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(Unedited)

Research Presentations

Con-Current Oral and Poster Sessions

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National Capital Section

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CONTENTS

Con-Current Sessions

*Session No. corresponds to sessions in the symposium program.

Session 2. Emerging Technologies and Data Management Tools

Moderator: Alaina Armel, AECOM

Can losses from flood events be successfully modeled using an open source machine learning framework? Predicting aggregated insurance claims from anonymized Open FEMA data by leveraging a stacked ensemble machine learning method
Jason Matney, PhD, Senior GIS Professional at Dewberry. Email: jmatney@Dewberry.com

Abstract
Floodplain managers at FEMA and other organizations are frequently tasked with accurately assessing flood risk at broad spatial scales. As machine learning frameworks mature, their potential for use in modeling anticipated losses from flooding is increasingly compelling. The goal of this research is to assess the ability of machine learning methods paired with open source data to model residential losses from flood events. The target variable for the predictive model is Open FEMA National Flood Insurance Program insurance claims in USD collected from 1985-2015 within the state of Indiana, USA. The predictor variables are approximately 65 attributes associated with each subwatershed, including geophysical characteristics, population demographics, discharge statistics, and mean insurance policy. The performance of four individual models – GLM, Random Forest, GBN, and ANN – were tested and compared using a k-fold train-test-validate protocol with gridded hyperparameter tuning using the H2O modeling framework. Predictions from hundreds of tuned models generated via grid search were supplied to a stacked ensemble method using several metalearners. Results indicate that the stacked ensemble method comparatively improved model performance. Next steps include scaling up the study area to a continental level while also incorporating more granular spatially indexed data as model inputs, thereby improving prediction accuracy.

Use of mobile, GPS-Enabled data collection tools and operational dashboards to efficiently manage water resource assessments. Alicia Ritzenthaler, Heather Bourne, Brad Udvardy, LimnoTech. Email: aritzenthaler@limno.com

Abstract
Comprehensive assessments of water resource assets require a robust, mobile, and GPS-enabled data collection tool to ensure data collected are complete and meet QAQC standards, are coupled to a desktop platform to allow office staff to monitor progress in real time, and efficiently manage resources. Given as a case study, this presentation will discuss the District Department of Energy and Environment's (DOEE) Rapid Stream Assessment Program and the customized mobile app and desktop dashboard that were integral to its success. This presentation will outline the limitations and constraints of existing off-the-shelf platforms for mobile data collection and describe the pros and cons of an adaptable tool LimnoTech has uniquely customized from ESRI's Collector for ArcGIS and Survey 123 apps. This custom-linked tool allows users to interact

with the powerful mapping of Collector (i.e. create new features, reference existing attributes) while leveraging the behind-the-scenes conditional programming of Survey 123 to guide field staff through data attribute questions, ensuring that the correct set of information is always collected. Fully integrated with ArcGIS Online, data collected by DOEE powers a real-time operational dashboard providing a platform for monitoring progress, reviewing data, and allowing for easy identification of actionable items and required next steps.

Mapping National Water Model (NWM) forecasts with FEMA HEC-RAS models – a pilot application in the Whitemarsh Run watershed, Maryland. Jennifer McGee, PE, CFM, Water Resources Engineer; Kristine Mosuela, EIT, Water Resources, Wood E&I.
Email: jenna.mcgee@woodplc.com

Abstract
The National Water Model (NWM) "is a hydrologic model that simulates observed and forecast streamflow over the entire continental United States (CONUS)", based on the National Hydrography Dataset (NHDPlusV2) stream network of ~2.7 million stream reach forecast locations. Most gaged locations have the benefit of capturing both the streamflow and the stage height at that location; allowing a flood inundation map to be generated for a limited distance upstream and downstream of the gage. With the NWM streamflow forecast data available in ungaged locations, the next step is to covert this hydrology into the associated flood inundation maps also. While there are several ways to accomplish this, the Maryland Department of the Environment (MDE), in coordination with the US Army Corps of Engineers (USACE), completed a pilot study in the Whitemarsh Run watershed to test an approach using the NWM streamflow forecast data and FEMA HEC-RAS models. The pilot study included a python-based script to download and evaluate the NWM forecast data and determine the associated depth grid to map. This presentation will provide a summary of the data acquisition, analysis, and summary of the pilot study results.

