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SCHOOL OF ENVIRONMENTAL SCIENCE AND ENGINEERING

# Abstract Proceeding

## The 11th International Conference on Water Resource and Environment

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# Table of Content

## Session 1_ Water Resources and Hydrology

### Keynote Speech: Urban Flood Modeling and Evacuation Route Optimization

Qiuwen Chen*
*Department of Eco-environmental Research, Nanjing Hydraulic Research Institute, China*

**Abstract.** Not Available

### Keynote Speech: DOM Transformation Driven by Water Mixing in South-To-North Water Diversion Project

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**Abstract.** This study conducted long incubation experiments with water and sediment samples from the South-to-North Water Diversion Project's recipient basins to reveal DOM transformations and their driving mechanisms. Results showed that aromaticity and molecular weight of DOM in the overlying layer exhibited obvious divergent characteristics after 75 d of incubation. Nitrate and ammonia nitrogen were the key water quality factors driving these differences. Metagenomic analysis further demonstrated that the inorganic nitrogen concentration level in the inflowing water altered the succession of microbial communities and functional metabolism. Proteobacteria and Cyanobacteria responded sensitively to nitrogen level changes at the phylum level. Furthermore, nitrate reduction pathways influenced refractory carboxylic-rich alicyclic molecules (CRAM) metabolism through the action of key functional genes. This study highlights the influence of inflowing water on the CRAM transformation process driven by sediments, thereby enhancing the understanding on DOM environmental fate in the recipient basins.

**Keywords:** Water Diversion Project, DOM, Nitrate, Metagenomic

### Invited Speech: Water is Life – Integrated and Holistic Response Imperative

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**Abstract.** From the advent of civilization, water plays a central and pivotal role in every aspect of development, human health, well-being and welfare. A major consequence of water use and misuse is effect on the weather, in particular climate. Changes have

increased forest fires, droughts, over flowing river and lakes, sea level rise, melting glaciers, Arctic, Antarctic ice, invasive species. The concept and practice of development have evolved from the major goal of primarily economic focused gains. Increasingly, the existential imperatives include ethics, ecological and human consequences. Development without Destruction, Ecodevelopment, Sustainable Development terminologies have evolved. Recently, the notion of Resiliency is considered a requirement beyond and above Sustainability. The presentation provides a brief overview of the existential threats and effects from the misuse of water and the potentials of increasing AI applications. Peer reviewed scientific literature and observed global empirical evidence continues to enrich knowledge base and importantly increase public awareness, in particular youth, business and industry. There is a growing refrain demanding actions and not procrastinations and continuing business as usual and silo practices. Do nothing is not an option. There is an urgent need for expeditious transition pathways towards reducing, minimizing and improving use of water. A Framework with the following components will be presented:

• Vision and Leadership. Above and Beyond Sustainability and including Systems and Systemic Resiliency.
• Governance that is responsive, accountable, transparent, just, humane.
• Change Behaviors and life styles.
• Whole of Institutions approach to include Public, Private, Administration, Community Based, international and indigenous organizations.
• Intra and Intergenerational Responsibilities that recognize and respect Present and Future Perspectives. Needs, Wants.
• Implementation mechanisms improving and increasing communication, and awareness, harnessing state of the art IT, traditional, electronic and social media.
• Incentives. Recognition, Rewards.
• Cooperation Increase and expand amongst disciplines, sectors at local, national, regional, international levels.
• Respect and Dignity. Young, elderly, vulnerable, infirm. Improving quality of life and standards of living.

**Current Situation, Pressure and Mitigation Paths of Agricultural Water and Land Resources Utilization in Jiangxi, Eastern China**

Shuai Fu
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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

## Is the Climate Change Reflected by the Breakpoints of the Meteorological Time Series?

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**Abstract.** Precipitation is a key component of the Earth's hydrological cycle, regulating water availability, supporting ecosystems, and sustaining human societies. However, in recent decades, the distribution, frequency, and intensity of precipitation events have been markedly influenced by climate change. As the global climate warms—largely due to increased concentrations of greenhouse gases—atmospheric dynamics and moisture content are changing in ways that disrupt long-established precipitation regimes. In this context, this article examines the changes in the monthly precipitation series, comparing the monthly precipitation series spanning 1965 - 2005 with those between 1965 and 2019, using records from a meteorological station in the Nature Reserve Danube Delta in Romania to answer the question if the precipitation evolution follows the same pattern from 2005 as that in the period 1965 – 2005.

**Keywords:** Precipitation, Changepoint, Trend

## Long-Term Hydrological Drought Modeling of Lake Nuntași-Tuzla

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**Abstract.** According to Romania's national implementation report of the UN Convention to Combat Desertification (UNCCD), prepared by the Ministry of Waters, Forests, and Environmental Protection in 2000, the most drought-affected areas are in southeastern Romania, including Dobrogea, the eastern Romanian Plain, southern Oltenia, and the central Moldavian Plateau. Several lakes in the region mentioned before have recently dried up. In October 2020, Lake Iezer in Călărași County, covering about 400 hectares, dried completely. Similarly, Lake Nuntași-Tuzla in Dobrogea dried up in August 2020. Understanding the parameters' describing drought is crucial for water resource management. These parameters fall into two categories: indicators and indices. Drought indicators include variables such as precipitation, temperature, river flow, groundwater and lake levels, soil moisture, etc. Drought indices, on the other hand, provide numerical representations of drought severity, using climatic or hydrometeorological data to assess drought location, severity, and duration. In this context, a study was conducted on drought hydrological indices in the Nuntași-Tuzla Lake, Dobrogea, Romania, using different models. The data were sourced from the National Meteorological Agency (ANM) and the National Institute of Hydrology and

Water Management (INHGA). The results show: (i) until the year 2000, there were no periods of hydrological drought due to supplementation of river flows either by increasing the base flow, as a result of water infiltration from irrigation and the rise of the groundwater level, or even by discharging water from irrigation systems at the end of the irrigation season, (ii) it took 10 years from the reduction in the operation of irrigation systems, and 4 years from their complete shutdown, for the groundwater body (BH) to start reacting and for hydrological droughts to appear, culminated in the complete drying up of Lake Nutași-Tuzla in August 2020.

**Keywords:** Hydrological Drought, Drought Indices, Modeling

**Evaluation of Both a Conventional and Venturi Incorporated Air Systems for A Rainfall Simulator**

Eli Beltran, Jamil Arone, Ada Arancibia*, Miguel Zubiaur and Julio M. Kuroiwa
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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

## Session 2_ Aquatic Ecosystems and Restoration

**Keynote Speech: Erhai Lake Overview and Preliminary Analysis of Organic Matter**

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**Abstract.** Erhai Lake, the second-largest freshwater lake on the Yunnan–Guizhou Plateau, covers an area of 252 km² with an average depth of 10.5 m, and its watershed is approximately ten times the size of the lake itself. In recent years, comprehensive management efforts have yielded remarkable improvements: the total nitrogen (TN) and total phosphorus (TP) loads from inflowing rivers have decreased by about 35% within six years, leading to a notable enhancement in overall water quality. However, the chemical oxygen demand (COD) and permanganate index have remained persistently high, emerging as critical factors preventing the lake from meeting water quality standards. Our study revealed pronounced shifts in the algal community

structure of Erhai Lake, with dominant taxa alternating among Cyanophyta, Bacillariophyta, Chlorophyta, and Pyrrophyta. Cluster analysis indicated a strong correlation between algal dominance, biomass, and COD concentration. Fluorescence spectroscopy and nuclear magnetic resonance analyses further demonstrated that extracellular polymeric substances (EPS) produced during algal growth and metabolism directly contribute to elevated COD levels. Notably, approximately two-thirds of the EPS produced by *pseudoanabaena* sp. are resistant to rapid biodegradation. Future research should therefore focus on algal community succession and organic matter transformation processes to support the sustained improvement of Erhai Lake's water quality and ecosystem stability.

**Keywords:** Erhai Lake, Overview, Pollution Control, Algal Organic Matter, Chemical Oxygen Demand (COD)

## Keynote Speech: EcoImprove: Revealing Aquatic Ecological Effects of Micropollutant Discharge from Municipal Wastewater Treatment Plants

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**Abstract.** Micropollutants (MPs) discharged from municipal wastewater treatment plants are of great environmental concern due to their toxicities to aquatic organisms. Given the knowledge gaps on how MPs affect receiving aquatic ecosystems, we initiated the EcoImprove project to unravel the causal relationship between MP discharge and variation in biocommunity (especially microbial community) composition and function in receiving aquatic ecosystems. After integrating laboratory studies, field investigations, and flume simulation experiments from 2014 to 2021, we investigated how different MPs affect the growth and metabolic function of microbial species, developed several microbial indicators to evaluate the effects of MP discharge on receiving rivers, and evaluated the ecological benefits of municipal wastewater treatment plant upgrade on receiving aquatic ecosystems. Here, we summarize the main outcomes of the EcoImprove project and propose future research plans to deepen our understanding of the ecological impacts of anthropogenic activity.

**Keywords:** Micropollutants, Aquatic Ecological Effects, Microbial Community, Ecoimprove Project

## Detection of Microplastics in Milkfish Harvested from Freshwater Farms in Laguna de Bay, Philippines: A Plausible Study and Its Solution

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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

## Internal Wave-Driven Variability of Dissolved Oxygen in a Large Dimictic Lake

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**Abstract.** Large internal waves are a ubiquitous feature in many thermally stratified lakes, and they can generate considerable wash-zones along the shallow slopes of lake basins. These internal seiches, dominated by Poincaré and kelvin waves with periods of 17hrs and 3-4 days respectively, can lead to substantial spatial variation in dissolved oxygen (DO) levels, yet we do not know how they affect the spatial distribution of DO. While the vertical distribution of DO has been well characterized through high-frequency measurements at fixed monitoring site, much less is known about the spatial patterns of DO across the lake, where observations are typically limited to monthly sampling at a few locations during summer. To address this gap, we initiated a new year-round monitoring program that includes DO measurements at 20 additional sites across Lake Simcoe, a large dimictic lake in Ontario, Canada. These measurements complement the existing high-frequency data collected at Kempenfelt Bay, resulting in a comprehensive dataset from 21 locations across the lake. Using this dataset, we assess both spatial and temporal variability in benthic DO concentrations. Our analysis will focus on two ecologically important DO thresholds: 3 mg/L, considered the incipient lethal limit for juvenile lake trout, and 7 mg/L, which is required to support a self-sustaining lake trout population. We will investigate how the depths of these oxyclines vary seasonally and how they are influenced by internal seiche activity. In addition, we calculate weekly variance in the depth of the 3 mg/L and 7 mg/L oxyclines, as well as in thermocline depth, to estimate the extent of the thermocline wash-zone—the vertical region where internal waves displace the thermocline along the lakebed. These findings will help improve our understanding of the dynamic oxygen environment experienced by cold-water fish species in large temperate lakes.

# From Erosion to Conservation: The Essential Role of Forests in Soil and Water Management

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**Abstract.** Forests are pivotal in conserving soil and water resources through their regulation of hydrological processes and erosion dynamics. As essential natural ecosystems, they enhance soil stability, promote water infiltration, and modulate runoff and sediment transport. This study is structured into two main sections: (1) the problem of soil erosion and the role of forests, and (2) the principles of vegetation-based soil erosion control. A comprehensive understanding of the interactions among forests, soil, and water is critical for effective soil erosion mitigation and environmental conservation. Soil erosion occurs naturally across all climates and continents, but unsustainable human activities have dramatically intensified its rate by up to 1000 times in some regions. Current estimates indicate that more than 75 billion tonnes of soil are lost annually worldwide, with the most severe rates occurring in areas undergoing rapid land use change or unsustainable management practices. This widespread degradation affects at least 3.2 billion people worldwide, posing a substantial threat to global food security and the achievement of the Sustainable Development Goals. Forests are unique and highly efficient regulators of the hydrological cycle, modifying key processes through their complex structure. Unlike non-forested ecosystems (e.g., grasslands or deserts), forests create a "hydrological buffer" that slows water movement, enhances storage, and filters water. Vegetation-based erosion control, often termed bioengineering or soil bioengineering, is not merely about planting trees; it is a sophisticated application of ecological principles to manage the forces of water and wind. Selecting the appropriate plant species is the cornerstone of any successful erosion control project. The ideal plant is not necessarily the fastest-growing or the most visually appealing, but the one whose traits align perfectly with the project's goals, site constraints, and long-term resilience. The principle of "right plant, right place" is the non-negotiable rule of ecological restoration and erosion control. This involves a thorough diagnosis of the site's abiotic and biotic conditions and selecting species whose physiological tolerances and ecological preferences align with them. In addition, emulating forest structural complexity is the highest form of vegetation-based erosion control, creating a system that is not only effective but also resilient, biodiverse, and self-sustaining.

**Keywords:** Soil Erosion, Erosion Control, Forest Hydrology, Forest Vegetation

# Habitat Connectivity Modeling for Urban Conservation Planning: A Case Study of Pileated Woodpecker (Dryocopus pileatus) in Hamilton County, Ohio, USA

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**Abstract.** Urban forests provide vital wildlife habitats, but as urbanization intensifies and tree resources dwindle, these habitats are becoming more limited and fragmented. Given the meager resources available for wildlife habitat conservation, there is a pressing need for affordable, user-friendly tools and indicators to help in the prioritization and optimization of habitat conservation efforts and in aligning habitat accessibility with broader conservation objectives. The aim of our study is to provide an approach to assess the importance of including small habitat units (stepping stones) as an indicator of overall habitat availability and accessibility for a forest bird species, Dryocopus pileatus (Pileated Woodpecker, PIWO), in Hamilton County, Ohio, U.S.A. To improve ecological relevance in our approach, we integrated PIWO's presence location data with detailed resource-based variables, as well as land use and land cover data, to better account for the heterogeneity in habitat quality and species distribution within land classes. To garner broader support from local communities for wildlife habitat conservation, we considered the diverse benefits of conservation projects by integrating landscape graph analyses with land acquisition decisions. This approach helped us identify large habitat patches and small habitat units that meet the PIWO's habitat requirements and evaluate how individual habitat patches/units, both existing and new, contribute to overall habitat availability and connectivity. The small stepping stones we identified could form least-cost corridors that connect large habitat patches, thereby enhancing species' accessibility to forest resources and promoting its long-distance dispersal across the landscape. This suggests the importance of stepping stones and habitat connectivity in PIWO conservation. The loss of these stepping stones would significantly hinder conservation efforts and be difficult to offset. We found that by incorporating local planning objectives in this analysis, potential land acquisition sites that can enhance ecological services and improve habitat connectivity and accessibility can be easily identified. These results are instrumental in preservation and reforestation efforts.

