic treatment of flue gas desulfurization (FGD) wastewaters for the biological removal of heavy metals, such as selenium, chromium, vanadium, etc. The major criteria used to evaluate the carbon sources included: (1) heavy metals removal performance, (2) ease of use of the chemical in full-scale operations and (3) cost-effectiveness.

Laboratory-scale studies were conducted using sugar (dextrose) and a proprietary liquid carbon source called MicroCg. Previous experiments indicated that methanol, a well-known carbon source for denitrification reactions, would not work effectively for this application. These carbon sources were fed into the patent-pending iBIO® anaerobic wastewater treatment system to test their performance. The iBIO® biological reactor system uses suspended growth activated sludge microorganisms in a two-stage continuously stirred-tank reactor. Results indicated that sugar and MicroCg achieved the desired degree of denitrification (>99.9% removal) and effluent selenium target concentration of <30 ppb. An overall evaluation of the use of these materials for full-scale treatment indicated that due to handling issues, MicroCg was preferred over the granular sugar. This paper will discuss the results and provide more details on the implications of using these carbon sources for full-scale treatment

## Demonstration Test of Iron Addition to an FGD Absorber to Enhance Flue Gas Selenium Removal

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This paper documents results of laboratory, and two full-scale demonstration tests of iron addition to forced oxidation flue gas desulfurization (FGD) scrubbers. Prior to the adoption of forced oxidation FGD systems, selenium in power plant wastewaters has been predominately in the chemically reduced selenite form. Selenite can be removed using chemical (iron salt addition) and physical (solids removal) technologies. With forced oxidation FGD systems, there has been a tendency for a significant portion of the selenium to be in the selenate form. Selenate is not amenable to iron addition treatment. Currently the only demonstrated technology for selenate removal from FGD wastewater has been biological treatment, something that adds to the complexity and cost of FGD wastewater treatment. The paper presents results that show that addition of an iron salt to the absorber vessel (supplementing iron already added as a constituent in limestone), results in precipitation of iron hydroxide, and the absorption of selenite before it can be oxidized to selenate, lowering the soluble selenium in the FGD wastewater, and allowing removal of the particulate selenium in simple solids removal processes.

## Case Study on Selenium Removal from a Combined FGD Wastewater and Landfill Leachate for a Power Plant on the Ohio River

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Selenium concentrations in FGD wastewater discharges are targeted for reduction by regulatory agencies in many states throughout the Ohio River Valley. Power utilities are being forced to respond to the regulatory requests while federal and state limits are being debated and evaluated at national and state levels. Additionally, the regulatory agencies are requiring power utilities to capture and treat other commonly discharged variable waste streams such as ash landfill leachate and treat them prior to discharge. To respond to the demands of the agencies, power utilities need to deploy efficient and reliable ! advanced treatment technologies in relatively short time frames. This paper describes the process developed to address the variability of influent quality while preserving sufficient design treatment margin to consistently remove particular constituents. In addition, this paper describes the design development and construction method of delivery that was used to achieve completion of the facility in the face of looming regulatory compliance deadlines.

## Evaluation of Thermal ZLD Treatment of FGD Purge Water Options Rev 3

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Since Flue Gas Desulphurization (FGD) systems have been installed in coal fired power plants the wastewater produced is under more scrutiny from regulators. As a result Southern Company is conducting a serious evaluation of applying ZLD technology to solve this problem. ZLD systems have been used in power plants and other industries to treat cooling water and low volume wastes for several years. This process appears to have a potential to treat FGD wastewater as well, however, there are only 6 full scale ZLDs in the world that are specifically used for FGD wastewater and all of them have very short running experiences .This paper will discuss the following issues: reliability, operation and maintenance, how system metallurgy fits the high Cl and high TDS water, are volatile metals such as mercury remit into the air or into the recycled water, power and steam consumption, cooling water needs, process selection such as brine concentrator + ash conditioning or brine concentrator + crystallizer or brine concentrator + crystallizer + ash conditioning, pretreatment requirements, foaming and scaling, conventional thermal ZLD or COLD ZLD, cleaning processes and effect, mist eliminator positions, affect of variable feed water, the best way to use the purified water (can it be used for boiler makeup?)

## Produced Water Softener Regeneration Using Boiler Blowdown

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Produced water softeners usually require substantial quantities of salt for regeneration in order to achieve the sub-ppm levels of hardness needed for the downstream OTSGs. High TDS produced waters usually contain enough salt but at much lower concentrations than the typical 10%to 20% needed. This Technical Report examines the feasibility of using the blowdown from the downstream OTSG to effectively regenerate such softeners.

## Filtration Process Review in SAGD Produced Water

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Turbidity is one of the key performance indicators for Steam Assisted Gravity Drainage (SAGD) produced water treatment. Currently, most SAGD producers rely on multiple “grab” samples for performance monitoring, which by itself is not enough to adequately detect the episodic process upset conditions. On-line turbidity meters are available commercially, but most of them are rated to perform below ~50ḍC. A new high temperature on-line turbidity meter was pilot tested successfully at a ConocoPhillips Canada's SAGD site. During a 60-day trial, the new probe performed satisfactorily under severe and varying process conditions without requiring any manual cleaning or maintenance. Importantly, the probe was able to provide real time data on process upsets and performance fluctuations on produced water streams with temperature varying between 80-85 °C. Throughout the test period, the new probe performance was found to be strongly correlated to the existing on-site hand-held turbidity meter. Based on the success of the trial, the new probe was integrated into the plant operation to monitor turbidity levels downstream of warm-lime softening unit, and boiler feed water tank, respectively. In our knowledge, this is the first installation of high temperature turbidity probe for SAGD produced water monitoring.