Be prepared: climate resilience and mitigation planning for the Washington Suburban Sanitary Commission. Miranda Santucci, PE, Water Engineer; Lee Tharps, PE, Water Engineer; Paula Sanjines, PE, Wastewater Regional Solutions Leader, Jacobs.
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Abstract
Washington Suburban Sanitary Commission (WSSC), a water and wastewater utility located in suburban Maryland outside Washington, D.C., is in the fifth year of a five-year Climate Change Vulnerability Assessment Adaptation and Planning (CCVAAMP) project, an initiative to prepare for climate change. This project has included the development of future climate scenarios, modeling of future flood conditions near WSSC facilities, assessment of facility vulnerability, and development of adaptation strategies. The project includes development of design guidelines for protecting facilities from future climate extremes. The project also includes annual updates to the WSSC greenhouse gas (GHG) inventory and Action Plan. The GHG Action Plan has been updated annually since 2012 and addresses organization-wide goals for reduction of GHG emissions. The presentation will provide an update on the CCVAAMP project with a focus on the methodology and results of the vulnerability assessment and flood adaptation analysis for WSSC facilities completed to date, including pump stations and wastewater treatment plants. The vulnerability analysis results in a calculated cumulative risk avoided value for each facility based on planning timeline, flood risk, asset replacement costs, and probability of failure of selected strategies. A discussion of the WSSC GHG inventory and Action Plan will also be included.

Session 4. Advances in Water Management Systems

Moderator: Matt Schley, Hydrologist, National Park Service

A low flow forecast system for water supply operations during droughts. Alimatou Seck, PhD, Water Resources Scientist; Cherie L. Schultz, PhD, Director of Operations; Luke Vawter, Research Support Analyst, ICPRB. Email: aseck@icprb.org

Abstract
The Interstate Commission on the Potomac River Basin (ICPRB)'s Low Flow Forecast System (LFFS) is a Linux based data and modeling platform designed for assisting in reservoir release decisions during droughts. The system is built in the Delft-Flood Early Warning System (FEWS) framework. On a daily basis, the LFFS automatically downloads and processes various meteorological data and runs a version of the Chesapeake Bay Program's Watershed Model, a Hydrologic Simulation Program Fortran (HSPF) based model, to simulate streamflow in the Potomac Basin. Internal flow forecasts have a lead time of 15 days. The LFFS publishes processed meteorological data and flow forecasts to the cloud, allowing for seamless integration with ICPRB's web-based drought operations tools. In addition to its internal flow forecasts, the LFFS uses available regional flow forecasts such as the Middle Atlantic River Forecast Center (MARFC) Hydrological Ensemble Forecast System (HEFS) streamflow forecasts which provides short- and long-range forecasts with lead times of up to 120 days. The integration of additional forecasts is currently under development, aiming for multi-model and probabilistic approaches for improved reliability in forecast and decision making during droughts.

Regional hydrological methods for estimation of maximum flood discharges in ungauged dry streambeds, Gobi Region, Mongolia. Myagmarsuren Bat-Erdene (doctoral student), Dept. of Geography, National University of Mongolia; and D.Oyunbaatar, Hydrology Section, Information and Research Institute of Meteorology, and Hydrology and Environment, Ulaanbaatar, Mongolia. Email: miga_b2006@yahoo.com