**Keywords:** InVEST Habitat Module, Land Acquisition, Landscape Graphs, Pileated Woodpecker (Dryocopus Pileatus), Stepping Stones, Urban Forest

**Copper Determination from Calancan Bay Seawater: A Method Optimization and Ruggedness Analysis**

Kathlia D. Cruz
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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

## Session 3 _ Water Circulation through Nature-based Solutions

**Keynote Speech: Impact of Emerging Pollutants on Aquatic Ecosystem Health and Management Strategies**

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**Abstract.** The intensification of land use in watersheds due to industrial development and urbanization has increased the environmental discharge of various emerging pollutants including pharmaceuticals and personal care products (PPCPs), endocrine disrupting compounds (EDCs), per- and polyfluoroalkyl substances (PFAS), and microplastics. These substances are not completely removed by conventional water treatment processes and continuously accumulate in the environment. Temperature rise and increased frequency of extreme rainfall due to climate change are altering the fate and ecotoxicity of these pollutants, threatening aquatic ecosystem health. Microplastics were detected at concentrations of 24 particles/L in stormwater runoff and 3.52 particles/L in wastewater. Korean freshwater fish studies revealed 4-48 particles per fish in intestines and 1-16 particles per fish in gills, indicating severe bioaccumulation levels. Korea's annual mean temperature has risen approximately 1.5°C since 1920, with increasing frequency of heavy rainfall intensifying runoff from non-point sources. Emerging pollutants cause endocrine disruption, immune system suppression, and reproductive impairment in fish. Microplastics induces gill inflammation, gastrointestinal blockage, and liver and kidney dysfunction, while transporting adsorbed toxic substances into organisms, resulting in complex toxicity. Nature-based Solutions (NbS) are crucial for addressing these issues. Secondary treatment of wastewater treatment plants through constructed wetlands, urban water circulation through Low Impact Development (LID) techniques, and floodplain restoration are effective approaches. The Taebaek City non-point source pollution reduction facility achieved removal efficiencies of 37.1% for total nitrogen and 62.8% for total phosphorus, while LID facilities demonstrated 93-98% microplastic reduction effectiveness. NbS also provide multiple benefits including carbon sequestration, flood control, and biodiversity enhancement. In conclusion, comprehensive approaches

encompassing pollution source management, NbS application, and climate change adaptation from a watershed integrated management perspective can protect aquatic ecosystem health from emerging pollutants and establish sustainable water environments.

## Invited Speech: Effect of Influent Conditions on Biomass Production and associated Microbial Communities in Duckweed Wastewater Treatment System

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**Abstract.** Bench-scale plug-flow type reactor with *Spirodela polyrhiza* and *Lemna aequinoctialis* duckweeds was applied to treat low-strength municipal wastewater. The experimental unit was operated at a constant hydraulic retention time of 4 days, during which duckweed was initially provided at 100% of the water surface area. During continuous operation, growing duckweed biomass was harvested twice a week to maintain the original coverage condition of duckweed on the water surface, and the amount of excess duckweed biomass was monitored. Municipal wastewaters containing different organic (COD) and nitrogen (TKN) concentrations, with their average values ranging from 45-118 mg/l and 17-70 mg/l, respectively, were examined on their effect on the treatment performance, duckweed biomass production, and associated microbial communities. The experimental results revealed the highest average biomass production of 6.5 g dry mass/m$^2$/day of *Spirodela polyrhiza* duckweed over 72 days of operation when influent wastewater with the highest COD concentrations was applied. At lower organic concentrations, lower average duckweed biomass production rates, ranging from 3-4 g/m$^2$/day for *Spirodela polyrhiza* and 0.2-1.5 g/m$^2$/day for *Lemna aequinoctialis* were observed. During the treatment of wastewaters, moderate average COD removal of 37-59% and TKN 22-47% were achieved. Microbial community analyses revealed predominance of Burkholderiales, Pirellulales, Verrucomicrobiales, and Rhizobiales bacterial consortium associated with *Spirodela polyrhiza* duckweed under high growth yield conditions, whereas Cyanobacteriales were found predominant on duckweeds cultivated under low COD conditions.

**Keywords:** Duckweed, Biomass Production, Microbial Communities, Influent Wastewater

**Acknowledgements:** This research work was carried out under the “Development of the Duckweed Holobiont Resource Values towards BCG Economy” project supported by Japan International Cooperation Agency (JICA) and Japan Science and Technology Agency (JST).

## Use of Rice in Floating Treatment Wetland for Water Purification and Crop Production

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**Abstract.** Coal mining has caused extensive land degradation and the formation of waterlogged zones, resulting in the loss of arable land and the deterioration of water quality. The subsidence areas frequently receive inflows from agricultural runoff and domestic sewage, leading to nitrogen and phosphorus accumulation. The restoration of such waters requires sustainable, low-energy, and nature-based treatment systems. Traditional floating treatment wetland (FTW) typically uses ornamental or emergent macrophytes to improve water quality but provide limited economic returns. Rice (Oryza sativa L.) naturally thrives in flooded or aquatic environments and exhibits strong nitrogen and phosphorus assimilation capacities. These physiological traits make it a promising candidate for dual-function as both a water purifier and a food producer. The present study designed two pilot-scale FTW systems: a floating rice wetland, and a traditional FTW as a control, to assess the potential of rice as FTW plant in water purification and crop production. Both systems were operated in batch mode, and the influent was simulated at two nutrient levels to represent the nutritional variation under dry and rainy days. The experiment was conducted outdoors in May throughout November in 2024. The results showed that the floating rice wetland demonstrated comparable removals of $BOD_5$, nitrogen, and phosphorus for 40%, 64%, and 45%, respectively; and markable suppression of algae by 30%. For crop production, it yielded a considerable output of rice for 9,150 kg/ha. The experimental operation indicates the potential of rice for use in FTW wetland pairing nutrient removal with crop production.

**Keywords:** Floating Treatment Wetland, Rice, Water Purification, Crop Production

**Acknowledgements:** This work was supported by the State Key Laboratory for Safe Mining of Deep Coal Resources and Environment Protection, China (No. HNKY-PG-JS-2023-228).

## A Geospatial Modelling Framework to Assess Nature-Based Solutions for Flood Mitigation

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**Abstract.** Nature-based solutions (NBS) are increasingly recognised as effective strategies for mitigating flood impacts. However, evaluating their effectiveness prior to implementation remains a key challenge, often obstructing their prioritisation in flood management planning. This study introduces a geospatial modelling framework to guide the pre-implementation evaluation of NBS for flood mitigation, aiming to enhance stakeholder confidence and support evidence-based decision-making. The framework consists of three stages: (1) initiation, (2) planning and execution, and (3) evaluation. These stages help identify the most suitable NBS based on their potential to reduce flood extent and peak water depth. Using the Selangor River catchment as a case study, the framework identified three viable NBS: afforestation, floodplain restoration, and wetlands. Among them, afforestation emerged as the most effective, achieving a 77% reduction in flood extent and a 95% decrease in maximum water depth. However, its large land requirement poses implementation challenges. Floodplain restoration and wetlands yielded minimal flood mitigation benefits, likely due to ineffective site selection. Despite the extensive area dedicated to wetland construction, the reduction in flood impacts was negligible, raising concerns about practicality in the catchment. The proposed framework provides a replicable and systematic approach for assessing the effectiveness of NBS before implementation, enabling more targeted and efficient flood management strategies. These insights can inform policy and planning efforts aimed at reducing flood risks, protecting infrastructure and protecting vulnerable communities.

**Keywords:** Nature-Based Solutions, Flood Mitigation, Modelling, Geospatial, Framework

## Nature-Based Solutions for River Restoration in Urban City – The Example of Haikou Yawei Brook

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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

## Effect of Land Use on Surface Runoff and Soil Loss

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**Abstract.** Surface runoff and soil loss were monitored in six land use types: secondary broadleaved mixed forest (BL), coniferous plantation (CF), extensively managed bamboo plantation (EB), intensively managed bamboo plantation (IB), economic forest (EF) and farmland (FL) in the east (Fuyang, Zhejiang Province), central (Pingjiang, Hunan Province) and west (Muchuan, Sichuan Province) of China. The results showed that (1) there were significant differences of surface runoff among the land use types. The surface runoff and runoff coefficient of FL ranked highest, followed by EB, then CF, IB and EF, with BL as the lowest. The surface runoff and runoff coefficient of FL was about 2-7 times of that of BL. (2) the effects were similar of land use type on the soil loss: the BL had the lowest soil loss, followed by CF, EB, IB and the highest in FL. (3) The characteristics of soil erosion for different land use types were significantly different along the gradient from east to west. The surface runoff coefficient and soil loss on the eastern China was significantly lower than that on the west, which may be attributed to the different natural conditions, social and economic development stage and the resources investment into soil and water conservation.

**Keywords:** Land Use, Surface Runoff, Soil Loss, Subtropical China

### Solar-Driven Ecological Water Cycling for Saline Soil Remediation

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**Abstract.** Solar-driven interfacial evaporation has emerged as a promising nature-based strategy for freshwater generation and soil desalination in resource-limited regions. This study presents an integrated ecological water-cycling system designed to remediate saline soils by coupling photothermal evaporation, freshwater condensation, salt rejection, and intelligent drip irrigation. The system enables efficient water/salt separation, stable long-term evaporation under high salinity, and sustainable freshwater recovery without external energy input. Through controlled soil-column experiments and outdoor field verification, the system demonstrates accelerated salt leaching, enhanced soil structure, and improved plant germination performance. The proposed solar-driven ecological cycling pathway offers a low-carbon, decentralized, and scalable solution for saline soil restoration and climate-resilient agriculture.

**Keywords:** Solar evaporation; saline soil remediation; ecological water cycling; photothermal materials; freshwater recovery; nature-based solutions

**Acknowledgements:** The authors acknowledge financial support from the National Natural Science Foundation

## Session 4 _ Drinking Water Safety

### Keynote Speech: From Probing to Application: Novel Analytical Methods for Ferrate (IV) Chemistry and Their Exploration in Environmental Detection

Xiaohong Guan*
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**Abstract.** Not Available.

### Keynote Speech: CuO Catalysis in Oxidative Water Treatment: The Good, the Bad, and the Ugly

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**Abstract.** Maintaining a residual disinfectant/oxidant, such as chlorine and chlorine dioxide, is a generally used strategy to control microbial contaminants and bacterial growth and to improve the hygienic drinking water quality in distribution systems. Secondarily oxidant, such as hypobromous acid (HOBr), can be formed during chlorination of bromide-containing waters. In copper pipe distribution systems, corrosion of pipes gives rise of cupric oxide (CuO). CuO generally enhanced the decay of these halogen-containing oxidants, leading to the loss of residual oxidants. Three pathways are involved: 1) catalytic disproportionation to yield an oxidized form of halogen (i.e., halate) and reduced form (halide or chlorite for chlorine dioxide), 2) oxygen formation, and 3) oxidation of a metal in a reduced form (e.g., cuprous oxide) to a higher oxidation state. The complexation of hypohalous acids (HOX, e.g., HOCl and HOBr) by the Lewis acid CuO increased their reactivities, leading to the formation of CuO-HOCl or CuO-HOBr complex and thereby enhancing the disproportionation, leading to the formation of bromate or chlorate. In the presence of dissolved organic matter (DOM), the CuO-HOX complex reactions with DOM moieties with slow reacting sites can prompt the formation of one- to two-carbon-atom disinfection byproducts (DBPs) during water chlorination. In addition, results showed that 0.1 g $L^{-1}$ CuO elevated the Chinese hamster ovary cell cytotoxicity of chlorinated waters by 20% and 120% at initial bromide concentrations of 15 and 415 μg $L^{-1}$, respectively. The preferential formation of brominated DBPs in the presence of CuO was ascribed to the higher formation rate constant of CuO-HOBr than CuO-HOCl complex and lower adsorption energies based on density functional theory calculation. Furthermore, the CuO-HOCl complex exhibits a higher reactivity towards hypoiodous acid, trichloroacetaldehyde, oxalic acid, and phenolic compounds than chlorine alone. These results demonstrate that CuO can enhance the oxidation capacity of chlorine for selected compounds. This work provides insights into the role of CuO into oxidative water treatment processes.

**Keywords:** Cupric Oxide, Oxidation, Chlorine, Bromine, Complexation, Disinfection Byproducts, Cytotoxicity

## Invited Speech: The Role of Extracellular Polymeric Substances on the Formation and Decay of Disinfection By-products: The Impact of Disinfection Methods and Divalent Ions

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**Abstract.** Disinfection by-products (DBPs), formed from biofilm extracellular polymeric substances (EPS) and organic matter during regular disinfection practices in drinking water distribution systems, poses a potential threat to drinking water safety. However, the diverse DBP formations induced by the intertwined organic matter and bacterial EPS remains elusive.

In this study, we investigate both disinfectant methods and divalent ions on DBP formation in simulated drinking water distribution system (DWDS). Biofilm analysis results revealed that at 0.5 mg/L of disinfectant residual, both $Cl_2$ and $NH_2Cl$ were not effective to remove biofilms. As the disinfectant residual increased, biofilms could be eradicated by $Cl_2$, while remaining biofilms were still present even under the highest allowable $NH_2Cl$ dose (4 mg/L). However, when $Cl_2$ residuals reached 2 mg/L, DBP concentrations in bulk water increased sharply, with trihalomethanes and haloacetic acids being the most prevalent DBP species. In addition, divalent ions in bulk water can significantly inhibit DBPs formation. Mechanistically, divalent ions promote the complexation of negative charged groups and thus inhibit carbonaceous DBP formation, while the hindering chlorine substitution of hydrogen atoms on α-carbon and amine groups reduces nitrogenous DBP formation. Conversely, $Ca^{2+}$ and $Mg^{2+}$ could facilitate biosorption processes that increased the yields of DBPs. Both EPS and adsorbed algal organic matter can provide halogenated reactive sites for DBP formation, exhibiting diverse aromatic substances and unsaturated (lignin and tannins) compounds. Overall, this study provides insights into optimizing disinfection protocols for water utilities by balancing the benefits of disinfection application for biofilm control with minimized toxic DBP formation in DWDS.

**Keywords:** Extracellular Polymeric Substances, Organic Matter, Disinfection By-Products, Divalent Ions, Drinking Water Distribution System

**Acknowledgements:** National Science Foundation of China (41867048, 42167050), National Science Foundation of USA (CBET1236433 and 1605185).

## Mitigating Biofouling in Seawater Reverse Osmosis Systems: A Case Study on the Application of KURIVERTER™ IK-110 with Tide-Responsive Dosing Strategies

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**Abstract.** The rapid global growth of seawater reverse osmosis (SWRO) plants has increased the need for improved and consistent system performance. A key challenge remains membrane biofouling—caused by bacterial adhesion and biofilm formation—which leads to reduced permeability, declining flux, increased energy consumption, and compromised water quality. To address this, Kurita trialed KURIVERTER™ IK-110, an NSF-certified online biofilm control agent, in a full-scale SWRO train at a Singapore desalination plant. SWRO performance before and after IK-110 application was evaluated as well as compared with a parallel control train. The trial revealed that neap tide conditions accelerate differential pressure (dP) increase, indicating elevated biofouling potential. Adenosine triphosphate (ATP) measurements confirmed greater biological activity during neap tides. Based on these findings, a tide-responsive IK-110 dosing strategy was developed:

- Non-neap tide: 20 mg/L intermittent dosing (0.5 h every 2.5 h)
- Neap tide: 10 mg/L continuous or 20 mg/L intermittent (0.5 h every 0.5 h)

IK-110 has proven effective in enhancing the operational stability of SWRO systems, achieving up to a 64% improvement in differential pressure (dP) suppression. This allows for more controlled and sustained SWRO performance. By adopting a tailored dosing strategy, continuous operation is maintained, and adverse effects associated with neap tides are significantly mitigated. Cost simulations reveal compelling economic advantages: a projected total treatment cost reduction of 18.6% was achieved. This includes substantial savings on membrane replacement and minimized water production opportunity losses, underscoring the financial benefit of implementing IK-110 in SWRO applications.