## An Innovative Solution to SAGD Blowdown Water---Blowdown Boiler Technology

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The treatment of blowdown water from boilers is critical to the overall water management performance in heavy oil industry. It has significant impact on the water recycle ratio and the water treating costs. The target recycle rate for fresh makeup water, regulated by EUB, is 90% or higher. Also brackish makeup water, that is not currently regulated, may eventually be included in the plant water recycle rate. To improve the operation, several scenarios of blowdown treatment have been developed, reviewed and evaluated. The idea of using a blowdown boiler is to feed the boiler blowdown to Once Trough Steam Generators (OTSGs) without any water treatment. Economic evaluation shows it has the lowest CAPEX and OPEX with the water recycle rate of approximately 90%, when compared to other possible solutions for blowdown treatment. However until this test it was an unproven process since it has never been done before. The purpose of the blowdown boiler pilot test was to verify the feasibility of this idea. A substantial amount of research has been done before set up, including discussions with industry experts, meetings with vendors, visiting other operators and conducting engineering studies. The first steam was generated on May 22, 2007 using blowdown water as feed water to OTSGs. Until the end of June 2008, the blowdown boiler ran for 166 cumulative days without any operational problems. All monitored parameters were normal. Two scheduled mechanical inspections were conducted in the test including x-ray, hardness, UT inspections and laboratory analysis of two sections of piping. Overall the results show the boiler is in good condition with minor corrosion/pitting, which may have been present prior to the test. Only very minor differences between the latest and the original readings were detected. As well, the boiler inspection confirmed there was minimal (if any) scaling. The pilot has been completely successful. After the pilot a commercial OTSG was converted to blowdown boiler and started up running with blowdown water in 2010. This concept has also been incorporated into commercial designs.

## Solidification: A New Approach to Zero Liquid Discharge (ZLD) in the SAGD Industry

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As the economics and environmental risks associated with the disposal of liquid waste from SAGD projects become less desirable, Zero Liquid Discharge (ZLD) process solutions are gaining momentum with heavy oil producers. The two existing SAGD projects that achieve ZLD utilize evaporation, crystallization, and drying technologies to eliminate liquid discharges. The evaporation and crystallization processes operate well at numerous SAGD facilities in Alberta, However, the drying process has been difficult to operate and maintain due to the nature of the solids present in SAGD produced water. While the drying process is improving through on-site modifications and research & development (R&D) efforts, an alternative technology that offers a number of benefits has been developed by GE. This paper will present technical details of GE's patent-pending solidification process, including bench and pilot test data, comparisons versus drying, and preliminary design information. Solidification is a technical and economical alternative to drying and GE is in the process of designing and supplying the first commercial solidification system for the SAGD industry.

## Chromate Removal at the Hanford Site

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Remediation of groundwater containing hexavalent chromium has been in progress at the Hanford site for more than 15 years. Although the early systems used type I (gel) strong- base anion exchange resin and off site regeneration, the most recent systems use a long-life single-use resin. Use of the long-life resin is projected to result in significant operating cost savings. This paper explores the history of the chromate remediation efforts at

the site, a review of more than 15 years operating experience with strong-base resin, and the operating results with the long-life resin.

## Advanced Oxidation Process with a New Nanstructured Material

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Graphene is considered a two-dimensional carbonnanofiller with a one-atom-thick planar sheet of sp2 bonded carbon atoms that are densely packed in a honeycomb crystal lattice. It is regarded as the “thinnest material in the universe” with tremendous application potential. Graphene is predicted to have remarkable properties, such as high thermal conductivity, superior mechanical properties and excellent electronic transport properties. These intrinsic properties of graphene have generated enormous interest for its possible implementation in a myriad of devices. RECAM® is a new mesoporous nanostructured mater! ial, that exploits the special properties of graphenes and is produced on an industrial scale, having extraordinary properties in terms of reactivity and crystallinity, with excellent results proved for removal of recalcitrant compounds from wastewater, recently introduced into the market. The application of most innovative developments in the field of nanotechnology, and particularly the use of RECAM®, enables to emphasize and fully develop the benefits of advanced oxidation and contaminants absorption processes, reaching levels of efficiency and economy much higher than traditional water purification approaches.Main benefits are possible to treat almost every kind of wastewater and a wide range of contaminants, no sludge production, system configuration that is both simple to build and modular, low investment costs ,chemicals used only for pH corrections.In the present paper are reported the fundamentals and case studies of application of RECAM® for advanced oxidation process with electroxidation and nanophenton.

## Absorbent Technology for Removal of Soluble Mercury at the Trace Contaminant Level (Low Part Per Trillion)

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Reduction of trace amounts of mercury of 2.0-3.5 parts per trillion (ppt)down to Reduction of trace amounts of mercury of 2.0-3.5 parts per trillion (ppt)down to 1.3 ppt or less has been successfully demonstrated by a metropolitan sewer district on water collected prior to the effluent stream. The technology employed is an alumina-based adsorption media. The water contacts the media in a fixed bed for a relatively short amount of time, approximately 3.5 minutes. An average removal of 66.5% of the mercury was observed. This application showed a removal of 8.8 ng of mercury per gram of media. The testing was stopped at 80 liters of throughput, greater than 5000 bed volumes, and the media had not reached exhaustion. The media has shown capability of removing mercury up to 75% of its weight in laboratory testing.