Abstract
Estimating maximum rainfall discharge with different return periods is one of the most sophisticated problems and also practical important in hydrological engineering. Recent development of the Gobi region in Mongolia with mining and infrastructure urgently requires need of different type's hydrological data and outputs of research studies to solve different practical issues related to water use and protection. At same time, faces serious lack observed data on climate and hydrology of the region. The study covers estimation of rainfall maximum flood discharge along the small creeks and dry beds in the selected region. The study area is located in the southern Gobi region of Mongolia, namely in territory of Omnegobi and Overkhangai provinces. During field study and measurement 35 river and pebble have chosen and checked their location, identified terrain pattern, conducted cross section 27 sites and data have been processed using geological information system. The catchment area of the selected creeks and dry beds varies from 0.4 to 95.2 km^2 with length of 17.9 km. For flow velocity estimation, the Chezy-Manning and V.V.Golubetsov's (year) methods were used. The V.V.Golubtsov formula to calculate flow velocity is modified for the Gobi region as V=1.14*h

$^{0.67} * J^{0.17}$ and flow velocity over pebbles is calculated with this empirical formula to compare flow velocity calculated by horizontal cross section. The correlation coefficient R between these velocities is R=0.90, and standard error=$\pm$0.06 m/s, showing that is possible to calculate flow velocity over pebbles. The maximum flood discharge with 100 year return period is estimated by the method so called: rainfall intensity method" adopted for Mongolian condition and applied for small rivers with catchment area of less than 200 km^2.

Impact on water supplies of projected changes in inter-annual variability of streamflows due to climate change.

C. Schultz, PhD, Director of Operations; S. Ahmed, Water Resources Eng. Analyst; A. Seck, Water Resources Scientist, ICRB
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Abstract
The Washington metropolitan area (WMA) water supply study, conducted every five years by the Interstate Commission on the Potomac River Basin on behalf of the region's major water suppliers, assesses the future reliability of the regional water supply system based on forecasts of water needs and water availability. The potential impact of climate change adds significant uncertainty to forecasts of future water availability. There is a large range of potential changes in long-term basin-wide mean streamflow derived from downscaled climate projections, and the variability of both precipitation and streamflow are expected to increase. In this study we use estimates of future changes in the interannual variability of mean streamflow in the Potomac basin to help evaluate the future impact of climate change on WMA water supplies. Climate scenarios are developed from an ensemble of bias-corrected, spatially downscaled (BCSD) coupled model intercomparison project 5 (CMIP5) projections. Mean annual streamflows are estimated from annual precipitation and temperature using a climate sensitivity function based on historical data. A quantile mapping approach is used to predict flow-dependent changes in future annual streamflows. Resulting daily flow time series provide inputs for a regional water supply planning model.

A reduced-adjoint variational data assimilation for estimating soil moisture profile. Parisa Heidary, Graduate Student; Leila Farhadi, Assistant Prof., George Washington University; Muhammad U. Altaf, Div. of Earth Sciences, King Abdullah University of Science and Technology, Saudi Arabia. Email: parisaheidary@gwu.edu

Abstract
Soil moisture plays an important role in the global water cycle and has an important impact on weather and climate, energy fluxes at the land surface, agricultural and irrigation management practices, food production and the organization of natural ecosystems and biodiversity. It also defines the boundary condition of terrestrial hydrological processes, including infiltration, runoff, and evapotranspiration. Soil moisture is highly variable in space and time owing to the dynamics in soil hydraulic properties, precipitation, vegetation cover and topography. Therefore, accurate estimation of soil moisture pattern is of critical importance for land surface and land- atmosphere interaction modeling. Satellite based soil moisture can be obtained in a global coverage and well-defined temporal resolutions. However, they only provide surface soil moisture, upper few centimeter of soil column. The problem with these remotely sensed data is the land surface models require the soil moisture profile through the depth. In this work, the potential of using surface soil moisture measurements to retrieve soil moisture profile will be explored in a synthetic study,

using reduced-order variational data assimilation and a 1D soil water model. Proper orthogonal decomposition (POD) is a model reduction technique, which is used to approximate the gradient calculation in Variational Data Assimilation (VDA). Two distinct approaches are proposed and developed in this study when using POD in VDA. In the first approach, an optimization algorithm is applied in order to minimize cost function entirely in the POD-reduced space. The second approach uses POD to approximate only the adjoint model. The accuracy and feasibility of the proposed approaches will be investigated through a synthetic study. The main goal of this study is to use these two techniques to retrieve initial soil moisture profile and finally estimate the unknown parameters of the soil by solving the nonlinear Richard's equation as soil water model.