**Keywords:** Seawater Reverse Osmosis (SWRO), Biofouling, IK-110, Tide-respondice Dosing, Desalination, Biofilm Control

# A Hazard Characterization of $La_2O_3$ Nanoparticles: Inverted Dose-Response Neurotoxicity from Low-Dose Redox Dysregulation to High-Dose Excitotoxicity

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**Abstract.** The increasing environmental release of lanthanum oxide nanoparticles ($La_2O_3$ NPs), particularly from water treatment applications, necessitates a thorough assessment of their hazards. This study characterized the neurotoxic potential and dose-response relationship of $La_2O_3$ NPs (60, 150, 300 mg/kg, i.p.) in a female murine model. Results reveal a critical, dose-dependent hazard: low to moderate doses induced severe oxidative stress (ROS), evidenced by a 40-80-fold increase in malondialdehyde and glutathione depletion, linked to the release of redox-active $La^{3+}$ ions that catalyze Fenton-like reactions. ICP-MS analysis confirmed significant brain accumulation of ROS and concomitant trace metals (Fe, Mn, Cu, Ti), alongside calcium depletion. Behaviorally, this manifested as motor hyperactivity. In contrast, high doses precipitated a distinct pathological pattern characterized by severe calcium dyshomeostasis, suppression of *Creb-Bdnf-Tau* neurotrophic signaling, and widespread neuronal pyknosis, resulting in significant cognitive deficits. This biphasic mechanism—where low doses cause metal-ion-mediated redox dysregulation and high doses cause excitotoxic catastrophe—indicates a complex hazard profile. The findings provide essential mechanistic data for ecological risk assessment, highlighting that $La_2O_3$ NP exposure poses a significant neurotoxic hazard, with low-dose oxidative stress being a particularly critical endpoint for defining safe environmental concentrations.

**Keywords:** Lanthanum oxide, Nanoparticle, Neurotoxicity, Hazard Assessment, Oxidative Stress, Dose-Response, Calcium Dyshomeosis, ICP-MS.

**Acknowledgement:** The authors extend their appreciation to the Ongoing Research Funding program (ORF-2025-177) at King Saud University, Riyadh, Saudi Arabia.

## Innovative Electrode Design and Interface Modulation in Electrochemical Reduction-In Situ Precipitation for Cr(VI) Removal

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**Abstract.** The electrochemical reduction-in situ precipitation technique presents a sustainable and reagent-free strategy for removing highly toxic Cr(VI) from acidic wastewater. The efficacy of this single-step process, which relies on cathodic Cr(VI) reduction coupled with the Cr(III) precipitation induced by electrogenerated hydroxyl ions, is critically limited by cathodic passivation stemming from the buildup of insulating Cr(III) precipitates. This study overcomes this fundamental limitation through innovative electrode engineering designed to regulate the electrode/solution interface. Key strategies involve the utilization of amidoxime functionalization to accelerate Cr(VI) mass transfer and kinetics, and the introduction of a sponge-encapsulated cathode. This novel structure establishes a confined crystallization-inducing microenvironment that achieves the spatial separation of the precipitation zone from the electron-transferring cathode surface. This strategic separation successfully mitigates passivation and ensures the maintenance of high and stable electrochemical activity. The developed system offers a robust, energy-efficient, and effective methodology for integrated Cr(VI) remediation and efficient solid product management, providing a novel technological paradigm for the treatment and management of various heavy metal wastewaters.

**Keywords:** Electrochemical Reduction, Cr(VI) Removal, In Situ Precipitation, Cathodic Passivation Mitigation, Interface Modulation

**Acknowledgement:** The authors acknowledge financial support from the National Natural Science Foundation.

## Research on Early Warning and Emergency Response for The Langshan Drinking Water Source in The Yangtze River

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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

## Session 5 _ Drinking Water Safety

### Keynote Speech: Emerging Trends in Advanced Nitrogen Removal from Municipal Wastewater and Microbial Mechanisms

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**Abstract.** Eutrophication driven by the excessive discharge of nitrogen and phosphorus is a global water pollution issue, making wastewater nutrient removal imperative. Conventional nitrification/denitrification is the dominant technology; however, as effluent standards worldwide become increasingly stringent, the limitations of traditional nitrogen removal processes—including inadequate efficiency, high energy consumption, and associated secondary pollution—have become increasingly apparent. There is a pressing need for more economical, efficient, and sustainable treatment technologies. Novel processes based on the synergistic coupling of partial denitrification (PD) with anaerobic ammonium oxidation (anammox) have opened new pathways for low-carbon, efficient nitrogen removal from municipal wastewater, emerging as a key research frontier. When treating municipal wastewater alongside nitrate-containing streams, this approach can save 100% of aeration energy and 80% of organic carbon demand compared to conventional nitrification/denitrification, while significantly reducing excess sludge production and greenhouse gas ($CO_2$, $N_2O$) emissions. This demonstrates considerable research significance and practical application potential. Recent years have seen advances in understanding the metabolic patterns and interactions between heterotrophic and autotrophic bacteria within PD/anammox systems. The synergistic regulation between denitrifiers and anammox bacteria enhances system performance, and the metabolic versatility of diverse anammox communities is crucial for stable and efficient operation. These theoretical and practical insights lay a solid foundation for innovating and optimizing future biological wastewater treatment processes.

### Keynote Speech: Membrane Distillation: Membrane Materials, Module Design and Applications in High-Salinity Wastewater Treatment

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**Abstract.** As a promising thermally driven separation process, membrane distillation (MD) is capable of treating challenging wastewaters. However, membrane fouling, and low thermal utilization efficiency of membrane modules limited the application of MD technology in large-scale wastewater treatment. To tackle these key challenges, a novel anti-wetting and anti-fouling multifunctional Janus membrane was developed at lab scale and successfully scaled up for industrial mass production via a two-step electrospray strategy. The resultant composite structure presented high omniphobicity (water contact angle of omniphobic sub-surface was 159.3±1.1°) and underwater superoleophobicity (underwater oil contact angle of hydrophilic top surface was 152.7±0.5°). During continuous MD treatment for emulsified oily hypersaline solution, the Janus membrane exhibited stable permeate flux (10 $L/m^2h$) and salt rejection (around 100%). To optimize the system performance, a vacuum-air gap membrane distillation (V-AGMD) module was designed and evaluated through computational fluid dynamics (CFD) simulation. The membrane module with finned air-gap cooling plate increased the flux by 16.5% compared to the module with flat air-gap cooling plate under extreme experimental conditions. Additionally, the gain-output ratio (GOR) and temperature polarization coefficient (TPC) were improved by 12% and 8%, respectively. CFD results show that fins achieve condensation efficiency enhancement by increasing the heat transfer area, breaking the boundary layer, and promoting turbulence. Based on these insights, the fabricated membrane and module were used to treat the concentrated landfill leachate, with particular focus on effects of different pretreatment methods on MD process. It was found that coagulation pretreatment could significantly reduce membrane fouling through removal of hydrophobic humic acids and aromatic organics. The hybrid Coagulation-Membrane Distillation process can reduce the discharge of concentrated landfill leachate by 80%, while ensuring that the produced water met the emission standards.

**Keywords:** Membrane Distillation, High-salinity Wastewater, Membrane Fouling, Membrane Module, Thermal Efficiency, Landfill Leachate

**Acknowledgements:** This research was financially supported by the National Key R&D Program of China (grant No. 2023YFC3207002 & 2023YFC3208002) and the National Natural Science Foundation of China (grant No. 51978650).

## Invited Speech: Perm-Selective Membranes and Engineered Electrocatalysts for Nitrate Reduction in Wastewater Treatment

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**Abstract.** In this presentation, a series of asymmetric polyethersulfone (PES) membranes are introduced for the wastewater treatment applications. Firstly, the effects of different additives during membrane preparation on the morphologies and physical

properties of fabricated membranes are discussed. It is found that the asymmetric membranes with three-dimensional pore networks in PES matrix without the presence of macrovoids can be achieved under optimal loading of water or polyvinylpyrrolidone (PVP) additives using non-solvent induced phase separation (NIPS) process. The resulted PES membranes exhibit a remarkable water permeation flux and a BSA rejection, which are suitable for ultrafiltration. Secondly, the synthesized PES membranes can be utilized as ion-selective membranes to concentrate the nitrate ions in water. Our results demonstrated that the high selectivity of nitrate ions over fluoride ions and sulfate ions can be obtained at low applied potential less than 3 V. The collected nitrate ions in water are further converted to ammonia through electrochemical reduction process, offering a promising avenue to address the environmental impacts associated with nitrate-containing wastewater and reduce the energy intensity as well as the carbon footprint linked to the traditional Haber-Bosch method for producing ammonia.

**Keywords:** Polyethersulfone, Ion-Selective Membrane, Nitrate, Polyvinylpyrrolidone

## Invited Speech: Z-Scheme g-$C_3N_4$/$TiO_2$ Nanotube Array Heterojunction for Enhanced Photoelectrochemical Degradation of Trichloroethylene

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**Abstract.** Z-scheme materials have drawn considerable interest for photocatalytic applications. In this study, titanium dioxide nanotube arrays (TNAs) were modified with graphitic carbon nitride (g-$C_3N_4$) to form a Z-scheme heterostructure to enhance the photocatalytic degradation of trichloroethylene (TCE). The g-$C_3N_4$/TNAs were synthesized via hydrothermal methods, and their properties were characterized by SEM, XRD, UV-vis spectroscopy, photocurrent measurements, electrochemical impedance spectroscopy (EIS), X-ray photoelectron spectroscopy (XPS), and Mott-Schottky analysis. Results of XRD confirmed the formation of anatase $TiO_2$ and the incorporation of g-$C_3N_4$, with characteristic peaks at 27.5°. XPS analysis showed shifts in binding energies indicating electron transfer from g-$C_3N_4$ to $TiO_2$, confirming the Z-scheme configuration. Photocurrent densities of TNAs, g-$C_3N_4$/TNAs-5, and g-$C_3N_4$/TNAs-10 were 8.6 μA/cm², 10.6 μA/cm², and 11.7 μA/cm², respectively, under a photoelectrochemical (PEC) system with a 13W LED light source, demonstrating enhanced photoactivity post-modification. In PEC degradation experiments with 100 ppb TCE, g-$C_3N_4$/TNAs-5 achieved a 62% degradation rate in 240 minutes, compared to 51% for unmodified TNAs. Purely photocatalytic systems showed that standalone g-$C_3N_4$/TNAs exhibited superior degradation efficiency comparable to that of TNAs in the PEC system, indicating that g-$C_3N_4$ modification significantly increased photogenerated electron lifetime, thereby enhancing photoelectroactivity. XPS analysis revealed binding energy shifts in Ti 2p and O 1s spectra, suggesting electron donation from g-$C_3N_4$ to $TiO_2$, which stabilized Ti bonds and supported the Z-scheme mechanism. Mott-Schottky and UV-vis DRS measurements confirmed the Z-scheme electron transport pathway. Elemental analysis showed an increase in C and N in g-$C_3N_4$/TNAs, confirming successful heterojunction formation. In the degradation process, by-products such as cis- and trans-1,2-dichloroethylene emerged, indicating the presence of a novel degradation pathway. This study demonstrates that the hydrothermally synthesized g-$C_3N_4$/TNAs Z-scheme heterostructure significantly enhances photocatalytic performance, offering a promising method for the efficient degradation of chlorinated pollutants.

**Keywords:** Z-scheme, TNAs, Photoelectrochemical, Trichloroethylene

## RED Determination of UV Wastewater Disinfection Systems based on Conserved Genes in Indigenous Bacteria

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**Abstract.** Ultraviolet (UV) radiation has been widely applied for wastewater disinfection. Biodosimetry is commonly used to experimentally assess the efficacy of UV disinfection systems by measuring the inactivation of introduced challenge microorganisms under various operational conditions. However, biodosimetry is expensive, labor-intensive, and unable to directly evaluate disinfection efficacy under actual operating conditions. Thus, a cost- and labor-effective method capable of evaluating actual UV disinfection system performance is highly desirable.
In this study, a novel approach using conserved genes (CGs) from indigenous wastewater microorganisms as challenge agents was developed. By measuring UV-induced damage to a CG from samples collected directly from system effluents and comparing the data against the UV fluence-response of that CG, the reduction equivalent dose (RED) can be determined. This method offers direct evaluation of operational UV systems, while significantly reducing cost and labor requirements as it eliminates the need for adding challenge microorganisms and specialized testing facilities. To evaluate the feasibility of this method, a kinetic model considering both photoreversible and irreversible CG damage was established. In addition, the effects of microbial diversity, cellular structure, and DNA repair mechanisms on the fluence-response behavior were examined. At last, validation experiments were conducted in a pilot-scale flow-through UV reactor using real wastewater.

The results show that the developed kinetic model accurately described the fluence-response behavior of conserved genes, improving fitting accuracy by 10 folds compared to the traditional Chick-Watson model. CGs (507, 919, and 1506 bp 16S rRNA gene)

from different bacterial species, including *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*, exhibited comparable fluence-response behaviors, indicating minimal impact from microbial diversity. The fluence-response behaviors of intracellular CGs were slightly lower (<10%) than those of extracellular CGs, suggesting small UV photon absorption by cell structure. The light/dark repair of CGs were significant at lower UV fluences (≤10 mJ/cm$^2$), but this effect could be mitigated by immediate preservation via liquid nitrogen freezing after sampling. Validation experiments conducted at flow rates of 30 and 40 L/min demonstrated that the RED values obtained through the proposed method (34±1 and 25±4 mJ/cm$^2$) closely matched those determined via biodosimetry using MS2 as challenge microorganism (34±2 and 26±1 mJ/cm$^2$, respectively). Thus, this CG-based method provides an innovative, practical, and resource-efficient alternative for assessing UV disinfection efficacy in wastewater treatment applications.

## Turning Waste into Oxidant: Sludge-Based Ferrate (VI) for Green Desulfurization of Fuels

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**Abstract.** In light of the environmental concerns surrounding fossil fuel use, waste-to-energy pathways are gaining attention as sustainable alternatives. This study investigates a green oxidative desulfurization (ODS) strategy using ferrate (VI) synthesized from drinking water treatment sludge (DWTS) for the treatment of sulfur-laden pyrolysis oil derived from waste tires. Crude potassium ferrate ($K_2FeO_4$), prepared via a wet oxidation method, was applied as the oxidant in a mixing-assisted ODS (MAOD) process using dibenzothiophene (DBT) as a model compound. Optimization was conducted across key parameters: ferrate (VI) concentration, phase transfer agent (PTA) dosage, mixing speed, and temperature. The optimal conditions—537 ppm Fe(VI), 114 mg PTA per 50 mL model fuel, 8,157 rpm agitation, and 41.7 °C—achieved a 99.7% sulfur-to-sulfone conversion. Applying these parameters to real pyrolysis oil (initial sulfur content: 8,804 ppm) resulted in a 53.2% desulfurization efficiency. The treated oil met industrial heating fuel standards established by the Taiwan EPA and the DENR Philippines. These findings highlight the dual benefit of valorizing wastewater sludge into a powerful oxidant while effectively reducing sulfur in alternative fuels, advancing circular economy goals and cleaner industrial fuel production.

**Keywords:** Dibenzothiophene, Pyrolysis Oil, Oxidative Desulfurization, Sludge

# Optimization and Kinetic Insights into the Degradation of Ciprofloxacin Using NiZnSe-Modified Nickel Foam Electrode

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**Abstract.** The persistence of untreated antibiotics in wastewater poses a critical global health risk, exacerbating the spread of antimicrobial resistance. Ciprofloxacin (CIP), a widely used fluoroquinolone, exemplifies the challenge due to its resistance to conventional treatment methods. This study explores the electro-Fenton (EF) degradation of CIP using a NiZnSe mixed metal catalyst synthesized via electrodeposition and drop-cast onto nickel foam. The catalyst's high porosity and catalytic activity, which is confirmed by SEM, TEM, FTIR, and Raman spectroscopy, enable efficient hydroxyl radical generation in a three-electrode undivided cell. Process optimization was conducted using central composite design (CCD), varying $Fe^{2+}$ concentration (1–3 mM) and applied current (200–350 mA). UV-Vis spectrophotometry revealed a maximum CIP degradation of 59.50% under optimal conditions: 1 mM $Fe^{2+}$ and 350 mA current for a 50 ppm solution over 60 minutes. Kinetic modeling indicated pseudo-first-order behavior ($k_{app} = 1.46 \times 10^{-2}\ min^{-1}$), with degradation efficiency positively correlated with higher current and lower $Fe^{2+}$ concentration. These findings demonstrate the potential of NiZnSe-modified electrodes for cost-effective antibiotic remediation in wastewater systems, contributing to safer water and reduced environmental antibiotic load.