## Iron Oxide Emplacement On Sand Media For Groundwater Arsenic Removal

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Iron oxide-bearing minerals have long been recognized as an effective reactive media for arsenic-contaminated groundwater remediation. This research aims to develop a technique that can achieve in situ oxidative precipitation of Fe3+ in a soil (sand) media to create a subsurface iron oxide-based reactive barrier that can passively immobilize arsenic (As) and other dissolved metals in groundwater. Our bench scale column tests showed

that our unique in situ iron oxide sand coating process is feasible and the resultant iron oxide-coated sand (IOCS) media can effectively remove large quantities of arsenic from contaminated groundwater before requiring refresh coatings. In contrast to conventional excavate-and-fill treatment technologies, this technique could be used to in situ replace a fresh iron oxide blanket on the sand media and rejuvenate its treatment capacity for additional arsenic removal. The competition for adsorption sites from other groundwater constituents such as carbonates (CO32-), sulfates (SO42-), and silicates (SiO32-) could potentially hinder the efficiency of arsenic uptake and ultimately reduce the overall as treatment life of the subsurface iron oxide-coated sand. Although refresh coatings could be repeated multiple times, the life cycle of the in situ FeOx reactive barrier may also be limited by the gradual loss of hydraulic conductivity induced by the accumulation of FeOx and other deposits in the pores over time.

## Challenges with the Use of Sea Water for Cooling and Development of a Novel Treatment and Monitoring Control

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Water is essential to many industrial processes, used primarily for cooling. Using impaired water in place of fresh water is a potentially attractive solution to the problems of water scarcity and competing demands. As the population increases, good fresh quality water is much more needed for human use including growing food. Tertiary sewage treated water has been successfully used in many industrial applications for cooling. The use of seawater is becoming quite popular for cooling applications in many coastal areas of the world. Although sea water provides an alternate source of cooling water but it poses its own limitations in terms of corrosion, scaling, biofouling both micro and macro. In addition these limitations there are also penalties due to higher salinity such as approach temperature, heat transfer coefficient, and pumping cost. The paper discusses the development of a novel treatment to mitigate fouling due to the use of sea water in cooling applications. The results of a field trial in Italy are also presented.

## A novel anti-scaling method and its use in zero liquid discharge mode in cooling tower operation

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A novel anti-scaling mechanism and methods for preventing scale formation is described here. The method is based on a new adsorption/co precipitation mechanism and the use of a diatomaceous earth based, synthesized adsorbent for the adsorption, dispersion and carrying away of the nucleation centers or microcrystalline seeds of scalants, thus to achieve the prevention of scale formation on water processing equipment. The new adsorbent is engineered to a unique structure with high surface area and high affinity toward the nucleation or microcrystalline seeds of a variety of scalants. Both laboratory and field studies showed that the new method can sustain a very high cycles of concentration (CoC) for waters of high or ultra-high hardness (>160 ppm). The new anti-scaling method was successfully demonstrated in industrial trials with a 500 m3 water capacity cooling tower of a sulfuric acid plant and achieved essentially zero liquid discharge for more than 90 days, while the conventional method can only sustain for 3 to 5 day (or 3 to 5 CoC). The advantages of this new method and the problems associated with conventional cooling tower operation will be discussed.

## A Review of the Cooling Water Methods for Sodium Hypochlorite Activation of Sodium Bromide into Hypobromous Acid Biocide

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The use of sodium bromide in conjunction with a source of sodium hypochlorite bleach to generate a hypobromous acid biocide has been a standard cooling water practice for decades. The suppliers of sodium bromide recommend effecting the activation by directing the sodium bromide and sodium hypochlorite solutions to a residence tank containing makeup water. Upon activation, the mixture is introduced to the cooling water to be treated. However, few water treaters adhere to this practice because it is cumbersome and more convenient ways of using the two products have evolved over the years. These include feeding sodium bromide and sodium hypochlorite solutions to a common tee before directing the mixture into the recirculating water; or introducing sodium bromide and sodium hypochlorite independently to the cooling water to effect the activation under more dilute conditions. This review examines the efficiencies of all three methods, in terms of % utilization of sodium bromide and sodium hypochlorite in addition to the relative rates of bromide ion activation. The benefits and limitations of all three activation methods will be discussed.

## Filll Selection and Chemical Treatment Methods to Minimize Scaling/Fouling in Cooling Towers

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As restrictions become tighter on the use of once-through cooling, power plants, refineries, and other industrial facilities may be looking at cooling towers as an alternative cooling process. Proper selection of cooling tower fill and chemical treatment programs is vital towards efficient operation of cooling towers and prevention of fouling-related structural failures. This paper outlines state-of-the art developments with regard to cooling tower fill selection and chemical treatment programs.

## Concepts in Zero-Liquid Discharge

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Recent developments in environmental regulations require more stringent emission control system for various industries. In the United States, industrial treatment standards are set by the Environmental Protection Agency (EPA) as National Categorical Standards. These are industry-specific limits that are technology-based. Being technology based, each limit is associated with a specific treatment technology that is 'economically achievable.' These limits form a baseline treatment technology for each industry. In addition to these standards, many areas of the country have added water quality based standards to protect specific bodies of water. In particular the coal fired power plants waste water discharge streams receive great attention due to the volumes and the complex composition of these waste waters. One of the largest waste water streams is generated by flue gas desulfurization (FGD) scrubber systems. Various solutions from deep well injection to zero-liquid discharge are currently considered depending to plant specifics and location. ZLD technology includes evaporation of the industrial effluent until the dissolved solids form crystals in solution. The crystals are removed and dewatered and the condensate from evaporation is condensed and returned to the process. This process may include pretreatment, membrane filtration, evaporation, followed by crystallization. Due to the volumes of FGD blow-

down, pretreatment has a tremendous impact on the operational costs and is therefore in many cases replaced by larger evaporation systems. Since evaporation systems remove volatile components (mainly water) from the waste water, all other components increase in concentration. Depending on the discharge method various components can accumulate and influence the crystallization process. The paper will discuss recent laboratory tests and operational experience of Zero-liquid discharge system for FGD waste water.