Use of autonomous instruments to conduct continuous, in-situ nutrient monitoring providing real-time results.

Alicia Ritzenthaler, Ed Verhamme, Greg Cutrell, LimnoTech
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Abstract

Aquatic ecosystems are under pressure from nutrient loads and the increased occurrence of harmful algal blooms are demanding the attention of communities around the nation. Management of nutrients and harmful algal blooms require an interdisciplinary approach and commonly encompasses both monitoring and modeling elements. Traditional nutrient monitoring programs are labor and resource intensive. Just one monitoring event can sometimes require two or more days of effort by one or more staff members in order to collect and analyze samples. The use of autonomous instruments can transform a monitoring program by allowing for continuous, in-situ nutrient monitoring, providing results in real-time. This presentation will discuss three recent case studies where nutrients (i.e. nitrate, phosphate, ammonia, total nitrogen, total phosphorus) were monitored in lake and riverine systems via autonomous instruments, using well-established wet chemistry methods, in order to provide water resource managers real-time data. Data can then be used as model input, to guide adaptive management, and to support informed decision-making.

Poster Session

Real-time flood forecast for the National Capital Region. Gustavo de A. Coelho, PhD Student; Celso M. Ferreira, Associate Professor, Department of Civil, Environmental and Infrastructure Engineering, George Mason University. Email: gcoelho2@gmu.edu

Abstract
Recurrent water related events showed that urban floods are still causing significant socioeconomic impacts over the United States, emphasizing the importance of build flood resilient communities to reduce damage and loss. An accurate water forecast system is a valuable tool in order to build resilience, once it can be used to identify significant oncoming events, to support decision making and to launch preparedness and response actions. In this context, the objective of this research is to quantify the contribution of most relevant hydrologic processes on urban flooding that can be represented by an operational real-time hydrologic model in a reasonable amount of time and computational cost. The National Capital Region is the focus of this study due to its exposure to combined water related hazards as riverine, urban and storm surge flooding, at the same time that is one of the most rapidly-growing urban region of the United States. This work is conducted as part of iFLOOD http://iflood.vse.gmu.edu that is a scientific experiment to incorporate multi-scale and multi-temporal physical processes for total water prediction, including large scale oceanic process, off-shore and near shore waves, estuarine hydrodynamics, coastal processes, riverine flows, urban runoff and storm water systems.

Compound urban flooding: The emerging hazard for Washington DC Metropolitan Area. Selina Jahan Sumi, PhD Student; Celso Ferreira, Associate Professor, Department of Civil, Environmental and Infrastructure Engineering, George Mason University. Email: ssumi@masonlive.gmu.edu

Abstract
Flooding is one of the costliest natural disasters in the United States causing severe damage to the economy and human lives. Frequent floods with unprecedented magnitudes have demonstrated the importance of understanding the compound flood characteristics in the river-estuarine transition zones. Like many other coastal areas, The National Capital Region is subject to compound flooding from urban runoff, riverine flows and surge-driven coastal inundation along the tidal Potomac River. Compound flooding, therefore, encompasses the complex interactions between the hydrological and coastal processes and the uncertainties in meteorological drivers. This study investigates the compound urban flood characteristics by analyzing the historical flood patterns in the Washington DC metropolitan region. The historical floods are classified based on the components of flooding: coastal, riverine or compound and the contributions from each of these components are estimated for different events. The upstream river flow peaks at Little Falls, DC and downstream water level peaks near the Chesapeake Bay at Lewisetta, VA provide insights on the duration and magnitude of compound flood events in DC. This study would help to identify the compound urban flooding locations and provide an understanding of the complex interactions of storm surge, riverine flooding and runoff from high precipitation.

