BUREAU OF RECLAMATION

2022 Desalination and Water Purification Research Program Research Projects

Alabama

University of Alabama: Selective Removal of Nano- and Micro-plastics from Water using Adsorptive Metal Organic - Framework-Positioned Membranes: Experimental and Modeling Investigations

Reclamation Funding: $250,000 **Total Project Costs: $500,000**

Nano- and micro-plastics (NMPs) pollution is one of the current water treatment challenges. The proposed work targets development of selective thin-film nanocomposite (TFN) membranes to remove different types of NMPs using adsorptive metal organic frameworks (MOFs). The main goal of this proposal is to employ MOFs to develop a new class of TFN adsorptive nanofiltration (NF) membranes with a high affinity to NMPs for treating NMP-contaminated water/wastewater. In this effort, an experimental and simulation approach will be used to understand the factors that control the selective removal of NMPs from the aquatic environment using newly developed NF membranes. The experimental and modeling studies will help evaluate adsorption mechanisms and kinetics and characterize fouling properties of different NMPs on the membranes.

California

Kennedy/Jenks Consultants, Inc: Use of Colloidal Particle Monitoring for Microfiltration/Ultrafiltration Optimization in Water Reuse Facilities

Reclamation Funding: $250,000 **Total Project Cost: $541,813**

The proposed project will test a novel colloidal particle measurement technology to improve water recovery and energy efficiency in membrane treatment processes. The testing will focus on increasing efficiency of cleaning microfiltration/ultrafiltration membranes and provide online monitoring capabilities for measuring membrane integrity which would prove cost savings for both operation/maintenance and capital costs.

Carollo Engineers, Inc.: Data-Driven Fault Detection and Process Control for Potable Reuse with Reverse Osmosis

Reclamation Funding: $641,900 **Total Project Cost: $1,284,100**

Reverse osmosis-based water reuse produces a high-quality purified water, but there is room for significant improvement to optimize energy and cost. Influent water quality can be dynamic and requires multiple treatment barriers for chemical and pathogen removal. In this work, faults detected will include abnormal water quality, equipment failure, and atypical fouling rate. Fault detection methods will include supervised machine learning and nonparametric hypothesis testing. Process control will include model predictive control and multiblock principal component analysis. Desktop evaluations of cutting-edge methodologies in year one will precede cloud or edge-based, semi-autonomous, near real-time implementation at demonstration-scale in year two.

Encina Wastewater Authority: Optimization of the MBR Process for Potable Reuse

Reclamation Funding: $800,000 **Total Project Cost: $2,728,227**

The proposed work will include testing of a 10 gallon per minute pilot potable reuse treatment train consisting of a membrane bioreactor (MBR), reverse osmosis (RO), and ultraviolet with advanced oxidation process (UV/AOP). The upstream MBR process will be operated over a range of varied conditions to help optimize unit process size, footprint, energy use, and chemical use, while ensuring that the performance of downstream advanced treatment (i.e., RO and UV/AOP) is not compromised. Additional goals of this research are to better understand the mechanisms of pathogen removal through MBR and to demonstrate use of a novel online RO integrity surrogate. Overall, this research will help optimize membrane treatment processes for potable reuse, advance the state of knowledge on pathogen validation through the MBR and RO processes, and help lower barriers to the implementation of potable reuse projects.

Colorado

University of Colorado: Simplified Water Reuse and Highly Selective Desalination using Pressure-driven Membrane Distillation

Reclamation Funding: $250,000 **Total Project Cost: $390,645**

Converting wastewater and seawater into potable water requires a high degree of pathogen and contaminant removal, which is energy-intensive and costly. This proposal will advance a new membrane-based water treatment train using pressure-driven membrane distillation (PDMD) integrated with strong oxidation for fouling mitigation and enhanced contaminant removal. The proposed work will experimentally determine the ability of PDMD to reduce treatment costs and energy consumption wastewater reuse and desalination. To demonstrate the promise of PDMD, the objectives of the proposed work are to (i) prepare PDMD systems and characterize membrane water productivity and selectivity; (ii) assess the fouling and contaminant removal performance of PDMD in wastewater reuse applications; (iii) evaluate PDMD performance for improved desalination; and (iv) communicate results to relevant stakeholders.