**Keywords:** Antibiotics, Degradation, Wastewater, Ciprofloxacin, Electrofenton, Nickel-Zinc Selenide

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## Insights into the Mechanism of Carbocatalysis for Peracetic Acid Activation: Kinetic Discernment and Active Site Identification

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**Abstract.** Peracetic acid-based advanced oxidation processes (PAA-AOPs) on metal-free catalysts have emerged as charming strategies for water contaminant elimination. However, the involved reactive species and their corresponding active sites are still ambiguous. Herein, using carbon nanotube (CNT) as a model carbocatalyst, we demonstrated that, under neutral conditions, the CNT−PAA* complex was the dominant reactive species to oxidize phenolic compounds via electron-transfer process (ETP), whereas the surface-bound hydroxyl radicals ($^{\bullet}OH_{surface}$) played a minor role, based on quenching and electrochemical tests as well as Raman spectroscopy. More importantly, the experimental and density functional theory (DFT) calculation results collaboratively proved that the active site for ETP was the $sp^2$-hybridized carbon on the CNT bulk, while that for radical generation was the edge-located hydroxyl group (C−OH), which lowered the energy barrier for cleaving the O−O bond in CNT−PAA* complex. We further discerned the real oxidation kinetic constants ($k_{oxid}$) of different pollutants from the apparent kinetic constants in CNT/PAA system. A significant negative linear correlation between $\ln k_{oxid}$ and half-wave potential of phenolic compounds was observed, implying that the pollutants with a lower one-electron oxidation potential (i.e., stronger electron-donating ability) are more easily oxidized. Overall, this study scrutinizes the hybrid radical and non-radical mechanism and the corresponding active sites of the CNT/PAA system, providing new insights into the application of PAA-AOPs and the development of ETP in the remediation of emerging organic pollutants.

**Keywords:** Nanocarbon, Peracetic Acid, Nonradical Oxidation, Catalytic Sites, Environmental Remediation

## Simultaneous Removal and Recovery of Lead and Zinc from Simulated Industrial Wastewater: A Kinetic and Characterization Study via the Fluidized Bed Homogeneous Granulation Process

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**Abstract.** This study focuses on the kinetics of the simultaneous removal of lead ($Pb^{2+}$) and zinc ($Zn^{2+}$) ions and the characterization of the recovered Pb/Zn granules produced through the Fluidized Bed Homogeneous Granulation (FBHG) process. Simulated lead-acid battery wastewater was treated under varying pH levels, reaction times, and initial metal ion concentrations to evaluate the rate and mechanism of metal removal. The FBHG process effectively integrates precipitation and granulation within a single reactor, promoting efficient recovery of heavy metals while reducing sludge formation. Kinetic analyses were conducted using pseudo-first-order and pseudo-second-order models to determine the governing mechanism of $Pb^{2+}$ and $Zn^{2+}$ removal. The results indicated that the simultaneous removal followed pseudo-second-order kinetics, suggesting chemisorption as the dominant mechanism. The recovered granules were characterized using Fourier Transform Infrared Spectroscopy (FTIR), X-Ray Diffraction (XRD), and Scanning Electron Microscopy (SEM). Characterization revealed carbonate-based crystalline compounds with compact, uniform morphologies, confirming successful granulation and metal recovery. Overall, the FBHG process demonstrated high efficiency in the simultaneous removal of Pb and Zn, producing stable, reusable granules suitable for potential secondary applications. This work underscores the potential of FBHG as a sustainable and cost-effective treatment alternative for heavy metal-laden industrial wastewater, contributing to circular economy practices in environmental engineering.

**Keywords:** Heavy Metal Removal, Kinetic Modelling, Fluidized Bed Homogeneous Granulation

## Selective Removal of Perchlorate from Water by Imidazole-Nitrogen Modified Activated Carbon: Statistical Optimization and DFT Insights

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**Abstract.** Perchlorate ($ClO_4^-$), a persistent and toxic contaminant, has been increasingly detected in groundwater at levels exceeding regulatory limits, yet suitable methods for its cost-effective removal from water are underdeveloped. Here, we developed a novel adsorbent by chemically grafting positively charged imidazole nitrogen (IDN) onto granular activated carbon (GAC), enabling highly selective $ClO_4^-$ removal from water. Using Response Surface Methodology, we systematically optimized the synthesis parameters governing $ClO_4^-$ adsorption capacity ($Q_e$), and established a quadratic model to identify the optimal adsorption performance. Statistical analysis revealed that: (1) the quadratic terms of reaction time ($t^2$) and mass ratio of IDN-to-GAC ($R^2$) exerted the most significant effect on $Q_e$; and (2) a maximum adsorption capacity of 300.05 mg/g was achieved under optimal conditions ($t$ = 45 min, $R$ = 1.2, $T$ = 70 °C). Rapid small scale column tests demonstrated that the optimized IDN-GAC achieved a 35-fold extension in bed life (to 15 μg/L breakthrough) over pristine GAC, when processing groundwater containing 100 μg/L $ClO_4^-$. This enhanced performance is attributed to the incorporation of imidazole-N, which significantly enhances the positive surface charge of GAC, thereby strengthening electrostatic attraction and imparting high selectivity for $ClO_4^-$ in the presence of competing anions. DFT calculations further confirm that IDN-GAC exhibits exceptional selectivity for $ClO_4^-$ over typical interfering ions such as $CO_3^{2-}$, $NO_3^-$, and $Cl^-$. This work highlights the efficacy of a statistics-guided optimization approach in significantly enhancing the $ClO_4^-$selectivity of IDN-GAC, offering a promising and efficient strategy for targeted $ClO_4^-$ removal from water.

**Keywords:** Perchlorate, Selective Adsorption, Imidazole Nitrogen, Surface Charge, DFT

## Investigation of Trends in Global Greenhouse Gas Emissions

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**Abstract.** Greenhouse gases (GHGs) are critical components of the Earth's climate system, as they trap infrared radiation and contribute to the greenhouse effect. Anthropogenic activities, however, have led to a substantial rise in atmospheric GHG concentrations leading to global climate change concerns. This research aims to analyze the temporal trends in greenhouse gas emissions among the world's top ten emitting countries. A trend analysis framework based on the non-parametric Mann-Kendall test was developed and applied to long-term emissions data. The results reveal strong statistically significant increasing trends in GHG emissions for China, India, Brazil, Indonesia, and Canada with p-values approaching zero. The United States and Japan display relatively moderate increasing trends, with p-values of 0.00189 and 0.00008, respectively, reflecting partial progress in emission control despite ongoing fossil fuel reliance. In contrast, Germany and the United Kingdom exhibit strong decreasing trends, suggesting the effectiveness of sustained climate policy measures. Russia, however, demonstrates no statistically significant trend, indicating variability in emissions without a clear direction. The findings of this research can support climate change mitigation strategies by highlighting regions requiring urgent policy interventions as

well as those demonstrating successful emissions reduction pathways.

**Keywords:** Green, House, Gases, Mann, Kendall, Trend, Global

## Novel High-Performance Dense Janus Membranes: Design and Mechanism in Membrane Distillation

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**Abstract.** The global shortage of freshwater and worsening water pollution are pressing issues. Membrane distillation (MD), due to its salt tolerance, efficient separation, and use of low-grade heat, is promising for (high-)saline wastewater treatment. However, MD membranes suffer from wetting, fouling, and scaling in practice, leading to performance decay and limiting industrial application. Recently, dense Janus membranes, with a sub-nanoporous hydrophilic top layer and hydrophobic base, have gained attention for their anti-wetting/fouling/scaling potential. Yet, high-performance Janus membranes remain scarce, facing challenges like unsynergistic anti-wetting/fouling/scaling, high mass transfer resistance, and unclear mechanisms. This study prepared novel dense Janus membranes via interfacial polymerization using tetrakis(hydroxymethyl)phosphonium chloride (THPC, a phosphorus monomer with abundant hydroxyls and tetrahedral structures) to enhance hydrophilicity and permeability. Compared to the base membrane, the optimized THPC/polyvinylidene fluoride (PVDF) Janus membrane (JM) showed up to 21.3% higher flux in saline feeds. It also exhibited multiple resistances, maintaining stable flux (decline <8%) and salt-water selectivity under high-concentration contaminants (0.4 mM SDS, 2 g $L^{-1}$ mineral oil, 20 mM supersaturated gypsum). Characterization and tests revealed enhanced mass transfer: first, increased intermediate water (IW: FW=1.69) promoted liquid water vaporization and diffusion; second, improved top-layer hydrophilicity and optimized sub-nanopores ensured rapid water replenishment. The hydrophilic, hydroxyl-rich top layer prevented contaminant penetration and inhibited oil/crystal adhesion via an interfacial hydration layer, achieving long-term MD stability. This work guides designing advanced dense Janus membranes for MD-based saline wastewater treatment.

**Keywords:** Dense Janus Membranes, Membrane Distillation, Water Flux, Scaling, Wetting

**Assessing Salinity Impacts and Modeling Rice Irrigation Demands under Climate Scenarios in Morocco's Gharb Irrigated Region**

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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

## Session 6 _ Keynote & Invited Talks Session

**Keynote Speech: Gas-driven Technology for Enhanced Groundwater Contamination Remediation**

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**Abstract.** Gas-driven groundwater remediation technology integrates the advantages of physical stripping, chemical oxidation, and biological enhancement, enabling the synergistic and efficient removal of multiple contaminants. However, conventional gas-driven remediation approaches suffer from several limitations: (i) gas flow is strongly constrained by the capillary resistance of aquifer media, leading to limited air channels, preferential flow bypassing low-permeability zones, a narrow influence radius, and thus low gas-liquid mass transfer efficiency; (ii) when dissolved oxygen is delivered via gas-driven technology, the inherently limited capacity of Fe(II) to activate oxygen results in low electron utilization efficiency and inadequate yields of reactive oxygen species (ROS), thus severely compromising the oxidative degradation performance; and (iii) functional microorganisms exhibit poor mobility and dispersion in heterogeneous aquifers, restricting the effective utilization of dissolved oxygen and reducing aerobic biodegradation efficiency. To address these challenges, this study developed a series of methods to enhance the physical, chemical, and biological remediation effect during the gas- driven process. For the physical stripping process, addition of surfactants enhanced gas penetration through the aquifer media, significantly improving gas-liquid mass transfer and achieving efficient volatilization-based contaminant removal. For the chemical oxidation process, the introduction of ligands enhanced the ability of Fe(II) to activate molecular oxygen, increased the production of ROS, and enabled the rapid chemical degradation of contaminants. For the biological enhancement process, colloidal gas aphrons were employed as a carrier to enhance the transport and distribution of degrading bacteria, thereby boosting the activity of aerobic microbes and increasing the efficiency of biodegradation. Finally, this study proposes an integrated “physical-chemical-biological” system for synergistic and enhanced remediation of contaminated groundwater based on the gas-driven technology. This study provides new theoretical insights and technical support for the efficient in situ treatment of complex groundwater pollution.

**Keywords:** Gas-Driven Technology, Molecular Oxygen Activation, Colloidal Gas Aphrons, Heterogeneous Aquifer, Enhanced Groundwater Remediation

## Keynote Speech: From Mercury Lamps to UV-LEDs: The Future of Point-of-Use Water Disinfection

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**Abstract.** Not available.

## Keynote Speech: Interfacial Electron Transfer in Soil Iron Cycling Driving Pollutant Transformation

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**Abstract.** Not available.

## Invited Speech: How Plant Leaves Absorb Dew by Isotope Tracing Technology?

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**Abstract.** Dew condensation is substantial and frequent, serving as an essential water source with significant ecological implications for plant growth. Numerous studies have shown that dew can supplement water to plant leaves; however, few studies have examined the absorption strength of plant leaves under varying amounts of dew. This study employed the isotope tracer experiment method to quantitatively investigate plant dew absorption under different dew quantities, examining the absorption ratios and influencing factors across various plant species. Results indicated that all four studied plant species can directly absorb dew through their leaf surfaces, with absorption rates ranging from 1.43±0.84% to 84.39±6.8%. Due to the unique shield-like depression structure on its leaf surface, Tillandsia exhibited a high dew absorption rate of 84.39±6.8%. In contrast, the shallow-rooted herb Oxalis triangularis 'Urpurea' had a low dew absorption rate of only 1.43±0.84% due to its leaf surface being covered with trichomes. Different plants also showed variations in dew absorption ratios under varying dew amounts. For instance, Tillandsia exhibited absorption rates of 92±3.71%, 89.60±2.43%, and 71.74±5.10% at dew quantities of 0.1, 0.2, and 0.3 mm, respectively, whereas Epipremnum aureum absorbed 3.72%, 6.15%, and 2.45% at the same dew levels. Dew provided essential moisture for plant growth, and varying leaf surface microstructures among different plants result in diverse dew absorption needs. This study offered a theoretical foundation for comprehensively understanding and utilizing dew resources.

**Keywords:** Dew, Foliar Water Absorption, Water Transport, Isotope Tracer Experiment, Leaf Microstructure

### Invited Speech: Sustainable Battery Recycling via Direct Regeneration of Cathode Materials

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**Abstract.** Lithium iron phosphate ($LiFePO_4$, LFP) is a widely adopted cathode material in lithium-ion batteries due to its intrinsic thermal stability, safety, and long cycle life. However, repeated charging and discharging cycles cause the lithium depletion (delithiation) and structure degradation, ultimately resulting in diminished battery performance and the accumulation of spent battery wastes. Conventional recycling methods, such as pyrometallurgy and hydrometallurgy, present significant limitations: pyrometallurgical processes are energy-intensive due to high-temperature smelting, while hydrometallurgical approaches rely on corrosive reagents and involve complex separation steps to recover high-purity precursors. Although effective in the short term, these methods are not conducive to achieving a closed-loop, environmentally sustainable battery economy. In this study, we explore a direct regeneration strategy for the recovery of spent $LiFePO_4$. This approach restores the electrochemical activity of the degraded material via relithiation and defect restoration, without disrupting its original crystal structure. Our findings show that approximately 80% of the original electrochemical performance can be restored through this method, highlighting its potential as a cost-effective and sustainable solution for lithium-ion battery recycling.

**Keywords:** Battery, Recycling, Energy

## Invited Speech: Sustainable Blue Economy Towards Finance-Led Tourism Growth Hypothesis in A R&D-Based Marine Growth Model

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**Abstract.** The blue economy, comprising fisheries, tourism, and seafood processing industries, is expected to drive economic development through natural resources and decarbonization through blue carbon. However, the complex interrelationships and conflicting interests between marine ecosystems and socio-economic activities hinder the realization of sustainable blue development. In this context, ESG finance for fisheries and tourism is expected to contribute to the dual goals of environmental conservation and economic development, but its mechanisms are not self-evident. This study uses an R&D-based growth model in the monetary economy to analyze the effects of financial policies targeting R&D, fisheries, and tourism on expenditure, growth, environment, money, and tourism. Rent-seeking behavior toward individual transferable quotas (ITQs) is considered. The lending rates for the fisheries and tourism sectors are lower than those for the R&D sector through risk premiums. In the non-blue economy, lowering interest rates for R&D firms leads to pollution reduction and economic growth, but this effect is undermined in the blue economy. Lowering interest rates for fishing firms through risk premiums creates a trade-off between economic growth and environmental quality. When interest rates for tourism firms are raised to an adequate level through risk premiums, this leads to economic growth, environmental improvement, and expansion of tourism and money supply, but also causes a decline in lending. Here, raising interest rates for R&D firms and increasing ITQs can limit the extent of interest rate hikes for tourism firms. This result implies the finance-led tourism growth hypothesis. This study suggests that a policy mix centered on financial policies targeting tourism is important when aiming for sustainable blue development.