Water resources of Mongolia. Myagmarsuren Bat-Erdene (Doctoral Student), S. Erdenesukh, Department of Geography School of Arts and Sciences, National university of Mongolia; D. Oyunbaatar, Hydrology Section, Information and Research Institute of Meteorology, and Hydrology and Environment, Ulaanbaatar, Mongolia. Email: miga_b2006@yahoo.com

Abstract
Total water resources of Mongolia are approximately 34.6 km^3. Groundwater storage estimated by hydrograph separation method is 12.6 km^3. About 83.7% of total water resources accumulates in lakes, 10.5% in glaciers and 5.8% in river system. 85% of surface water is fresh and 75% is Khovsogol Lake. Water available per capita is 13 740 m^3/capita/year and by this indicator Mongolia ranks 56th place amongst 182 countries. At present, over 80% of the water usage is supplied by groundwater and less than 20% is provided by surface water. According to a study conducted in 2018, Mongolia uses approximately 500 million m^3 water annually and based upon population growth, it is predicted to grow even more. Annual water usage by sector: drinking and consumption 80million m^3 (14%); industrial services 63 million m^3 (11.1%); agricultural 305 million m3 (53.5%), energy 32 million m^3 (5.6%); mining 90 million m^3 (17%). The Gobi Desert region uses groundwater. The future projection for the desert area water use is 3567 L/s. The desert area includes Tavan Tolgoi (Five Hills) Coal Mining Company (65 L/s); Oyu Tolgoi Mining Company (918 L/s); Dalanzadgad (47 L/s); and other organizations will use 2425 L/s. Obviously both supply and demand management need to be implemented. In light of the above Mongolia must not only develop water resources but also improve water efficiency and implement water reuse.

Spatiotemporal-based assessment of drinking water quality problems using NYC311 Data. Miah Cohall, Undergraduate Researcher; Juneseok Lee, Associate Professor, Department of Civil and Environmental Engineering, Manhattan College, Riverdale, NY. Email: mcohall01@manhattan.edu, juneseok.lee@manhattan.edu

Abstract
Residents in New York City (NYC) have utilized the NYC 311 online reporting system, an innovative approach to increase communication between local government agencies and the public, which aims to further understand public concerns that are negatively affecting their community. Over two million requests are received by the NYC311 system annually, which are publicly available on the NYC Open Data server. It's noted that there are voluminous and various types of drinking water quality complaints reported in NYC311datasets including, but not limited to, 'Chemical', 'Bitter', 'Musty', 'Chlorine', or 'Unknown.'The goal of this study, therefore, was to utilize NYC 311's drinking water complaints data to assess spatiotemporal patterns and identify hotspots using ARC-GIS. Each water quality complaints yielded information regarding specific location, complaint type, and reported date. These data were imported into ARC-GIS and various hot spots/ cold spots were identified such as consecutive hot spots, emerging hot spots, and new hot spots. This study will provide an in-depth research opportunity regarding the forecasting of location and frequency of drinking water quality complaints throughout NYC, which will eventually help aid in establishing the strategy of sustainable drinking water infrastructure management and operations in large urban cities like NYC.

Classical and deep learning based time series forecasting of drinking water quality complaints in New York City. Jarai Sanneh, Graduate Researcher; Juneseok Lee, Associate Professor, Department of Civil and Environmental Engineering, Manhattan College, Riverdale, NY. Email: jsanneh01@manhattan.edu, juneseok.lee@manhattan.edu

Abstract
New York City (NYC) have utilized the NYC 311 online reporting system for effective communication of public and government agencies. NYC residents can easily report their concerns, which can negatively affect the life quality of the communities. In this presentation, we are specifically drawing attention to drinking water quality complaints reported in NYC 311. Our preliminary assessment showed that there's an increasing trend of the NYC311's water quality complaints. The objectives of this research are to: i)
develop classical time series models and deep learning-based time series models to forecast water quality complaints data in water quality complaints hotspots and ii) compare the performance of both models, and develop solutions to improve the performance of deep learning-based time series. An autoregressive integrated moving average model have been used to find the best fit of a time-series model to historical values (for the classical time series analysis) while a long short-term memory network was used for the
deep learning-based time series analysis. Time series forecasts of water quality complaints will be crucial in improving water quality management in NYC, thereby leading to higher level of service, public wellbeing, as well as safer drinking water infrastructure operations/ management practices.