Colorado School of Mines: Biological Water Softening for More Sustainable Membrane Desalination of Inland Brackish Waters

Reclamation Funding: $249,818 **Total Project Cost: $341,486**

The vision of this project is to enable intensification of water recovery in BWRO desalination by pre-treating brackish water using a novel engineered algal biomat. This sustainable "biological water softening system" operates without chemical addition and under facile management strategies. The proposed project will evaluate a fully functional laboratory scale hybrid wetland and reverse osmosis system on brackish groundwater toward three hypothesis-driven investigations: 1) quantify enhancements such as reduced membrane fouling and improved water recovery within a membrane-based desalination system after wetland pre-treatment using synthetic and/or real water, 2) evaluate arsenic and boron removal during reverse osmosis after wetland pre-treatment, and 3) perform a cost/benefit analysis that focuses on contrasting chemical, material and energy costs for a base case RO system with chemical additions versus a coupled engineered wetland/RO system.

Colorado School of Mines: Closed Circuit Desalination with Novel Scaling Control System

Reclamation Funding: $800,000 **Total Project Cost: $1,250,473**

This project seeks to ensure stable water supplies to remote communities by improving reverse osmosis (RO) technology through scaling control and concentrate minimization. A 20 gallon per minute 8" element closed-circuit reverse osmosis (CCRO) demo unit from Dupont Water Solutions will be augmented with a smart scaling precursor detection system to minimize required pilot testing time, need for chemical cleaning, and ultimately replacement of membranes. Additionally, a novel integration of commercially available components will be tested to enable resource recovery from the concentrate.

Project 7 Water Authority: Pellet Softening Reactors for Mineral Removal and Filtration Pretreatment: A Novel Surface Water Treatment Concept for the Western US

Reclamation Funding: $612,059 **Total Project Cost: $1,224,118**

This project will test an innovative approach to dissolved solids (TDS) and minerals removal from a surface water reservoir with high hardness and TDS. The intent is to show that treatment trains, without the use of osmotic or nano-porous membranes, can be implemented to cost-effectively add water resources to Western water supply portfolios that were previously considered difficult to utilize. The project will test an advanced, up-flow pellet softening reactor (PSR) as a pretreatment for direct filtration. This innovative treatment train for high TDS, 'hard' surface waters, will be compared to an often-applied treatment approach in western states, ultrafiltration (UF) followed by brackish water reverse osmosis (RO) membranes. The project seeks to demonstrate the compliance of the two treatment trains with both State and Federal drinking water regulations and water quality standards.

Michigan

University of Michigan: Novel Highly Charged Ion-Exchange Membranes for Brine Concentration via Electrodialysis

Federal Funding: $250,000 **Total Project Cost: $396,000**

The overarching goal of the proposed study is to rationally design scalable, highly permeable, and highly selective ion-exchange membranes (IEMs) for treating concentrated salt solutions (e.g., brines) via electrodialysis (ED). The research team will synthesize highly charged IEMs with varying degrees of water content using inexpensive commercially available monomers and cross-linkers, fully characterize the transport properties of the membranes, and identify potential candidates with transport properties suitable for brine concentration via ED. Pore-filled IEMs will then be fabricated with the optimized formulations by polymerizing the ion-exchange polymer within the pores of a microfiltration membrane. Lastly, the pore-filled IEMs will be implemented in the current membrane manufacturing process at SUEZ to make large area membrane sheets suitable for commercial scale ED. The suitability of the large area pore-filled IEMs for treating concentrated salt solutions will be tested via bench-scale ED experiments.

New Jersey

New Jersey Institute of Technology: Ominphobic Interfacial Heating Membranes with Robust Antifouling, Antiwetting Performance and Superior Thermal Efficiency in Membrane Distillation

Reclamation Funding: $250,000 **Total Project Cost: $501,627**

Membrane Distillation (MD) is a thermally driven process where the vapor pressure gradient over the porous hydrophobic membrane leads to the transport of water vapor. To ensure an efficient driving force, the feed solution is continuously heated in conventional MD, which consumes substantial energy or leads to energy waste via heat loss. MXenes are a novel class of 2D transition metal carbides and/or nitrides. This project will investigate the electromagnetic induction heating mechanism on a suite of MXenes and evaluate the MD performances. This project will further investigate the impacts of solution characteristics, induction energy intensities and membrane surface properties on the performances of MD and mitigation of membrane wetting in MD. The results will provide important new insights into cost-efficient and sustainable MD processes for desalination and water purification.