## The Use of Constructed Wetlands in the Treatment of Flue Gas Desulfurization Wastewater

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Constructed wetland treatment systems use natural biological processes to reduce the concentrations of constituents in the wastewater and have demonstrated promise for the treatment of flue gas desulfurization wastewater. However, limited industry and academic research has been conducted and very few full scale applications have been undertaken. Constructed wetland treatment systems have been used effectively for the treatment of other industrial and municipal wastewaters but widespread use in the power generation sector has not yet developed due to lack of research and project experience. A major power producer has decided to undertake a constructed wetland treatment system pilot project to evaluate the technology. The constructed wetland, currently in operation, is approximately 2 acres in size and treats approximately 7 percent of the plant FGD wastewater stream. The constructed wetland will be operated two years to evaluate A pilot project of this scale in an area of the country without a round-year growing season has yet to be undertaken in the U.S. This presentation will cover the design, construction, and operation of the pilot wetland treatment system as well as initial performance results.

## Solidification of FGD Wastewater with Fly Ash: Feasibility and Fate Analysis

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As regulations governing the discharge of Flue Gas Desulfurization (FGD) wastewater grow more and more stringent, zero liquid discharge becomes more appealing. Zero Liquid Discharge generally includes evaporation, crystallization and dewatering. However, some facilities are considering 'Partial ZLD' which involves concentrating the wastewater to reduce the effluent volume and mixing it with flyash to make a solid which can be landfilled. Infilco Degremont, Inc. along with the Degremont Technologies North American R&D Center (DENARD) recently completed a study of this process, proving that flyash can be used to solidify FGD wastewater while producing a nonhazardous landfillable solid waste. This study included the determination of how much flyash is required to 'solidify' a liter of concentrate. Additionally, a fate analysis was performed to determine what portion of the contaminants removed is simply transferred to the landfill leachate. Several potential additives such as quicklime and Portland cement were studied both for their effect on the flyash volume as well as their effect on the fate of the contaminants.

## Selenium Control in Wet FGD Systems

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Selenium in flue gas desulfurization (FGD) liquor may be found in many forms and oxidation states. The various selenium species respond differently to wastewater treatment processes, and the selenium species present may drive the selection of treatment processes for FGD chloride purge water. The general assumption is that forced oxidation wet FGD systems will produce selenate as the primary selenium species, which is difficult to remove with traditional wastewater treatment (WWT) processes. However, field measurements show that a wide range of selenium species may be present. Research programs sponsored by the Electric Power Research Institute and the U.S. Department of Energy have studied the factors impacting selenium speciation and phase partitioning in limestone forced oxidation (LSFO) wet FGD systems. Over 50 bench-scale tests conducted from late 2008 through late 2010 have measured the impacts of operating parameters, such as oxidation reduction potential (ORP), and key FGD constituents on selenium behavior at the bench scale. Strategies to control selenite oxidation and phase partitioning have included control of operating parameters and application of scrubber additives; these strategies have successfully demonstrated the avoidance or decrease of selenite oxidation in synthetic FGD liquors at the bench scale. Pilot-scale testing, scheduled for mid-2011, will test selenium management approaches developed at the bench scale. This paper will discuss results from the bench- and pilot-scale scrubber test campaigns as well as ongoing efforts to develop improved sample handling methods for measuring selenium species.

## Experiences and Challenges for Measuring Total Iron in Produced Water

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The determination of different constituents in Produced Water is a challenge due to the diversity and quantity of interferences present. Many of the test methods available for clean potable and surface waters fail to give accurate results when used for testing in Produced Water systems. Recognition of this has led to the development of a credible “total iron” field test method that is comparative with more advanced analytical methods like ICP.

## On-site Laboratory Methods for Determination of Silica and Alkalinity for Steam Generators for In-Situ Bitumen Recovery

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Steam Assisted Gravity Drainage (SAGD) produced water is unique in many ways due to high temperature, silica, and organics concentration. One of the primary challenges of SAGD produced water analysis is identification appropriate analytical methods for on-site process monitoring. Most analytical procedures are set-up for drinking water analysis and not for produced water analyses. Procedures followed to preserve/analyze drinking water samples often produce incorrect test results when applied to SAGD produced water. The primary focus of this paper will be on identification of suitable on-site analytical methods for quantification of dissolved silica and alkalinity in boiler feed water for Once through steam generators and drum style boilers. In addition, the paper will provide a review of various analytical procedures, identify various interferences affecting the measurement, and document best industry practices for silica and alkalinity measurements in SAGD environment.

## ANALYTICAL METHODS FOR STEAM GENERATORS USED IN ENHANCED OIL RECOVERY (EOR)

E. J. Van Doorn, Ph.D., Baker Hughes Inc., Houston, TX

The manufacturers of steam generators used in the EOR industry have set maximum feed water quality limits for the concentration of petroleum hydrocarbon that can be tolerated for steam generation; therefore, the accurate measurement of this contaminant is crucial to the successful operation of the steam generators. This presentation discusses the various test methods used to differentiate various organic species and measure the concentration of total petroleum hydrocarbon (TPH) in produced waters. Also discussed in this presentation is the use of on-line analyzers to measure oil-in-water continuously.

## New No Solvent Method for fast, field Oil in Water Sample Measurement

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Traditional field methods for oil-in-water analysis of produced water require the oil to be extracted into an organic solvent prior to measurement. Many of the organic solvents used for extraction are either flammable, hazardous to human health or both. The chlorinated hydrocarbons are expensive and must be either recycled or have disposal issues. All major airlines and many helicopter services consider the risk so serious that it is difficult to transport the solvents in aircraft. The new No Solvent Method from Turner Designs Hydrocarbon Instruments, Inc. has addressed these issues. The methodology uses a small amount of a special surfactant making oil in water measurement possible with an extraction solvent. The surfactant converts the dispersed oil in the sample into an optically clear micro emulsion that is ideal for direct fluorescence measurements. Unparalleled repeatability of results from different operators is achieved because this method eliminates the volume measurement of water and solvents. This method can measure Water Soluble Organics independent from Free and Emulsified Oils. It can be shipped without hazardous identification labels and can be carried on commercial airlines and helicopters without declaration.