Assessing water quality contamination in Washington, DC: Determination of trace metals in Anacostia Tributary sediment by ICP-MS. Maryam Saur, Candidate of Professional Science Master's in Water Resources Management; Sania Rose, Project Assistant, Water Resources Research Institute; Sebhat Tefera, Project Specialist, Water Resources Research Institute; Tolessa Deksissa, Director, Professional Science Master's Program, College of Agriculture, Urban Sustainability and Environmental Sciences, University of the District of Columbia.
Email: maryamsabur@gmail.com , tdeksissa@udc.edu

Abstract
The Anacostia River and its tributaries are impaired and do not meet designated water quality standards. Stormwater runoff and sewer outfalls are major sources of Anacostia tributary contamination. Water quality contaminants include trace metals such as Arsenic, Lead, Zinc and Copper. Trace metals are of concern due to the potential for biomagnification and toxic bioaccumulation in human and aquatic life. The objective of this study was to assess the level of trace metal contamination in three Anacostia River tributaries. Composite samples of 5 cm depth sediment was collected from the Lower Beaverdam Creek and Watts Branch tributaries; 0-3, 3-6, and 6-9 cm depth sediment core samples was collected from the Hickey Run tributary. The sediment samples were digested with nitric acid and analyzed using inductively coupled plasma mass spectrometry (ICP-MS). (ICP-MS) is the most powerful analytical tool among atomic spectrometry techniques due to its high sensitivity, low detection limits and multi-element detection capability. In ICP-MS analysis a sample is atomized in a high temperature argon gas plasma. The ions are extracted through a quadrupole mass spectrometer according to their mass-charge ratio (m/z), and the concentration of ions are measured at the detector. The results of this analysis will be presented at the conference.

Monitoring polycyclic aromatic hydrocarbons in the downstream tributaries of the Anacostia River in Washington D.C.
Sania Rose, Project Assistant; Maryam Sabur, Research Assistant; Tolessa Deksissa, Director, Professional Science Master's Program, College of Agriculture, Urban Sustainability and Environmental Sciences, University of the District of Columbia. Email: sania.rose@udc.edu, tdeksissa@udc.edu

Abstract
Recent researches showed various way of onsite remediation of contaminated river sediments, however managing continuous sources of contaminated sediments in an urban river watershed is challenging. Anacostia River is one of the rivers that is highly contaminated with Polycyclic Aromatic Hydrocarbons (PAHs), metals and polychlorinated biphenyls (PCBs) in the nation. The success of any onsite remediation action to manage elevated levels of PAHs in the Anacostia River sediment depends on the level of contamination of its tributaries. The objective of this research project is to monitor PAHs in the downstream tributaries of Anacostia River in DC, and to access the significance of PAH level in the sediment. PAHs occur naturally but are mainly caused by anthropogenic activities and they have become persistent in the environment. These organic compounds are potentially carcinogenic, and can bio accumulate through the food chains. The Environmental Protection Agency (EPA) has listed 16 PAH compounds on their priority list. This project will identify tributaries in DC with higher contribution of contaminated sediment (Watts Branch, Hickey Run, Lower Beaverdam). The sediment samples were collected from the downstream tributaries of the Anacostia River located in Washington, DC. Sediment samples were extracted using EPA method 3546 Microwave extraction and cleanup using EPA method 8270E using Solid Phase Extraction and DryVap Concentrator for sample concentration. The samples were analyzed for PAHs using Gas Chromatography and Mass Spectrometry. The findings of this research project will be presented.