**Keywords:** Economic Growth, Rent-Seeking, ESG Finance, Blue Economy, Finance-

Led Tourism Growth Hypothesis

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## Keynote Speech: Fluidized-Bed Homogeneous Crystallization and Related Approaches for Nutrient Recovery from Livestock Wastes

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**Abstract.** Phosphorus (P) is a finite, non-renewable resource, and excessive nitrogen (N) and P discharges from livestock wastewater contribute to eutrophication. This talk reviews emerging technologies for recovering N and P from livestock wastes, with a focus on fluidized-bed homogeneous crystallization (FBHC). Various crystallization approaches, including struvite ($MgNH_4PO_4 \cdot 6H_2O$) formation for simultaneous N and P recovery, and precipitation of tricalcium phosphate ($Ca_3(PO_4)_2$) and ferric phosphate ($FePO_4$) for phosphorus recycling, are discussed. The principles, operational parameters, and performance of these technologies are highlighted, including the use of swine slurry, magnesium sources, and industrial wastewater streams. Advantages of FBHC over conventional methods, such as high removal efficiency, low moisture content, and scalable production of crystalline products, are emphasized. The potential applications of recovered products as fertilizers and raw materials for bioactive materials are also addressed. This review provides insights into sustainable, circular strategies for livestock wastewater management, demonstrating how FBHC and related crystallization techniques can support nutrient recovery, environmental protection, and resource reuse.

**Keywords:** Swine Slurry, Nitrogen Recovery, Phosphorus Recovery, Fluidized-Bed Reactor

## Keynote Speech: The Oxidative Reaction Zone Built on Fe-Based Particles for Groundwater Remediation

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**Abstract.** In situ reactive zone has been recognized as an effective method to deep groundwater remediation. The traditional reactive zones depend on reduction or microbial degradation for contaminant removal with the aid of the emplaced materials such as zero valent iron nanoparticles. These traditional reactive zones, however, are not effective in removing diverse organic contaminants which are recalcitrant to reductive or microbial transformation. The oxidative reactive zone, which activates in situ the oxidants injected to degrade contaminants, offers an alternative to the traditional one since oxidation, typically advanced oxidation processes, has much less selectivity to contaminants. The Fe-based materials, such as Fe minerals, Fe-based complex metal oxides and Fe-doped carbon, has high potential in application for the oxidative reactive zone due to the potential of Fe-containing compounds to activate oxidants and the high availability of these materials. The successful application of the method asks for success in two aspects: one is the high efficiency and sustainability of the Fe-based materials for activation of oxidants such as persulfate and $H_2O_2$, and the other is the high transportability of the materials in micro or nano particle form in pores of the aquifer for deployment of the reactive zone. Also, the cost-effectiveness of contaminant removal should also be counted, especially when the concentration of the contaminants is low. that A series of studies have been conducted by the research team in recent years to address these needs and this presentation will report the results in a comprehensive way.

**Keywords:** Recalcitration Organic Contaminants, Oxidative Reactive Zone, Fe-Based Particles, Groundwater Remediation

**Acknowledgements:** The work was supported by Yongjiang Talent Introduction Programme of Ningbo (2023A-385-C), Natural Science Foundation of Ningbo (2024J012), and the National Key R&D Program of China (2024YFC3713002).

**Invited Speech: Electrochemical Degradation and Sensing of Aqueous Pollutants Using Copper-Based Electrodes**

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**Abstract.** In this study, copper-based electrodes were fabricated and successfully applied for the electrochemical sensing of the herbicide Diuron. The sensor exhibited a fast response, remarkable stability, and an exceptionally low detection limit, confirming the strong catalytic and analytical capability of the Cu material toward environmental monitoring. To further enhance pollutant remediation, bimetallic palladium–copper

(Pd/Cu) electrodes were prepared by varying the palladium deposition duration between one and three minutes. Comprehensive physicochemical characterization revealed that palladium nanoparticles were uniformly dispersed across the copper substrate, forming a stable Pd/Cu composite structure. X-ray diffraction, X-ray photoelectron spectroscopy, and transmission electron microscopy analyses confirmed the coexistence of metallic Pd and oxidized Cu phases, signifying successful alloy formation and favorable surface properties for catalysis. Electrochemical evaluation demonstrated that the Pd/Cu electrode markedly outperformed the pure copper electrode in nitrate reduction. A pronounced reduction peak indicated efficient nitrate conversion, with nearly complete removal and high selectivity toward nitrogen gas at constant current density. Collectively, the results reveal that copper-based and Pd/Cu electrodes offer a dual-function platform capable of rapid Diuron sensing and highly selective nitrate reduction, representing a promising and sustainable approach for advancing water purification technologies and safeguarding aquatic ecosystems.

### Invited Speech: Optimizing Direct Contact Membrane Distillation for Seawater Desalination: Porous PVDF Membrane Performance via Response Surface Methodology

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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

## Postgraduate Forum (1)

### Keynote Speech: Household Climate Action and Sustainability in China

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**Abstract.** Micro-level evidence on household climate action remains scarce in global sustainability research. From 2023 to 2025, our research team conducted three large-scale household surveys in China, creating a unique dataset that links energy behavior, climate perception, and sustainability outcomes. Initial surveys focused on household adoption of distributed solar photovoltaics, documenting pathways and barriers. The final survey employed a comprehensive Household-SDG framework assessing economic, educational, health, gender, and environmental dimensions. Findings indicate distributed solar offers meaningful decarbonization opportunities, yet financial,

institutional, and operational hurdles persist. The assessment also uncovers major disparities in climate literacy and low-carbon behaviors. We propose a scalable methodological framework for evaluating household climate action, offering empirical support for designing targeted, socially grounded interventions to aid low-carbon transitions.

**Keywords:** Household, Climate Action, Sustainability, Household Survey, Distributed Solar PV

## Enhancing Vegetation Monitoring through Deep Learning-Based Super-Resolution Fusion of Multi-Source Satellite Indices in the Korean Peninsula

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**Abstract.** Terrestrial vegetation monitoring is essential for water resources management, understanding watershed ecosystem processes, and climate change assessment. In the Korean Peninsula, characterized by complex topography and pronounced seasonality, vegetation distribution exhibits dynamic spatiotemporal patterns throughout the year. For comprehensive monitoring of these dynamic patterns, the acquisition of high-quality satellite-based vegetation indices remains indispensable. The GEO-KOMPSAT-2A/2B (GK-2A/2B) satellites provide daily vegetation indices at 2 km and 250 m resolutions, while Harmonized Landsat and Sentinel-2 (HLS) offers 30 m resolution with 3 to 7 days intervals. The Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation indices (MOD13Q1) has proven its reliability through widespread research applications, but its spatial resolution of 250 m and 16 days temporal resolution limit its capability in detecting rapid vegetation changes. In this study, we proposed a framework utilizing image-based deep learning algorithm, to generate high-resolution gridded vegetation indices by integrating from GK-2A/2B and HLS. The framework incorporated land cover and digital elevation models to account for topographical and geographical variations. The reliability of this framework was validated against MOD13Q1, which have been extensively verified through numerous

previous studies. This framework, comprising convolutional layers for multi-scale feature extraction, effectively learned and reconstructed high-resolution features from low-resolution inputs. Through its multilayer structure, the model successfully captured both local variations and broad-scale distribution patterns of vegetation indices. This innovative approach demonstrated the ability to generate spatiotemporally continuous, high-resolution vegetation indices, overcoming existing satellite imagery limitations. This framework expects to enhance ecosystem monitoring accuracy and support early warning systems for rapid environmental changes.

**Keywords:** Vegetation Indices, Image-Based Deep Learning Algorithm, GK-2A/2B, HLS, MODIS

**Acknowledgements:** This work was supported by Korea Environmental Industry & Technology Institute (KEITI) through Wetland Ecosystem Value Evaluation and Carbon Absorption Value Promotion Technology Development Project, funded by Korea Ministry of Environment (MOE) (2022003640001) and by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education(RS-2024-00465925) and by by the Korea Environmental Industry & Technology Institute (KEITI) through Water Management Program for Drought, funded by the Korea Ministry of Environment (MOE)(RS-2022-KE002032).

## Evaluating the Characteristics of Short-duration Rainfall Extremes on Urban and Rural Areas from Minutely Data in Korea

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**Abstract.** This study examines the statistical characterization of short-duration extreme rainfall in Republic of Korea using minutely rainfall data collected from 2000 to 2023. Frequency analyses are performed on annual maximum series for durations of 10, 20, 30, 60, 120, and 180 minutes at eight Automated Synoptic Observing System (ASOS) stations, comprising four urban and four rural areas. The primary objective is to identify appropriate probability distributions that effectively capture the extreme characteristics of minutely rainfall data and to determine suitable distributions based on whether the observation sites are located in urban or rural areas. Goodness-of-fit is assessed using multiple criteria, including the Akaike Information Criterion (AIC), Bayesian

Information Criterion (BIC), Probability Plot Correlation Coefficient (PPCC), and the Chi-square test. Results reveal significant differences in distribution parameters and design rainfall estimates across return periods between urban and rural areas. The findings highlight the importance of minutely rainfall data—which are seldom employed in conventional frequency analysis—for accurately capturing short-duration extremes that drive flash flood risk, particularly in urban environments. This study provides a methodological basis for improving urban drainage design and disaster preparedness in response to localized extreme events.

**Keywords:** Minutely Rainfall, Short-duration Extremes, Frequency Analysis, Probability Distribution, Design Rainfall

**Acknowledgements:** This work was supported by the Korea Environmental Industry & Technology Institute (KEITI) through Water Management Program for Drought and Wetland Ecosystem Value Evaluation and Carbon Absorption Value Promotion Technology Development Project, funded by the Korea Ministry of Environment (MOE) (RS-2022-KE002032 and 2022003640001) and was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (RS-2024-00334564).

## Quantification of Agricultural Drought Damage in South Korean Paddy Fields Using Remote Sensing and Machine Learning Framework

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**Abstract.** This study presents a remote sensing and machine learning framework to quantify drought-induced damage in South Korean paddy fields. Current drought statistics, published annually by joint ministries (2018–2022), rely primarily on field surveys conducted by local governments, raising concerns about their methodological consistency and transparency. To address this, we employed high-resolution Harmonized Landsat and Sentinel-2 (HLS) data (30 m) to extract vegetation indices indicative of water and vegetation stress. The study focused on Chungcheong-do, a region that experienced significant drought damage in 2018, 2019, and 2022. We used non-drought years (2020–2021) to derive time series profiles of five indices—NDVI, MSI, BSI, NDWI, and SAVI—for both paddy and bare land areas. These were used to

train a machine learning-based time series classification model, which was then applied to 2018 and 2019 data. Areas showing paddy land classification but bare land-like temporal behavior were identified as drought-affected. The results were validated against official statistics, demonstrating the potential of this method for timely, objective, and scalable agricultural drought damage assessment. This approach contributes to enhancing drought monitoring capabilities and informing water resource policy decisions.

**Keywords:** Agricultural Drought, Remote Sensing, Machine Learning, Time Series Classification, Paddy Fields, Vegetaion Indices, Harmonized Landsat Sentinel-2 (HLS)

**Acknowledgements:** This work was supported by the Korea Environmental Industry & Technology Institute (KEITI) through Water Management Program for Drought, funded by the Korea Ministry of Environment (MOE)(RS-2022-KE002032) and Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (RS-2024-00356439).

## Seasonal Dry-Wet Alternation Influences Nitrogen Speciation and Enhances Bioavailability in Sediments of Erhai Lake

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**Abstract.** Global warming has intensified the distinction between dry and wet seasons in monsoonal climates. The synergistic effect of high temperatures and rainfall during the wet season promotes the release of endogenous nitrogen (N) and eutrophication within lake ecosystems. However, the seasonal variations in sediments N speciation and bioavailability, and their intrinsic connection to release potential, remain unclear. This study employed sequential extraction method and Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (FT-ICR MS) to characterize extractable N (Ex-N) in Erhai Lake sediments during dry and wet seasons. The results indicated that ion-exchangeable organic form N (IEF-ON) serves as a substrate for microbial mineralization, with the highest proportion of protein-like substances (26.2%). The influx of N-containing polysaccharides and poly-N glycoproteins during the wet season further increased its bioavailability. Algal-derived N exists as the weak acid-extractable organic form N (WAEF-ON), which has the highest lipid proportion (11.7%) and the lowest double bond equivalent (DBE) values. Overall, elevated water temperatures and N input during the wet season accelerate both the mineralization rate of organic N (ON) and the content of labile N components. This potentially triggers a "priming effect" that could further activate the refractory N components in the sediments. Additionally, the wet season reduces sediment pH and redox potential, making WAEF-ON and strong

alkali-extractable form N (SAEF-N) more labile and susceptible to release. This study reveals the adverse effects of seasonal variations on N sequestration in lake sediments, complicating the control of endogenous pollution release under the backdrop of climate change.

**Keywords:** Lake Sediment, Seasonal Variation, Nitrogen Speciation, Extractable Organic Nitrogen, FT-ICR MS

## Non-Tariff Measures in Environmental Governance for International Trade: Insights on Fisheries Trade

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**Abstract.** International trade involves socio-economic and ecological interactions yet these dimensions are frequently analysed in isolation. Consequently, environmental impacts arising from trade—such as biodiversity loss, habitat degradation and water pollution—persist without adequate governance, driven by actors whose activities affect distant ecosystems. Framing global trade as a telecoupled socio-ecological system, this study proposes Non-Tariff Measures (NTMs) as instrument of environmental governance. Using a gravity model with high-dimensional fixed effects, we examine the impact of sustainable fisheries-related NTMs on fish trade between 2012 and 2023, taking into account exporters with differing levels of environmental performance in the fisheries sector. The results show that NTMs restrict trade in fish products associated with environmental damage while stimulating trade between nations that already exhibit stronger governance or are in the process of improving their fisheries environmental indicators. Furthermore, these measures help prevent the diversion of unsustainably sourced exports to unregulated markets, fostering more balanced environmental management of global fisheries trade. The evidence highlights the potential of NTMs capable of steering international trade towards a more environmentally sustainable pathway. The evidence underscores the strategic relevance of NTMs in steering global trade toward an environmentally sustainable trajectory, whereby commercial policies are aligned with integrate socio-economic and ecological interdependence between trade partners.

**Keywords:** International Trade, Non-Tariff Measures, Telecoupling, Environmental Governance, Fisheries

**Research on Key Technologies for Climate-resilient Sponge Cities Using Eco-bioengineering and Smart Regulation Strategies**

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**Abstract.** Not available.