## Optical Based Software Techniques for Real-Time Analysis and Classification of Produced Water

Kent Peterson, Fluid Imaging Technologies, Inc., Yarmouth, ME

Optical instrumentation has many advantages over other technologies for the analysis of oil content and particles in produced water. The rapid microscopic characterization of particles sets itself apart from other rapid particle characterization via its morphological advantages. As well as measuring suspended oil in water concentrations (PPM), Optical techniques coupled with advanced data analysis and pattern matching can be used to effectively distinguish and then classify two particles of identical size and shape from one another. This paper illustrates the efficacy of various imaging techniques for use in the real-time characterization and quality assurance of produced water.

## Membrane Pretreatment Considerations with Seawater Reverse Osmosis

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One significant basis for the definition of success at a seawater membrane desalination facility is the capability of the pre-treatment system to provide acceptable, reliable, and consistent quality to a seawater reverse osmosis (SWRO) membrane. One common thread amongst many SWRO membrane pre-treatment systems is the inability of the pre-treatment system to meet these requirements on a consistent basis. Conventional multi-media filtration is a standard pre-treatment step for many plants. Operation of these systems can be onerous at best in order to maintain a suitable and reliable feed water quality to a downstream SWRO facility. Other types of “conventional” pre-treatment include dissolved air flotation, flocculation/sedimentation, and precoat diatomaceous earth

filtration. These pre-treatment methods are primarily installed for reduction in colloidal matter, suspended solids, and turbidity in order to meet SWRO membrane feedwater quality requirements. Membrane pre-treatment offers the potential to eliminate some of the operational and filtrate quality challenges that can plague many conventional media filtration systems treating seawater using a physical membrane barrier for reduction or removal of suspended material, log-reduction of bacteria, zooplankton, and even rejection of viruses. Pilot and demonstration tests have taken place to better quantify the effects of seawater on the downstream SWRO membrane, and the pretreatment membrane itself. Although the choices among various membrane pre-treatment configurations may initially appear very simple, the designer must pay significant consideration to the suspended solids, organics, and biomass content of the feedwater prior to selecting a preferred configuration. Feedwater constituents of material significance pose operating challenges t and can lead to unexpected results. This paper addresses a current need in the industry to gain a more comprehensive understanding of the design issues and comparative effects of the membrane pre-treatment process.

## Anti-fouling membrane system for industrial wastewater treatment and recovery

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One of the main challenges of implementing membrane technology for the industrial wastewater is fouling. BKT's anti-fouling membrane system called FMX was developed to address these issues. FMX membrane system has been in full-scale operation for methylcellulose treatment, anaerobic digester effluent for the biogas plant, and livestock waste treatment. The technology has also been tested in dozens of industrial and commercial sites including motor oil waste treatment, nano silver recovery, beer fermentation process recovery, landfill leach ate treatment, food waste treatment, latex manufacturing wastewater treatment, algae biomass harvesting for biogas production, wine stillage waste, or any application where conventional membranes cannot be used. FMX uses any membrane material including MF, UF, or NF from various suppliers. In 2004, BKT started development of a reliable membrane system to be used for methylcellulose wastewater from Samsung Fine Chemicals (SFC) manufacturing facility, where all previous treatment systems failed. BKT developed a vortex generating system that prevented membranes to foul in high viscosity and high solids loading in the feed water. SFC now operates 6 full-scale FMX systems and 2 additional units will be installed this year. The membranes installed in the first FMX unit at SFC lasted for 5 years without being replaced. In 2009, 3 full-scale FMX units were also installed in Netherlands to treat anaerobic digester effluent at a biogas plant owned by Mosch Thermische Installaties (MTI), where FMX system improved the biogas generation rate by 30%. These case studies and background on the FMX will be presented in this paper.

## Using Permeat Suction to Reduce Concentration Polarization In Spiral Wound Nanofiltration Module

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Fouling in a nanofitration membrane module is usually a result of concentration polarization. The effect of permeate suction on the slightly negatively charged spiral wound nanofiltration membrane is investigated. According to the film theory, the mass transfer coefficient is inversely proportional to concentration polarization. The effect of permeate suction destabilizes the boundary layer. This will decrease the concentration polarization layer, and consequently will increase mass transfer through the membrane's surface. To validate the hypothesis, experiments were carried out on a NF membrane that can be described by the solution-diffusion model. This model has coefficients that can be measured experimentally. Using the membrane wall concentration in this model instead of the bulk feed concentration can help estimating the mass transfer coefficient more appropriately. Two experimental studies were carried out, one with a standard high pressure pump, and another one with the added effect of suction pressure applied to the permeate collector tube. Three different concentrations of binary dilute solutions of NaCl , MgSO4 , and MgCl2 , at three different pressures (low, medium, and high) were tested. For all tested solutions, permeate suction increased the diffusive Peclet number as a function of the feed concentration. With the increase of the Peclet number, it was observed that the concentration polarization decreased, and both the product flow and the product quality were improved. It was concluded that permeate suction reduced concentration polarization, increased product flow rate, and improved product quality. Thus, adding permeate suction has beneficial consequences because it reduces membrane fouling and extends its useful service life.