Investigating extreme precipitation events and the error propagation from satellite-based input precipitation to output water quality indicators simulated by a hydrologic model. Jennifer Solakian, Doctoral Student, Viviana Maggioni, Associate Professor, Department of Civil, Environmental and Infrastructure Engineering, George Mason University; Adil Godrej, Research Associate Professor/ Co-Director, Occoquan Watershed Monitoring Laboratory, Department of Civil and Environmental Engineering, Virginia Tech.
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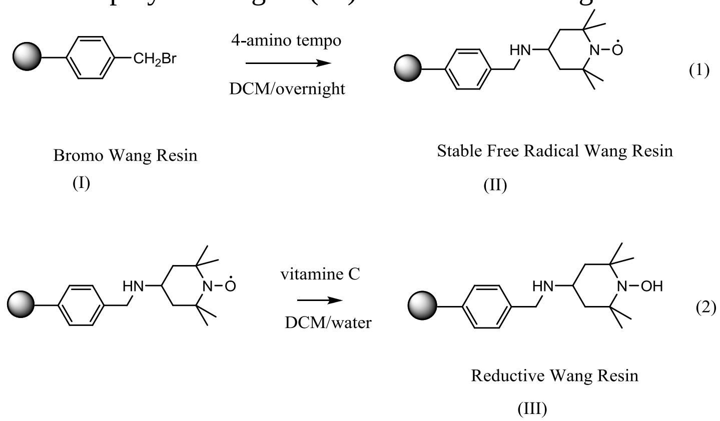
Abstract
This work investigates the potential of using satellite-based precipitation products (SPPs) in a hydrological model to estimate water quality indicators in the Occoquan Watershed, located in the suburban Washington D.C area. Three satellite-based precipitation products with different spatial resolutions and based on different retrieval algorithms (TMPA 3B42-V7, CMORPH, and the PERSIANN-CCS) are compared to gauge-based records over a five-year period across the study region. The 3 SPPs and the gauge-based dataset are used as input to a hydrology and water quality model then compared to the reference model simulation forced with the gauge-based observations, in terms of streamflow and water quality. The propagation of error from input precipitation to simulated output streamflow and water quality indicators for each of the 3 SPPs are evaluated through error metrices. Additionally, error associated with extreme precipitation events (floods and droughts) are investigated. Overall, results indicate that the spatio-temporal variability of the satellite-based products, along with the algorithms used by these products to estimate precipitation, have a quantifiable impact on not only streamflow, but also water quality output from the hydrology model.

Chlorine removal from drinking water by a polymer bonded novel reducing agent. X. Song, Associate Professor and Chairman of Division of Sciences and Math; W. Li, Visiting Associate Professor; Akil Mondie, Student Senior, Division of Science and Math, University of the District of Columbia. Email: william.li@udc.edu, xsong@udc.edu

Abstract

We successfully synthesized a polymer-bonded material, using the reaction between bromo-Wang Resin and 4-aminotempo. The 4-amino-tempo was reduced by vitamine C and/or alcohol/HCl.The polymer reagent (III) contains a reducing molecular structure.



Scheme I

Chlorine or bleach oxidizes iodide to give iodine that will produces dark color when contacting starch. This color reaction is used to check if our Resin III can remove chlorine in aqueous solution. The results in figure 1 clearly shows that Resin III can successfully remove chlorine in water. We are going to scale it up and to seek potential applications in other areas.

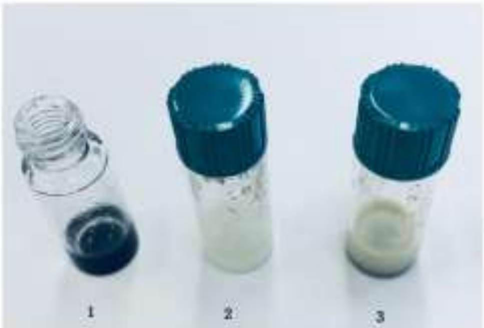


Figure 1. Vial 1: Control experiemnt;
Vial 2: Resin III successfully removed chlorine
Vial 3: Resin III partially removed chlorine