**Hydrological Performance of Extensive Green Roofs under Extreme Rainfall and Antecedent Wet Conditions in High-Andean Cities**

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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

**Developing a Climate-Stratified Extreme Weather Exposure and Resilience Index for Nature-based Stormwater Infrastructure under Future Climate Scenarios**

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**Abstract.** Extreme weather events, including heavy rainfall, prolonged droughts, and heat waves, are expected to intensify under future climate scenarios, placing increasing stress on urban infrastructure. Green stormwater infrastructure (GSI), a nature-based stormwater technology like permeable pavements and green roofs, has been widely adopted to mitigate stormwater runoff and alleviate urban heat island (UHI) effects. However, their long-term vulnerability to intensifying climatic extremes remains insufficiently quantified. To address this gap, a comprehensive framework was developed to assess the exposure and resilience of GSI across Korea's eight major cities, particularly Seoul, Incheon, Daejeon, Daegu, Gwangju, Busan, Ulsan, and Jeju under SSP1-2.6 and SSP5-8.5 scenarios. Exposure indices were constructed using seven bias-corrected climate extreme indices (TXx, TNn, HWD, CWD, CDD, Rx1day, R20mm) derived from CMIP6 models and corrected using quantile mapping. Indicator weights were obtained using the Analytic Hierarchy Process (AHP), Principal Component Analysis (PCA), and entropy weighting to capture expert judgment, statistical variance, and data-driven variability. For permeable pavements, AHP results emphasized extreme precipitation (E5 = 0.220), maximum temperature (E1 = 0.217), and heat wave days (E3 = 0.178) as dominant stressors, while for green roofs, heat waves (E3 = 0.204), drought duration (E4 = 0.198), and heavy rainfall (E6 = 0.201) were most influential. PCA results, explaining 45.9–51.6% of total variance, similarly identified TXx and HWD as key co-varying indicators, whereas entropy weighting prioritized CDD and CWD due to their higher spatial variability. Across the analyzed cities, exposure patterns differed by infrastructure type, climate zone, and emission scenario. Under AHP weighting, Seoul exhibited the highest exposure index for permeable pavements (EI = 0.616) driven by combined heat and cold stress, while Busan and Daegu showed elevated exposure for green roofs (EI = 0.413 and 0.377, respectively), reflecting their sensitivity to both drought and rainfall extremes. Stratified analysis using the Köppen–Geiger classification revealed that Dfa (humid continental) cities such as Daegu and Daejeon were more exposed to heat and drought, while Cfa (humid subtropical) cities such as Busan and Jeju were more sensitive to cold extremes and heavy rainfall. Under entropy weighting, Daegu's permeable pavements (EI = 0.848) and Jeju's green roofs (EI = 1.132) showed the highest exposure under SSP5-8.5, indicating pronounced variability-driven vulnerability. Rank correlation analysis confirmed strong consistency between AHP and PCA (ρ = 0.74–0.93), suggesting convergence between expert- and data-driven results, while entropy provided complementary insights into localized climatic variability. When combined with resilience indicators simulated through laboratory tests, such as infiltration recovery, compressive strength, and post-heatwave moisture retention, the framework enables a quantitative estimation of GSI vulnerability by integrating exposure and resilience indices. Overall, the findings underscore the importance of localized, resilience-based GSI design strategies and demonstrate the framework's applicability as a data-informed tool for climate adaptation planning and environmental impact assessment, ensuring long-term functionality of urban GSI under future climate extremes.

**Keywords:** Climate Change Adaptation, Extreme Weather, Green Stormwater Infrastructure

**Acknowledgements:** This research was supported by the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (No.RS-2023-00277793).

## A Multi-Dimensional Index for Assessing Blue-Green Network Connectivity in Urban Environments

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**Abstract.** Rapid urbanization has significantly altered natural drainage systems and fragmented ecological networks, thereby reducing the capacity of blue and green infrastructure to provide effective flood mitigation and ecosystem regulation. To address this challenge, this study developed a Blue-Green Network Connectivity Index (BGNCI) as a spatially integrated framework for evaluating how hydrological, structural, and functional components of urban landscapes interact. The proposed framework was implemented to assess the connectivity of 12 Low-Impact Development (LID) facilities within a university campus in South Korea using multi-source datasets, including satellite-derived NDVI, LiDAR-based elevation, land-cover maps, and field observations. The analysed LID systems include constructed wetlands, bioretention cells, infiltration gardens, planters, trenches, rain gardens, and tree box filters, which manage runoff from roads, parking areas, and rooftops while enhancing water quality, mitigating floods, and alleviating urban heat island effects. The selected indicators were grouped into three domains: Hydrological Connectivity (HCI), Structural Connectivity (SCI), and Functional Connectivity (FCI). After normalization and weighting, the resulting maps indicated that areas with dense vegetation and a higher proportion of Low-Impact Development (LID) features exhibited stronger hydrological linkages, while zones containing LID facilities and large green patches supported greater structural coherence and habitat connectivity. Functionally, enhanced carbon storage and cooling effects were concentrated around wetland areas and adjacent LID facilities. Collectively, these findings demonstrate that the BGNCI provides a reliable and scalable method for visualizing the multidimensional connectivity of BGI systems. The framework serves as a practical decision-support tool for identifying priority zones, guiding restoration strategies, and enhancing the climate resilience of urban environments.

**Keywords:** Blue-Green Infrastructure, Connectivity Index, Urban Resilience

**Acknowledgements:** This research was supported by the National Research Foundation of Korea (NRF) funded by the 476 Ministry of Science and ICT. (No.RS-2023-00277793).

## Spatial Layout Optimization of Nature-based Solutions Considering the Impacts of Precipitation Characteristics

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**Abstract.** Rapid urbanization profoundly modifies surface runoff generation and confluence processes. Coupled with the increasing frequency of extreme rainfall events induced by global climate warming, these changes exacerbate urban flooding and non-point source pollution, threatening public safety and watershed ecosystems. In this study, an SWMM model is developed to simulate and analyze the runoff and pollution control performance of seven nature-based solution (NBS) schemes under different precipitation characteristics. Based on the overall performance of each scheme, the unit cost-effectiveness is further evaluated. Results show that all NBS schemes exhibit consistent trends in runoff reduction, pollutant control, and cost-effectiveness under varying precipitation characteristics. Among single measures, permeable pavement achieves the highest cost-effectiveness, while the combined application of green roofs, permeable pavements, and rain gardens yields the best overall performance due to synergistic effects such as spatial flow redistribution, peak delay, and functional complementarity. As rainfall intensity increases, the performance of all schemes declines while unit cost-effectiveness improves, indicating system overloading under extreme rainfall. Permeable pavements show the most sensitive response, rain gardens maintain stability, and the combined scheme performs well only under moderate rainfall. Moreover, rainfall pattern exerts a significant influence on NBS efficiency. Under Type I rainfall, all schemes demonstrate markedly lower control efficiency and higher costs, identifying it as the least favorable pattern for the study area. This study provides insights into optimizing NBS combinations for resilient urban water management.

**Keywords:** Nature-based Solutions, Optimization, Sponge City Construction, Storm Water Management Model, Precipitation Characteristics

## Impact of Wastewater Treatment Plants Upgrade on Nitrogen-Cycling Microorganisms and DNA Viruses in Receiving Rivers

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**Abstract.** Upgrading wastewater treatment plants (WWTPs) is implemented to improve downstream river water quality, but its effects on aquatic microbial and viral communities remain poorly understood. We investigated two urban rivers in Beijing over 10 years, with one river receiving upgraded WWTP effluent and another serving as a control. The results showed that, for nitrogen-cycling bacteria, overall alpha diversity (Shannon index) remained steady after the WWTP upgrade, but community composition changed significantly. Beta diversity analysis revealed a clear post-upgrade shift in microbial community structure in the impacted river compared to the pre-upgrade state. Partitioning of beta diversity revealed that species nestedness dominated community variation in the TH River, and its contribution increased substantially from 68% prior to the upgrade to 86% afterward, indicating that community differences were driven more by the retention of a stable core microbiome with partial taxa loss/gain, rather than complete species turnover. Functionally, the median nitrifier-to-denitrifier abundance ratio decreased by 87% following the upgrade, indicating a shift of nitrogen cycling toward enhanced denitrification. This was supported by metagenomic data showing higher abundances of denitrification genes post-upgrade, consistent with observed stable ammonium and declining nitrate levels in the river. In contrast, viral communities exhibited only subtle changes following the WWTP upgrade. Viral community structure remained largely stable over time, with differences mainly attributable to temporal species replacement rather than permanent loss or gain of taxa. Additionally, viruses in the upgraded river post-upgrade showed increased representation of replication/structural genes and a decrease in host metabolic auxiliary genes, while the overall proportion of lysogenic viruses remained unchanged. The WWTP upgrade substantially altered the composition and functional profile of nitrogen-cycling microbial communities in the receiving river—promoting denitrification—whereas the resident viral community demonstrated resilience with minimal compositional disturbance.

**Keywords:** WWTP Upgrade, Receiving River, Nitrogen-Cycling Microorganisms, Metagenomic, Virus

**Acknowledgments:** This work was supported by the National Natural Science Foundation of China (52450009 and 52388101). We kindly thank Hui Lin and Lutong Yang for their helps in the experiments.

## Mn-Mn Diatom Catalysts for Sustainable Oxidative Polymerization of Phenols in Fenton-Like Reactions

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**Abstract.** Peroxymonosulfate (PMS)-based advanced oxidative polymerization processes (AOPPs) are promising to realize simultaneous phenolic pollutant removal and carbon sequestration, but restricted by the rapid deactivation of the catalysts due to the strong adhesion of polymeric products. This study demonstrates a Mn-Mn diatom catalyst ($Mn_2$/CN) efficiently activates PMS to selectively drive C-O coupling of phenols into polymeric products with weak adhesion toward the catalyst surface, thus realizing sustainable AOPPs for water purification. Different from the single atom catalyst Mn/CN driving the formation of $Mn^{IV}$=O and phenoxy radicals, $Mn_2$/CN diatoms facilitate the formation of ($Mn^{IV}$=O)2 species, which oxidize phenol molecules into phenoxonium cations via a double-electron pathway, thereby directionally driving C-O coupling to produce polymers with large molecular weight and low surface energy, reducing their adhesion energy onto $Mn_2$/CN and mitigating catalyst deactivation. This work provides a promising diatom-catalyst strategy to mitigating the deactivation of catalysts in AOPPs, and brings insights for water purification by selective oxidative polymerization.

**Keywords:** Advanced Oxidative Polymerization Processes, Diatom Catalysts, High-Valent Mn(IV)-Oxo, Peroxymonosulfate, Phenolic Pollutants, Catalyst Deactivation

## Interfacial Phosphate Ions Dehydration for advanced Phosphate Removal and Recovery

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**Abstract.** Phosphate removal and recovery by adsorption is vital in addressing the phosphorus-induced water eutrophication and mitigating the depletion of phosphorus resources. However, the formation of hydrated phosphate clusters serves to impede the mass transfer of phosphate from water to the adsorbent. Herein, we demonstrate that interfacial phosphate ions dehydration, by regulating the interfacial hydrogen bonding between water molecules and the surface polar groups of malonamide-modified $La(OH)_3$ (MA-$La(OH)_3$), can deliver superior phosphate removal and recovery. The malonamide carbonyl and amino groups weaken the phosphate ions hydration layer via hydrogen bonding interactions with hydrated $H_2O$ (C=O···H and NH···O), thereby enhancing the phosphate ions charge density to promote their migration and coordination with La sites. Impressively, MA-$La(OH)_3$ exhibited an excellent phosphate removal rate of 99.0% with a high adsorption capacity of 175.4 mg P $g^{-1}$, far surpassing $La(OH)_3$ (79.0% and 112.4 mg P $g^{-1}$). The adsorbed phosphate was concentrated to 429.5 mg $L^{-1}$ into the residual alkaline solution from MA-$La(OH)_3$ synthesis and further converted to struvite, reducing the total removal cost by 17.5%. This study offers a proof-of-concept strategy for advanced phosphate removal and recovery, and highlights the importance of interfacial phosphate ions dehydration in enhancing mass transfer and surface adsorption.

**Keywords:** Phosphate Adsorption, Dehydration, Interface, Hydrogen Bonding, Resource Utilization

### Groundwater Flow System and Hydrochemical Analysis in Typical Area of China

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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

## Postgraduate Forum (2)

### Keynote Speech: Key Technological Pathways for Achieving Carbon Neutrality in Energy Use at Wastewater Treatment Plants

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**Abstract.** Reducing carbon emissions and achieving carbon neutrality stand a critical global challenge. The wastewater treatment plant (WWTP) is a major contributor to carbon emissions. Under the background of China's "Carbon Peaking and Carbon Neutrality" goals, the WWTPs in China face dual pressures of reducing pollution loads and cutting carbon emissions. This study conducts a carbon accounting analysis using typical WWTP in Shanghai as a case study. The carbon emission intensity was found to be 0.50 - 0.57 kg $CO_2$-eq/$m^3$, with total carbon emissions decreasing from 42,899 t $CO_2$-eq in 2021 to 41,385 t $CO_2$-eq in 2023. Direct emissions from electricity consumption and biochemical reactions are the primary contributors to carbon emissions in the WWTP. Electricity consumption is the largest source of carbon emissions, accounting for over 50% of total emissions. Based on traditional carbon accounting methods, a new classification framework for carbon reduction pathways is proposed, categorized as "carbon reduction, carbon sequestration, carbon substitution, and endogenous carbon negativity." Key technological pathways for achieving energy carbon neutrality in WWTPs are outlined from three perspectives: energy recovery and reuse from wastewater (internal cycling), utilization of clean and renewable energy (external supplementation), and integrated energy utilization. The research findings provide scientific support for achieving carbon neutrality goals in WWTPs.

**Keywords:** Carbon Neutrality, Reshaping of Wastewater Treatment Process, Energy Recovery, Integrated Energy Utilization, Wastewater Treatment

## Keynote Speech: Investigation of Catalyst Design and Reaction Mechanism for Efficient Electrosynthesis of Singlet Oxygen from Molecular Oxygen

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**Abstract.** Electrochemical $O_2$ activation offers a green approach for efficient synthesis of singlet oxygen ($^1O_2$). However, it is commonly determined by adsorption-dependent $O_2$ activation and transformation and can suffer from the sluggish desorption of surface-bounded superoxide species (•$O_2^{-}$*/•OOH*). Our recent works have demonstrated the adsorption/desorption-independent $O_2$ activation strategy for efficient $^1O_2$ electrosynthesis. Firstly, a dual $O_2$ coactivation pathway on shortened $Fe_1{-}O_V{-}Ti$ sites is constructed by subtly controlling the distance of adjacent catalytic sites. This desorption-independent pathway bypasses the formidable •$O_2^{-}$*/•OOH* desorption process, as the Ti−•$O_2^{-}$ and Fe−•OOH will be recombined through exothermic disproportionate reaction on catalyst surface. Furthermore, an adsorption-independent $O_2$ activation pathway via an $O_2$ mono-hydrogenation process is discovered on compressive-strained rutile $TiO_2$ (CSR−$TiO_2$). This compressive-strained surface suppresses the formation of reductive unsaturated sites for the $O_2$ adsorption and enhance the reductive ability of atomic hydrogen (H*), favouring the $O_2$ mono-hydrogenation pathway and avoiding the generation of traditional surface-bound •OOH*. Based on these adsorption/desorption-independent $O_2$ activation pathway, we realize a state-of-the-art $^1O_2$ generation rate (148.26 μmol $l^{-1}$ $min^{-1}$ in acid condition, 54.5 μmol $l^{-1}$ $min^{-1}$ in neutral condition). This $^1O_2$ electrosynthesis system, which requires only oxygen and renewable electricity, enhances the biodegradability of wastewater while avoiding the generation of toxic substances, thereby offering a promising and sustainable pretreatment solution.