## Factors Impacting Silica/Silicate Control Agent Performance in Industrial Water Systems

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The formation and control of silica/silicate-based deposits presents enormous operational challenges for industrial water systems including brackish water reverse osmosis, evaporative cooling, and geothermal systems when silica super saturation levels exceed saturation limits. Water technologists typically maintain silica levels below 180 mg/L in absence of silica inhibitor to avoid silica-based deposition because once formed silica scale is extremely difficult to remove and often requires the use of mechanical and/or chemical cleaning methods. Water shortages, increasingly poor quality water supplies, and environmental regulations that limit wastewater discharges have resulted in more silica/silicate limited industrial water systems. Consequently, there is a growing need for effective chemical treatments to minimize silica/silicate-based fouling. Effective silica/silicate chemical treatments should both (a) effectively inhibit crystalline scale forming salts and (b) function as amorphous silica inhibitors. This study focuses on the effects of water hardness levels, system temperature, and pretreatment chemicals on the performance of a new silica/silicate control agent in comparison to other commercially available inhibitors. Silica-based deposits formed in both the presence and absence of inhibitors is characterized.

## Advanced On-line Sodium Measurement

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Water treatment performance and determination of purity have depended on sodium measurement for nearly four decades. Monitoring cation exchange performance and the purity of makeup water, steam and condensate has benefitted from measurement of this key parameter. This ion-selective electrode method has been refined for these applications over the period. Described here are yet further improvements to sodium measurement technology including a unique combination electrode system that measures pH as well as sodium to assure proper reagent delivery. The system design minimizes reagent consumption and reduces maintenance requirements well below current practice. The new sodium system uses a particularly simple automatic calibration method and also provides the ability to measure grab samples easily. Its implementation with an operator interface common to other parameters including conductivity, dissolved oxygen, pH and ORP makes it especially convenient for installation and operator training.

## Double Pass Electro-Deionization

Steven Gagnon, AVANTech, Inc, Columbia, SC

Troy Gill, AVANTech, Inc Columbia, SC

This paper will review the lessons learned in designing, commissioning and operating a water treatment system consisting of second pass reverse osmosis system, complete with an antiscalant feed, sodium bisulfate feed system and cartridge filters as pretreatment; followed by a membrane degasifying system, polishing electro-deionization; followed by a second pass polishing electro-deionization system for a combined cycle co-generation power plant. This paper shall provide background on equipment selection, unit operation, water quality issues, system rework, operational problems, system profiling and validation protocol. Special consideration will be placed on profiling the reverse osmosis system (ROS) and electro-deionization (EDI) system performance due to radical changes in feed water quality and system operation.

## In Search of the Highest Purity Resin Available Stretching the Limit of Ion Exchange in Microelectronics

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The impurity levels of such common impurities as sodium, TOC, Silica and Boron continue to be driven down to detection levels. As micro circuitry is measured in the NANO scale the need for ever purer deionized water is understandable. This paper will review recent data compiled to evaluate resins used in the Microelectronics Industry using parameters such as rinse time and baseline impurity levels. In addition, recent resin product developments to support the Semiconductor Industry's ITRS (roadmap) will be reviewed. The ability to reuse these high quality resins in downgraded uses will be discussed in keeping with sustainability initiatives.

## Carbon Electrode-based Demineralization at a Wastewater Facility

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Electrochemical demineralization using high surface area carbon electrodes has been an area for interest since the pioneering work of Murphy and Johnson in the 1960's. A study of this process which included several field pilots was undertaken in order to look at the performance and cost of this technology vs. commercially available electrodialysis and reverse osmosis systems. Electrode and stack configuration for the capacitive DI unit are key parameters that affect the overall performance of the device. Specifically, the nature of the ion selective layer adjacent to the electrode surface controls both the overall energy consumption and the current efficiency. These parameters will be discussed in light of the results from the pilot trials at a municipal wastewater facility.

## Hydrodynamic Cavitation for Cooling Water Treatment: A Technology Update

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Membrane processes, such as reverse osmosis, ultra-filtration, and nano-filtration are an increasingly popular technology in chemical processing, water purification, and wastewater treatment. Scaling and fouling of membranes are an on-going performance issue for most applications. Scaling interferes with membrane performance, requires that the membrane be chemically cleaned, and can significantly shorten the service life of the membrane. A manufacturing facility produces sugars and enzymatic products. Part of the wastewater load (approx. 10%) is pretreated in an ultrafiltration (UF) unit followed by reverse osmosis (RO). In practice, reverse osmosis has failed due to the rapid and permanent fouling of the membrane likely due to precipitation of dicalciumphosphate dihydrate. Therefore, the removal of calcium with Controlled Hydrodynamic Cavitation (CHC)

treatment could assist the RO system with calcium and phosphorus removal before biological treatment. CHC technology has been demonstrated in cooling towers to precipitate calcium that can be easily removed from the treated water by filtration. This paper will describe the CHC technology and the information presented will demonstrate the effectiveness of CHC as a membrane pretreatment technology for calcium and phosphorus removal. The data will show that:
1 Precipitating the calcium with phosphate by the CHC system made it possible to use RO filtration.
2 Phosphorus removals was enhanced
3 All the filtration systems that were tested gave higher flux rates after CHC treatment
4 CHC was easily implemented into the existing filtration systems
5 The technology is suitable for reverse osmosis and nanofiltration systems and in some occasions for ultrafiltration systems.

## On-site Sodium Hypochlorite Generation System Improves Safety, Reliability, and Reduces Cost

Luis Diaz, NextEra Energy, Juno Beach, FL

On site sodium hypochlorite generation (OSG) is not new. In fact, OSG has been in existence since the early 1900. What makes this technology a viable alternative to gaseous chlorine and commercial bleach is the technical advances made in the last few years which have reduced cost, increase reliability and safety of the generation equipment. OSG systems use salt, water and electricity to produce a low concentration bleach solution. Bleach produced by OSG is identical in properties and effectiveness in controlling biological activities as gaseous or commercial bleach applications. Since most facilities have eliminated gaseous chlorine in favor of commercial bleach, this paper will only compare the benefits of OSG to commercial bleach. A case study of bleach treatment for a reclaimed water facility will be examined in details to illustrate the benefits of each system including safety, operation and cost.