Montclair State University: Hydrated Electron-Driven Advanced Reduction Process Enables In-Situ Ion Exchange Resin Regeneration for Efficient Mitigation of PFAS in Water Reuse

Reclamation Funding: $249,999 **Total Project Cost: $315,085**

Per-and poly-fluoroalkyl substances (PFAS) challenge established water reclamation practices due to their prevalence, mobility, persistence, bioaccumulation, trace concentrations, and adverse health effects. Ion exchange (IX), though widely applied to PFAS treatment, suffers from high operational costs due to off-site regeneration and requires costly management of toxic regenerant waste. Emerging advanced reduction processes (ARPs) driven by highly reductive

hydrated electron have been well demonstrated in laboratory studies to effectively degrade different PFAS in water. The overarching goal of this project is to provide the scientific basis for ARP-driven in-situ regeneration of IX resins for concurrently restoring resin capacity and degrading sorbed PFAS. Although this study targets PFAS in water reuse, the approach can be readily applied to other persistent organic pollutants at trace concentrations in water.

New Mexico

New Mexico State University: Evaluation of Innovative Produced Water Treatment Technologies and Assessment of Risk and Toxicology during Reuse

Reclamation Funding: $250,000 **Total Project Cost: $310,000**

One of the major barriers for using treated produced water (PW) as an alternative water source is lack of comprehensive assessment for its impacts on environment and public health. The study will focus on a risk and toxicology assessment for treatment and safe use of treated Permian Basin PW. It will evaluate the efficiency of an innovative membrane distillation system and newly developed electrodialysis brine concentrator and seawater reverse osmosis system for PW. Appropriate pre-treatment and post-treatment will be employed to ensure the performance of these systems and the quality of treated water for reuse or discharge. The overarching goal of the project is (1) to demonstrate the technical viability of innovative PW treatment technologies with comprehensive water quality characterization, and (2) to evaluate the risks and toxicology during different reuse applications in the Permian Basin through toxicity assessment.

New York

Clarkson University: Low Energy and High Water Recovery Desalination of Brackish Groundwater Using a Compact and Redox- Driven Electrochemical System

Reclamation Funding: $250,000 **Total Project Cost: $503,433**

The goal of the proposed project is to develop an electrochemical separation process driven by a redox couple, called redox flow desalination (RFD), for low energy and high water recovery desalination of brackish groundwater (BGW) at a practical productivity range. Such an electric-field-driven process consumes less energy than the widely used reverse osmosis. Remaining challenges of RFD for a broader implementation are to assess and mitigate scaling and precipitation formation due to the presence of minerals in BGW. To address these challenges, this study will focus on three research objectives: (1) Fabrication and optimization of carbon-based electrodes for low energy desalination; (2) Synthesis and characterization of monovalent-ion-selective membranes for high water recovery desalination; and (3) Integration and optimization of a bench-scale redox-driven electrochemical system for real BGW desalination.

Texas

Texas Tech University: Robust Electroconductive Laser-Induced Graphene (E-LIG) Membrane for Application in Membrane Distillation

Reclamation Funding: $249,999 **Total Project Cost: $379,345**

Scaling/fouling, poor energy efficiency, and lack of suitable commercial membranes have been identified as the major barriers for widespread application of membrane distillation (MD). Using Joule heating to directly heat the membrane surface can obviate the need for the chain of heat exchangers, reduce the heat loss, and thereby, increase MD's overall energy efficiency. The overall objective is to design, develop, and optimize superhydrophobic Electroconductive LIG (E-LIG) membranes that can be heated with Joule heating - only on the surface. The central hypothesis is that the surface heating reduces the need for costly heating process equipment and reduces inefficiencies associated with the heat exchanging. Additionally, optimizing the heating conditions can significantly mitigate the scaling/fouling obstacle.

Utah

University of Utah: Recalcitrant Surfactant Effects on Membrane Filtration of Viruses and Formation of Disinfection Byproducts in Water Reuse Systems

Reclamation Funding: $249,989 **Total Project Cost: $429,989**

Surfactants are ubiquitous in wastewater and incompletely removed in conventional wastewater treatment systems. Surfactants can pose a risk in water reuse systems in two ways. First, surfactants may be transformed into disinfection byproducts (DBP) during oxidation. Second, surfactants can change their surface properties and thus pass-through membranes. This study will conduct a combination of field investigations, replicated laboratory experiments and modeling to improve the design of water reuse systems to limit these risks. The work will leverage the expertise of facility managers and treatment systems at five indirect reuse water treatment plants in Utah.

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