**Keywords:** Singlet Oxygen, Electrocatalysis, Oxygen Activation, Sustainable Wastewater Treatment

## Enhanced Visible-Light Degradation of Diclofenac using $TiO_2$/g-$C_3N_4$ Nanocomposite with PMS Activation

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**Abstract.** Pharmaceutical contaminants in aquatic environments, have raised serious environmental and health concerns due to their persistence, toxicity, and resistance to conventional wastewater treatment methods. Among emerging treatment approaches, advanced oxidation processes (AOPs) offer promising potential for the complete mineralization of such micropollutants. In this context, the present study focuses on the development and application of a visible-light-responsive $TiO_2$/g-$C_3N_4$ (titanium dioxide/graphitic carbon nitride) nanocomposite for the degradation of diclofenac in aqueous media, assisted by peroxymonosulfate (PMS) activation. The $TiO_2$/g-$C_3N_4$ nanocomposite with different weight ratios was synthesized via a facile thermal and ultrasonication method, ensuring optimal heterojunction formation to enhance interfacial charge transfer and suppress recombination of photogenerated electron-hole pairs. Comprehensive characterization techniques, including XRD, SEM-EDS, BET, FTIR, and UV-Vis DRS, were employed to confirm the structural, morphological, and optical properties of the composite. Photocatalytic degradation experiments were conducted under visible light irradiation, with PMS acting as an oxidant. The $TiO_2$/g-$C_3N_4$-PMS system exhibited superior performance in DCF removal compared to individual components, achieving over 99.08% degradation within 180 minutes under optimized conditions of [DCF]= 5 mg/L, [PMS]= 0.25mM, [catalyst]= 150mg/L and pH= 5.85(without adjustment). The synergistic interaction between the photocatalyst and PMS facilitated the generation of reactive oxygen species (ROS) for the degradation of DCF. The effects of operational parameters such as catalyst dosage, PMS concentration, solution pH, initial DCF concentration, and presence of coexisting ions were systematically studied. Moreover, the catalyst exhibited good reusability and structural stability over multiple cycles, indicating an efficient, sustainable, and visible-light-driven AOP for the real-world wastewater treatment applications.

**Keywords:** Titanium Dioxide/Graphitic Carbon Nitride, Photocatalytic Degradation, Advanced Oxidation Processes, Wastewater Treatment

**Acknowledgements:** This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2022R1A2C2091561).

## Peroxymonosulfate Activation by Hemin-Modified Biochar for Ciprofloxacin Degradation

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**Abstract.** The widespread occurrence of antibiotics in groundwater and wastewater treatment plants poses a major threat to environment and public health. Although advanced oxidation processes (AOPs) offer promising solution to address this issue, the development of efficient, low-cost, and sustainable catalytic systems remains a key challenge. This study addresses this gap by exploring bamboo-derived biochar modified with hemin (BBC@Hemin) as an effective peroxymonosulfate (PMS) catalyst for ciprofloxacin (CIP) degradation. The BBC@Hemin composite was synthesized via a simple one-step pyrolysis to enhance redox activity and catalytic efficiency. Comprehensive characterization results from SEM, BET, FTIR, XRD, XPS, and Raman spectroscopy techniques, confirmed successful incorporation of Fe and nitrogen-doped carbon on BBC. Degradation data revealed that the optimized BBC@Hemin/PMS system is capable of removing 92.14% of CIP within 120 minutes (at pH = 5.85). Scavenging experiments and electron paramagnetic resonance (EPR) spectroscopy results confirmed the generation of reactive oxygen species (ROS) in BBC@Hemin/PMS system. In addition, the effects of cations ($K^+$, $Na^+$, $Ca^{2+}$, $Mg^{2+}$), anions ($Cl^-$, $SO_4^{2-}$, $HCO_3^-$, $H_2PO_4^-$), humic acid (HA) and natural groundwater conditions were also investigated. The influence of antibiotic structure on degradation efficiency and reactive species interactions was systematically investigated to assess the full potential BBC@Hemin/PMS and to gain mechanistic insights. This study highlights the versatility and effectiveness of BBC@Hemin as a low-cost, eco-friendly, and robust catalyst for antibiotic removal, contributing to the development of sustainable water purification technologies.

**Keywords:** Antibiotics, Bamboo Biochar, Hemin, Peroxymonosulfate, Advanced Oxidation, Wastewater treatment

**Acknowledgements:** This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2022R1A2C2091561).

## Recovery of Cobalt from Cobalt-Containing Wastewater Using Fluidized Bed Homogeneous Crystallization Technology

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**Abstract.** Cobalt is an essential strategic raw material for energy storage, catalysis, and advanced electronic devices. However, its supply chain is heavily reliant on production in Congo, raising geopolitical and sustainability concerns. Therefore, recycling cobalt-containing wastewater is crucial for ensuring resource security and reducing import dependence. This study employed fluidized bed homogeneous crystallization (FBHC) technology to recover cobalt from simulated wastewater. Using cobalt chloride and sodium hydroxide as feeds, pH, hydraulic retention time (HRT), reflux ratio, and surface loading were investigated. At a pH of 9.3, an HRT of 32 minutes, a reflux ratio of 12.8, and a surface loading of 0.517 kg/m²·h, the system achieved a total removal efficiency (TR) of 99.8% and a crystallization rate (CR) of 97.2%. Characterization of the resulting particles revealed a nanosheet-like morphology with nearly spherical aggregates. Consequently, the cobalt concentration in the effluent could be less than 1 mg/L. These results demonstrate FBHC as an effective and sustainable approach for cobalt recovery and circular resource utilization.

**Keywords:** Cobalt Recovery, Fluidized-Bed Homogeneous Crystallization, Circular Resource Utilization

**Recovery of Zirconium from Zirconium-Containing Wastewater Using Fluidized Bed Homogeneous Crystallization Technology**

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**Abstract.** Zirconium (Zr) has been widely applied in ceramics, chemical products, and nuclear fuel cladding due to its unique aqueous chemistry and low toxicity. However, the global zirconium supply is constrained by limited mineral resources and the presence of radioactive elements during refining. Recovery of zirconium from industrial waste remains limited because of low efficiency, high cost, and environmental concerns, leading to supply–demand imbalance. Despite its reputation as a low-toxicity element, recent studies indicate potential bioaccumulation risks, emphasizing the need for efficient Zr removal and recovery from wastewater. In this study, the Fluidized Bed Homogeneous Crystallization (FBHC) technique was applied to treat Zr-containing wastewater, overcoming the sludge generation problem typical of chemical precipitation. The method achieved efficient Zr removal from 500 mg-Zr/L to 5 mg-Zr/L, producing low-moisture crystalline granules. Preliminary jar tests identified optimal pH and reaction conditions for Zr hydroxide precipitation, which were further applied in FBHC experiments. Under optimized conditions, total Zr removal (TR) reached 99% and crystallization rate (CR) reached 95%. Solid analysis confirmed that the recovered product consisted of homogeneous $Zr(OH)_4$ crystalline granules.

**Keywords:** Zirconium Recovery, Fluidized-Bed Homogeneous Crystallization, Circular Resource Utilization

## Large-Sized Topological Defect-Driven Electron Shuttling: Efficient Carbon-Based Persulfate Activators Prepared by Reverse Engineering

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**Abstract.** Defect engineering has been recognized as a highly promising strategy for high-performance carbon-based catalysts. However, achieving sustainable and efficient generation of specific topological defects within stable graphitic carbon frameworks for high catalytic activity remains a significant challenge. Herein, we revealed an innovative reverse defect-engineering approach that enables the creation of carbon catalysts with a high density of large-sized topological defects via an in-and-out strategy, i.e., manipulating the defects by removing pre-doped sacrificial element (nitrogen) on carbon. Using a mechanochemical method with precisely controlled energy input, graphitic nitrogen was selectively incorporated into the carbon matrix, enabling the control of the afterward formed defect species. Subsequent high-temperature thermal treatment induced the decomposition of graphitic nitrogen, leading to the formation of eight-carbon ring defects and their evolution into larger topological defects, evidenced by advanced morphology and spectroscopy analysis. The resulting defect-rich carbon catalyst exhibits exceptional performance in peroxydisulfate (PDS) activation, achieving a fast tetracycline degradation (0.0365 $min^{-1}$), low reaction stoichiometric efficiency (8.2%), excellent adaptability to diverse water matrices, and outstanding long-term stability. Through a combination of quenching experiments, electron paramagnetic resonance spectroscopy, electrochemical analysis, and density functional theory calculations, we identified that an electron shuttle mechanism, exclusively facilitated by the large topological defects, governs the enhanced catalytic process. Specifically, the large topological defects (modeled as 5-8-5 carbon rings) feature a reduced HOMO–LUMO energy gap, which promotes efficient electron transfer from tetracycline to PDS and results in superior catalytic efficiency compared to carbons with other defect structures. This work not only introduces a novel pathway for precise defect engineering in carbon catalysts but also deepens our mechanistic insights into the catalytic mechanisms.

## In-situ Removal of PFAS in Groundwater Using a Combination of Adsorption and Advanced Oxidation Processes on Metal-Modified Zeolites

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**Abstract.** Per- and polyfluoroalkyl substances (PFAS) in groundwater are challenging to remediate. Conventional physical separation methods transfer but do not mineralize PFAS, while chemical oxidation suffers from radical quenching and mass transfer limitations. The integration of adsorption and advanced oxidation processes (AOPs) offers a promising alternative, leveraging bifunctional materials such as metal-modified zeolites to achieve in situ "capture and destruction" of PFAS. These materials combine high adsorption capacity—enabled by tunable porosity, Si/Al ratio, and hydrophobic/electrostatic interactions—with catalytic activity for persulfate activation, generating radicals that degrade PFAS within confined zeolite pores. However, critical knowledge gaps hinder practical implementation. First, the adsorption mechanisms of PFAS across different zeolite topologies and the role of metal modification remain inadequately understood. Second, the coupling between PFAS adsorption and persulfate activation—such as degradation pathways, potential non-radical mechanisms, and material regenerability—is unclear. Third, the performance of this integrated system under realistic groundwater conditions, including heterogeneous flow, competing ions, and natural organic matter, has not been systematically evaluated. This study aims to address these gaps by: (1) elucidating the structure-dependent adsorption mechanisms of PFAS on metal-modified zeolites; (2) clarifying the synergistic relationship between PFAS enrichment and persulfate activation, including degradation pathways and material stability; and (3) evaluating the technology's feasibility under complex hydrogeochemical conditions. The findings are expected to provide a scientific foundation for developing efficient and sustainable in situ PFAS remediation strategies.

**Keywords:** PFAS, AOPs, Zeolite, In-situ Treatment, Metal Modification

## Regulating the Oxygen-Containing Functional Groups on Carbon Material Surfaces to Achieve Synergistic Adsorption and Catalytic Degradation for the Removal of Pollutants from Water

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**Abstract.** Carbon materials exhibit significant advantages in the integrated adsorption and catalytic activation of persulfate for the removal of organic pollutants from water. However, the surface chemical structural characteristics related to adsorption and catalysis, as well as the synergistic mechanisms between these two techniques, remain unclear. In this study, carbon nanotubes (CNT) were employed to modulate surface oxygen-containing functional groups to investigate their impact on adsorption and catalytic performance. Additionally, the synergistic relationship between adsorption and catalytic degradation was examined through mathematical model fitting. The results indicate that high-temperature annealed carbon nanotubes primarily enhance the adsorption of pollutants with extensive conjugated π systems via π-π interactions and hydrophobic interactions, while significantly boosting the degradation of electron-rich pollutants. Unlike previous studies, our degradation system relies on surface bound superoxide radicals and diffusible singlet oxygen. In addition, pre-adsorption only has a promoting effect in the early stages of degradation, but does not enhance the final degradation effect of the system, which may be due to the fact that adsorption is not the limiting step in the degradation process. Our research provides deeper insights into the preparation of high-performance adsorption-catalysis bifunctional materials and the understanding of the synergistic relationship between adsorption and catalytic degradation.

**Keywords:** Adsorption, Advanced Oxidation Processes, Bifunctional Materials, Organic Pollutants, Synergistic Effect

**Divergence in Denitrification Behavior of Solid Carbon Sources and Its Underlying Mechanism**

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**Abstract.** Solid-phase carbon source denitrification is a promising technology for treating waters with a low C/N ratio. However, a significant knowledge gap exists regarding the specific processes and mechanisms involved, as research has predominantly focused on efficiency and screening. To address this, we evaluated the denitrification performance and microbial community composition driven by six carbon sources: cellulose, starch, chitin, PBS, PCL, and PLA. Our investigation separately analyzed the two key stages: initial hydrolysis/carbon release and subsequent denitrification of the hydrolyzate. By comparing the denitrification efficacy of the hydrolyzate's DOM with that of the corresponding polymeric monomers, this study aims to unravel the mechanistic reasons for the performance differences among solid carbon sources.

**Keywords:** Solid-Phase Carbon Source, Denitrification, Microbial Community, Composition of Dissolved Organic Substances

**Mapping Groundwater Potential Zones and Recharge Using AHP Techniques and Remote Sensing Data**

Osama Abdul Rahim
*Tongji University, China*

**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

## Novel Photo-Electro-Fenton Process with Natural Air Diffusion Electrode Coating Recycled Zn-Mn/C Catalysts from Spent Zn-Mn Dry Battery: Fast Generation and Activation of $H_2O_2$

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**Abstract.** The development of photo-electro-Fenton (PEF) technology has become a pivotal focus in advanced environmental remediation, offering an innovative solution to significantly enhance the degradation efficiency of persistent organic pollutants that plague water systems worldwide. However, the high costs of efficient electrodes and catalysts for generating and activating hydrogen peroxide ($H_2O_2$) constrained its industrial application. To address these challenges, a natural air diffusion electrode (NADE) was introduced and coated with recycled Zn-Mn/C catalysts from spent Zn-Mn dry battery to fabricate the recycled Zn-Mn/NADE (rZM/NADE) cathode, for fast generation and activation of $H_2O_2$. NADE can generate $H_2O_2$ by atmospheric oxygen without aeration, and it exhibited a high $H_2O_2$ generation rate (998.3 mg·L$^{-1}$, 10 min) and Faraday efficiency (94.4%, 10 min). $H_2O_2$ was significantly utilized after recycled Zn-Mn/C catalysts loading (residual $H_2O_2$: 51.7 mg·L$^{-1}$, utilization efficiency: 94.8%, 10 min). Within the constructed PEF system, three complementary reaction pathways, cathodic electro-Fenton, photo-Fenton, and anodic oxidation, operated synergistically to co-generate multiple ROS, creating a robust oxidative environment that targets pollutants through multiple mechanisms. When applied to tetracycline, the system achieved an outstanding degradation efficiency of 98.86%, confirming its strong practical applicability. This work provided valuable insights for further reducing the cost and enhancing the efficiency of PEF technology, laying a solid foundation for the scalable and sustainable implementation of PEF in real-world wastewater treatment scenarios.

**Keywords:** Natural Air Diffusion Electrode, Spent Battery, Hydrogen Peroxide Synthesis, Photo-Electro-Fenton, Tetracycline

## Tire Wear Particles as an Emerging Precursor for Toxic Disinfection Byproducts

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**Abstract.** The pervasive release of tire wear particles (TWPs) into surface waters presents a critical challenge for drinking water treatment, particularly when oxidative processes are employed. This study investigates how both the environmental ultraviolet (UV) aging due to sunlight and engineered advanced oxidation processes (AOPs) influence the potential formation of disinfection byproduct (DBP) formation during subsequent chlorination from TWPs. While UV radiation in the environment pre-ages TWPs, processes like $O_3$, $O_3/H_2O_2$, and UV/$H_2O_2$ used in treatment actively enhance the leaching of organic compounds, thereby increasing the precursor load for DBPs. Ozone-based treatments were the most impactful, with $O_3$ pretreatment elevating trihalomethane and haloacetic acid formation from 8.1 to 14.5 μg $L^{-1}$ and 7.7 to 12.4 μg $L^{-1}$, respectively, and higher $O_3$ doses further increased DBP yields. Additionally, dry UV aging was shown to increase overall DBP yields by 1.5–2.0 times and alter leachate composition, as evidenced by excitation-emission matrix parallel factor (EEM-PARAFAC), which revealed a 2–3 fold increase in humic-like and protein II-like components, indicating oxidative polymer breakdown. Critically, both dry UV-aged and AOP-pretreated TWPs generated a wider spectrum of chlorinated byproducts, with a distinct shift from simple aliphatic compounds toward more hazardous aromatic and trichlorinated species. These findings collectively underscore that oxidative treatment, while intended for purification, can inadvertently transform TWPs into a potent source of more diverse and toxic halogenated byproducts, complicating the safety of finished drinking water. Meanwhile, environmental conditions like UV irradiation can work as a trigger for the enhanced DBP formation from TWPs.