## SAGD ZLD approaches

Mark Nicholson, P.E.,HPD, a Veolia Water Solutions & Technologies company, Plainfield, IL

In recent years, evaporation has been successfully applied for SAGD water treatment in Alberta. One of the lingering technology gaps in applying the evaporative approach is handling the evaporator blowdown waste. Evaporator concentrate has proven to be difficult to treat for deep well disposal or Zero Liquid Discharge (ZLD) treatment systems. A single ZLD approach, as has been done in the power industry, is not acceptable as each SAGD producer has different requirements and environmental limits to work within. Several ZLD solutions are required as the industry requires flexible disposal options for future consideration. In recent years, there have been fundamental advancements with established alternate process steps to make ZLD a practical and reliable approach to evaporator concentrate treatment. This paper discusses the various ZLD process options that are presently available for evaporator concentrate treatment. Both existing and future systems will be discussed with emphasis on what has been tried, what is achievable, and what can be expected to be the future focus of this technology.

## Organic Removal with Granular Activated Carbon (GAC) from Distillate Water with Bio-Fouling Tendency, and associated issues: A Follow-up

Emmanuel Quagraine, Ph.D., Saskatchewan Power Corporation, Shand Power Station, Estevan, SK, Canada

At IWC-2009, results of a case study evaluating organic removal options for a zero liquid discharge power plant was presented [IWC-09-27] and subsequently published in Power Plant Chemistry [2010, 12(1), 22]. For the conditions at this site, GAC was best suited and was hypothesized that the mechanism of organic removal was via mainly

adsorption at the early stages of operation, but dominated by biodegradation of organics as GAC bed ages. With this notion, two GAC beds previously operated in parallel were switched to series to take advantage of organic removal via biological degradation with the upstream bed whilst reducing excessive microbial growth on the downstream bed-the principle of biological activated carbon. The upstream bed was to be changed every 2 years and switch valves to allow the newest bed as last (downstream) in series before the mixed beds. Thus, carryover of bio-fouling potential from the carbon bed to mixed beds would be minimized. It is over 2-years now that the beds were run in series and this report is to provide an update of performance since and provide evidence to support the mechanism of organic removal from the distillate water. Discussions will include; comparing organic removal data (TOC, haloacetic acids (HAAs) and trihalomethanes (THMs)) by the beds in series versus parallel, evaluation of cessation of glutaraldehyde disinfection and implementation of more frequent backwash on beds' performance (including reducing slime formation), and lastly impact on the performance of the mixed beds and how silica may be related.

## Case Study Evaluation on Implementing Safety Hazard Avoidance in Design Build Projects

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Safety hazards are inherent to the construction and operation of facilities that treat water and wastewater. Avoiding or mitigating the risks present during the construction is paramount to the safety of the workforce. Successful completion of a project includes avoiding disruption to the lives of the workforce and the project schedule. Further, anticipating the operational needs during the design phase is important to mitigating the exposure of operating personnel to hazards that are present during regular operation of the facility. This paper reviews three projects involving the installation of different water treatment systems for the power and mining industries using a design-build delivery method. Each project had different site conditions and interfaces with owner facilities. Common construction hazards are identified and the mitigation strategies deployed are described. Evaluation of operational considerations, integration with the clients' haz-op review procedures, and the design approaches to mitigate the exposures are also discussed with regard to capital cost versus operational cost options. Readers will be able to use these case studies to evaluate ways that safety hazard avoidance can be part of the scope, design and plan for plant operation during the development of water and wastewater projects.

## Using Patents to Monetize Innovative Ideas

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Patents provide an effective tool to turn innovative ideas into money that can help finance related research and development. In addition to providing for a limited monopoly that can result in increased sales and prices, patents can provide access to otherwise inaccessible markets through licensing, provide leverage in securing cross-licensing agreements and negotiating partnering ventures, attract venture capital, and indicate technical superiority which can in turn attract consumers. Compared to trade secrets, patents are more robust and flexible for realizing return on research and development. To maximize the value of a patent throughout its life cycle, from the initial filing of an application through the expiration of the patent's term, the patentee should have clearly defined business goals, pursue these goals through specific features of the patent, and be aware of milestone events in the patenting process. Patent drafting, patent prosecution, marketing, and enforcement strategies can be essential in the successful development of an intellectual property portfolio and the achievement of business goals. This paper and presentation describes and explains the above principles.

## Public- Private Partnership Projects Influence on Cost and Performance For Seawater Desalination Projects

Javier Gaztelu, INIMA-OHL Group, Miami, FL

Alfredo Andres, INIMA-OHL Group Miami, FL

A variety of Public-Private Partnership (PPP) projects exist depending upon many factors such as: public entity involvement, finance responsibility, project ownership, design, environmental management, permitting and risk management. These types are Build-Own Operate (BOO), Build-Operate-Transfer (BOT), Buy-Build-Operate (BBO), Design-Build-Operate (DBO), Build-Develop-Operate (BDO) and Design-Build-Operate-Transfer (DBOT). Recent regulation opens the door to a new source of funds from the Federal Administration for PPP projects. This low interest funding will certainly boost the number of these types of project! s on U.S territory in the future. Public-Private Partnerships are certainly one of the most common approaches worldwide for the Sea Water Desalination application due to the highly specialization required to undertake these projects. An integrated DBO process creates the best environment to develop cost and performance benefits from the preliminary design to the O&M period rewarding the outcome of these projects. As a result, increased efficiency, cost reductions, public health benefits, are among many of the benefits of any PPP process. In a Seawater RO treatment project these benefits are for example low energy cost configurations, appropriate material selection, reliable post-treatment solutions. Operating experience is the most valuable feedback designers can obtain for a successful outcome as well as the technical background of the O&M personnel ensures the most efficient operation. Also economics of scale play an important role in seawater desalination projects through worldwide agreements between suppliers and DBO firms. Four of the latest Seawater RO treatment plants Design-Build-Operate (DBO), Alicante II (Spain), Mostagamen (Algeria) and Los Cabos (Mexico), and Design-Build-Operate-Finance (DBOF), Taunton (US), show consistency in affordable capital and operating costs. The Alicante II Sea Water Desalination Plant is capable of treating 17 MGD and was commissioned in 2008. We were involved in the Design, Construction and is currently Operating this plant. Some peculiarities of this plant include a mixed ground and surface water supply. The client for the project was the local 'Mancomunidad de Canales del Taibilla' subsidiary of the Spanish Environmental Ministry and worked on this DBO project ensuring that current and future water needs in the tourism dependant region of Alicante are met.

## A Holistic Water Management Approach to Changing Power Plant Regulations

Michael Preston, Black & Veatch, Overland Park, KS

The world of power plant regulations is evolving quickly. Many of these new and proposed regulations will significantly affect how power stations view and utilize water resources and address wastewater discharge. Often the temptation is to simply address these as isolated issues that are created in the wake of these new and proposed regulations. However, the new regulations offer many utilities an opportunity to take a more holistic approach to their water management plans. The process is initiated by a thorough study of the existing facility water management approach followed by proposed modifications to address new regulations or improve water efficiency. It is expected that this approach results in superior and more sustainable utilization of water resources and minimization of additional treatment. This is particularly true for facilities built prior to the current concerns for water resources and availability and wastewater discharge. This paper provides a framework for performing a typical facility water management review and describes several cases where this was performed and the results.

## Boiler Deposit Control - Informed Selection Improves Boiler Protection

James Robinson, GE Power and Water, Trevose, PA

Dennis Dyer, GE Power and Water Trevose, PA

Numerous chemicals have been used to control deposition in industrial boilers. While nearly all of these chemicals have been successful in certain situations, understanding where and how to use each chemical is critical to achieving long-term reliable plant operation. This paper will review the benefits and limitations of individual

treatment chemicals to enable informed treatment selection based on plant operating conditions. In addition, with the trend to higher purity feedwater for low-pressure boilers, the need to address the potential for flow accelerated corrosion (FAC) as well as deposit control is discussed.

## Development of an Interactive Water Management Program for Orlando Utility Commission's Curtis H. Stanton Energy Center

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Orlando Utilities Commission (OUC) Stanton Energy Center site in Orange County, Florida includes two 465 MW (nominal) coal fired units and a 633 gas-fired combined cycle plant. An additional 300 MW combined cycled facility currently is being constructed. The Stanton Energy Center (SEC) is a very unique plant from a water and wastewater operations standpoint. The SEC includes both coal and gas fueled units, a number of water supply sources, various drainage and flow equalization ponds, and advanced wastewater treatment systems to achieve zero liquid wastewater discharge. Recycle and reuse of wastewaters is extensively used. With such complexity, it has been challenging to predict all the impacts of various operational regimes and weather events. With possible development of new environmental regulations, OUC may also desire to change its fuel mix in the future, which could have direct impact on water and wastewater management at the SEC. Therefore, OUC decided that better tools were needed to ascertain the impact of various operational scenarios and environmental events on water management. OUC determined that an interactive computer program approach using the detailed plant water mass balance diagram as the basis was needed. A program has been developed using Microsoft © Office Excel 2003 and Microsoft Visual Basic 6.5. The program utilizes an interactive process flow diagram that utilizes the Visual Basic user forms for entry of operational parameters for plant unit operations specific to the Stanton Energy Center. Detailed water management calculations are performed “behind the scenes” and displayed on a user-friendly interface. The program is able to model the water balance impacts of present and future events, such as rainfall, equipment outages, changes in projected unit load, changes in coal properties, scrubber operational changes, and maintenance events. Inputs include daily rainfall amount and duration, expected capacity factor for each unit, water management pond levels, chemistry of makeup water sources, water usage flow rates for each plant subsystem, cooling tower operation including chemistry control limits, seasonal evaporation rates, coal quality, FGD scrubber operational parameters, and similar factors.

## Mineral Scale Prediction and Control at Extreme TDS

Robert Ferguson, French Creek Software, Inc., Kimberton, PA

Traditional methods for predicting mineral scale deposition and optimizing scale inhibitor dosages are not effective in high ionic strength brines such as shale fracturing flowback fluids. This paper discusses techniques for modeling scale formation and its inhibition in high to extreme TDS brines. The technology discussed is applicable to fracturing operations, produced waters, seawater membrane systems, and zero discharge industrial environments. The advantages and disadvantages of traditional and viral equation approaches are discussed on a practical basis. The thermodynamics and kinetics of mineral scale prediction and dosage optimization are discussed. Implications of open and closed systems, reducing and oxidizing environments are also covered.

## Field trial experience using chlorine dioxide as a cleaner for biofilm control in an RO application

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Biofilm is the last great challenge in reverse osmosis system design and operation. Technological advances have increased flux and rejection, brought down costs, and increased membrane life, but biofilm remains a problem. It decreases flux rate, which causes energy costs to rise and production to suffer. It decreases the time between membrane cleanings, because it cannot fully be removed so that the membranes re-inoculate themselves with their own bacteria. It shortens membrane life, because it causes the membranes to reach a point where they can just no longer be cleaned. In other words, biofilm is the enemy of reverse osmosis membranes. This paper will describe results from a field trial comparing chlorine dioxide with DBNPA on two 500 gpm RO systems where biological fouling has been an ongoing operational issue. The discussion will include purity requirements for safe use of the chlorine dioxide with TFC membranes, the method of chlorine dioxide application and performance of the chlorine dioxide relative to DBNPA. Chlorine dioxide was found to be much more effective than DBNPA without damaging the membranes