**Keywords:** Tire Wear Particles, Oxidation Processes, UV-aging, Disinfection Byproducts, Water Disinfection

## Optical Field Revelation in UV-LED Reactors Propels Source Transition in UV Disinfection

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**Abstract.** Ultraviolet (UV) disinfection is undergoing a source transition. However, unresolved photon transport and optical field in emerging UV light-emitting diode (UV-LED) reactors hinder reactor optimization, energy-consumption assessment, and

rigorous, fair comparison with conventional low-pressure (LP) mercury lamps, which still retain advantages in wall-plug efficiency (WPE) and industrial maturity. Here, we develop a U-shaped micro-fluorescent silica detector (uMFSD) for resolving optical fields inside compact bottom-multiple-LED (BML) reactors across different layouts and UV transmittances. The uMFSD measurement and biodosimetry enable precise validation and refinement of computational fluid dynamics (CFD) model, further supporting the evaluation of reactor photon transfer efficiency (PTE) and guiding layout optimization. The optimized BML designs mitigate near-wall fluence losses relative to LP mercury lamp reactors and achieve higher PTE. For end-of-pipe drinking-water disinfection, we propose an energy consumption evaluation framework that traces the pathway from electrical input to delivered reduction-equivalent fluence (REF), and identify WPE thresholds (3.1–9.6%) required for energy parity between UV-LED and LP mercury lamps. This work addresses the central challenges and provides quantitative framework and clear WPE targets for mercury-free and low-carbon transition of UV disinfection sources.

**Keywords:** UV-LED, U-shaped Micro-Fluorescent Silica Detector, Computational Fluid Dynamics, Photon Transfer Efficiency, Wall-Plug Efficiency Thresholds

## Postgraduate Forum (3)

### Keynote Speech: Transforming Biomass Waste into Advanced Antimicrobial Materials: A 3D-Resolved Pathway for Sustainable Water and Environmental Protection

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**Abstract.** Waterborne microbial contamination continues to pose significant challenges to global public health and environmental sustainability. This study integrates circular-economy biomass valorization with advanced photochemical disinfection and near-native 3D cellular imaging to develop next-generation antimicrobial materials for water and environmental applications. Fishery-waste-derived chitosan (CTS) was combined with polyphenol-rich fruit-pomace extracts (JAE) to create multifunctional bioactive films exhibiting vigorous antibacterial activity, antioxidant performance, and biocompatibility. CTS–JAE composites achieved >5.7-log reduction of *E. coli* and effectively inhibited microbial activity through synergistic electrostatic membrane disruption and polyphenol-mediated oxidative stress. To enhance applicability in environmental systems, a visible-light-responsive CTS–N-$TiO_2$ photocatalytic composite was further developed, achieving 99.999% inactivation of *S. aureus* and 99.9% of *E. coli* under visible light, and maintaining disinfection

capability even under dark conditions through combined ROS-driven oxidation and CTS-induced metabolic inhibition. A key contribution of this work is the first application of Transmission X-ray Microscopy (TXM) and Cryogenic Soft X-ray Tomography (SXT) to resolve the near-native 3D morphology and subcellular dynamics of microorganisms during inactivation. The imaging results reveal progressive cell-wall fragmentation, membrane lysis, intracellular matrix shrinkage, organelle leakage, and nanoscale structural collapse across full 360° perspectives—behaviors that remain undetectable in conventional 2D SEM/TEM observations. Overall, this research establishes an integrated framework—from waste-derived antimicrobial materials to visible-light photocatalysis and 3D mechanistic visualization—supporting sustainable water treatment, microbial risk reduction, and circular-economy-driven material innovation. The findings offer a scalable, low-carbon technological pathway with strong potential for advancing environmental biotechnology and water pollution control across diverse global settings.

## Rapid Inactivation of *Enterococcus faecalis* by an Innovative Magnetic Confinement-enabled Zerovalent Iron Flow-through Reactor

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**Abstract.** A low-cost technology is needed to address arsenic and microbial contamination in groundwater. We previously developed a zerovalent iron (ZVI)-based magnetic confinement-enabled column reactor (MCCR) proven effective for arsenic removal. This study investigated *Enterococcus faecalis* (*E. faecalis*) removal performance of MCCR in relation to dissolved oxygen (DO) concentration and hydraulic retention time (HRT). Continuous aeration (high DO concentration) significantly enhanced *E. faecalis* removal at a 5-min HRT, achieving 1–2.5 log reduction compared to 0.5–1.0 log under non-aeration (low DO concentration). Furthermore, a 4-min HRT under the high DO concentration achieved peak disinfection efficiency (3.5 log removal), whereas a 2-min HRT yielded lower efficiency (2.5 log) and extending to 14 min provided no significant improvement over the 4-min HRT. The rapid disinfection observed under the high DO concentration and short HRT is mechanistically attributed to magnetic field-enhanced iron dissolution and release, driving reactive oxygen species (ROS) generation through Fenton reaction. In the MCCR, concentrations of solid-phase iron (oxyhydr)oxides formed in bulk solution via oxidation of ZVI at 0.4 g/mL dose reached 5–10 mg/L, far exceeding those from equivalent-dose ZVI oxidation without magnetic confinement (~2 mg/L). This led to elevated ·OH concentrations (80–250 μM) enabling rapid disinfection, whereas ·OH in solution was undetectable without magnetic confinement. Additionally, with continuous aeration, high iron release promoted post-disinfection co-settling of E. faecalis with iron (oxyhydr)oxides. A 2–3 log reduction of *E. faecalis* was achieved after 24-h settlement, maintaining *E. faecalis* concentrations in the supernatant ≤10 CFU/mL throughout the 144-h operation of MCCR. This study demonstrates significant advantages of MCCR for simultaneous arsenic and pathogen removal, effectively overcoming permeability loss and reactivity loss in traditional flow-through systems containing ZVI. Crucially, MCCR achieves treatment of higher water fluxes (4–5 mL/min vs. 0.2–1.6 mL/min) using lower ZVI densities (0.4 g/cm3 vs. 4.8 g/cm3), offering clear economic and operational benefits.

**Keywords:** Rapid Disinfection, Magnetic Confinement, Zero-Valent Iron, Dissolved Oxygen, Oxidation; Settlement

## Modified Phosphated Zero-Valent Iron in Groundwater Contaminant Degradation and Their Reaction Mechanism and Migration Behavior

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**Abstract.** Iron (Fe), as the most abundant environment-friendly transition metal in the Earth's crust, possesses the ability to drive the redox transformation of pollutants due to its incompletely filled valence d-orbitals and variable oxidation states, playing a crucial role in the Earth's material cycle. Contamination control technologies based on iron-based materials have become a research hotspot in environmental chemistry, driven by the concept of "green synthesis". Therefore, this study investigates the practical application of phosphated zero-valent iron in the in-situ remediation of groundwater pollution through the following four aspects: the improvement of degradation performance of phosphated modified zero-valent iron in groundwater pollutant degradation; the migration and enhancement methods of phosphated modified zero-valent iron in porous media; the laws and synergistic mechanisms of phosphated modified zero-valent iron in the reductive and activated oxidative degradation of complex organic pollutants; and the description of the reactivity and transport behavior of complex pollutants under the in-situ action of phosphated modified zero-valent iron.

**Keywords:** Zero-Valent Iron, Green Synthesis, Groundwater

**Effects of Atomic-Scale Constraints on the Molecular Migration During the Hydration of Bentonite: A GCMC Simulation Study**

Shengyi Yan
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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

**Detection of Surface Soil Moisture Through Hybrid Ensemble Learning with Interpretable Features**

Shengkui Tian
*Tongji University, China*

**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

**Mineralogical Stability and Reaction Mechanisms of Bentonite in Saturated Portlandite Water**

Xiaoya Li
*Tongji University, China*

**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

**Explainable Physics-Informed Bayesian Graph Neural Networks (PI-BSTGNN) for Groundwater Surrogate Modeling and Sensitivity Analysis**

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**Abstract.** Groundwater contamination modeling demands a balance of predictive accuracy, physical consistency, and interpretability. We propose a Physics-Informed Bayesian Spatio-Temporal Graph Neural Network (PI-BSTGNN) that integrates Latin Hypercube–Simulated Annealing sampling with a two-stage Bayesian GNN architecture. Physics-informed loss functions enforce mass conservation and boundary conditions, while Bayesian regularization ensures robust uncertainty quantification. SHAP analysis enhances transparency by attributing predictions to hydrogeological drivers. Evaluated across heterogeneous 2D and 3D aquifer scenarios, PI-BSTGNN achieves RMSE values of 2.64 m for heads and 1.11 mg/L for concentrations, with $R^2$ values above 0.78 and 0.86, respectively. Compared to data-driven benchmarks, it shows superior robustness, especially for solute transport in irregular hydrogeological settings. Physical constraints reduce global errors and confine residuals to hydrologically sensitive zones, producing spatially coherent, interpretable outputs. This interpretable framework reveals head dynamics driven by aquifer geometry, heterogeneity, and historical states, while concentrations hinge on boundary hydraulics, vertical structure, and well operations—aligning with hydrogeological intuition. PI-BSTGNN thus offers a scalable, physically consistent surrogate that bridges mechanistic and data-driven approaches, delivering accurate predictions, uncertainty quantification, and clear insights into groundwater flow and transport processes.

**Keywords:** Groundwater Surrogate Modeling, PI-BSTGNN, Bayesian Uncertainty Quantification, Physics-Informed Machine Learning, Explainable AI Analysis

## Topology-Adaptive Graph Attention Networks Coupled with Radial Basis Functions: A Novel Framework for Hydraulic Conductivity Inversion in Unstructured Meshes

Zhao Guo, Futian Ren, Danbing Mei, Fan Liu, Zenghui Li, Xiaowei Lu, Lei Huang*
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**Abstract.** Accurate inversion of spatially distributed hydraulic conductivity (K) under sparse observations and unstructured meshes is essential for realistic groundwater simulation and effective resource management. This study presents a physics-informed deep learning framework that integrates a Multi-Resolution Radial Basis Network (MRRBN) and a Topology-Adaptive Graph Attention Network (TAGAT) to jointly reconstruct domain-wide head fields and invert the K field. The MRRBN employs multi-resolution spatial interpolation and data-driven weighting to recover continuous head fields from limited measurements. The TAGAT incorporates graph topology and physics-informed flow characteristics derived from Darcy's law, including instantaneous fluxes and local source-sink dynamics, to capture short- and long-range dependencies across unstructured meshes. Evaluated on synthetic aquifer scenarios featuring heterogeneous conductivity, variable boundary conditions, and stochastic rainfall, the proposed model achieved the following metrics (training, validation): $R^2$ (0.89, 0.83), RMSE (0.683, 0.844), MAE (0.530, 0.642), and maintained robust accuracy under realistic levels of measurement noise. Residuals concentrate along conductivity-transition bands and mid-gradient zones where the sensitivity of head to K is low. We benchmark against graph-network baselines, treating multi-order topology and physics-informed features as independent factors, and we control model

size by matching parameter counts under fixed data and training protocols. Results indicate a physically consistent, mesh-native solution for conductivity inversion with practical implications for site-scale groundwater analysis.

**Keywords:** Hydraulic Conductivity Inversion, Unstructured Mesh, Topology-Adaptive Graph Attention, Radial Basis, Physics-Informed Learning

## Collaborative Catalysis of Single Atoms and Atomic Clusters as Dual Sites for Confined Peroxymonosulfate Activation to Coordinate Radical and Singlet Oxygen Pathways

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**Abstract.** Single-atom catalysts have attracted tremendous research interest in advanced oxidation water treatment, while their efficiency and recyclability were restricted by speciation. Deliberate manipulation of single-atom (SAs) accumulation and distribution to tune the catalyst efficiency and route constitutes an area of great interest but a challenging pursuit. Here, we developed a series of novel spherical porous carbon materials from biomass waste with a three-dimensional distribution of Fe. Fe SAs and atomic clusters (ACs) are simultaneously formed in catalysts, and their distribution from the outer surface to the inner core varies with pyrrolic N content. The cooperation of SAs and ACs serves as a pair of redox sites linked with graphitic carbon to coordinate the electron circulation with peroxymonosulfate (PMS), generating radical and singlet oxygen for antibiotic degradation. The confined environment and the cooperation of dual sites perpendicular to the carbon plane were first reported, which enhanced the generation of reactive species. These advantages afforded efficient degradation (up to 229% improved in kinetics and 133% improved in degradation) with heightened recyclability (up to 150% improved) compared to surface-doped SAs or ACs-dominated catalyst. Furthermore, this approach achieved efficient utilization of atomic metal sites compared to previously documented metal-based ADCs. This study reveals the synergy of SAs and ACs in a confined environment for cyclic electron transfer and inspires a new version for designing atomically dispersed Fe within the 3D structure for advanced water decontamination.

**Keywords:** Atomic Fe Sites, Three-Dimensional Distribution, Peroxymonosulfate Activation, Confined Environment

## Quantitative Analysis of Coastal Waterway Construction Impact Based on Ecopath Model

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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

## Exploring Phosphorus Retention, Transformation and Bioavailability in Biochar Produced from Microalgae

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**Abstract.** Advanced wastewater treatment utilizing microalgae has emerged as a promising strategy for enhanced water purification. Following treatment, the harvested microalgae are enriched with nitrogen (N) and phosphorus (P), essential nutrients for crop growth and global food security. Converting these microalgae into biochar offers dual benefits in resource recovery and fertilizer application. This study investigated the potential of microalgae-derived biochar as a phosphorus source for agriculture. Microalgae (*Arthrospira platensis*) were subjected to pyrolysis at temperatures ranging from 400 to 550°C for 60 minutes. The Total Phosphorus (TP) content, evaluated using a modified dry ash method, demonstrated that the biochar was nutrient-rich, achieving a maximum value of 30.38 mg-P/g at 550°C. However, phosphorus bioavailability was limited, as indicated by low solubility in 2% Citric Acid (CA), 2% Formic Acid (FA), and water solubility tests. To enhance phosphorus bioavailability, co-pyrolysis experiments were conducted at 500°C and 550°C with microalgae mixed with organic potassium compounds ($CH_3COOK$ and $C_6H_5K_3O_7$) in various ratios. Co-pyrolysis significantly improved the phosphorus bioavailability in the biochar, as evidenced by Hedley Fractionation. The findings suggest that co-pyrolyzing microalgae with specific chemical salts can effectively increase phosphorus bioavailability, rendering the modified biochar a promising phosphorus fertilizer source.

**Keywords:** Bioavailability, Biochar, Fertilizer, Microalgae, Phosphorous Fractionation

## DISoptimizer: A Machine Learning-Driven Framework for Optimizing Disinfection in Drinking Water Treatment

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**Abstract.** Drinking water disinfection has been highly effective in preventing waterborne disease; however, the formation of disinfection byproducts (DBPs) poses a significant public health concern. Optimizing disinfection strategies to minimize DBP formation without compromising disinfection efficiency remains a critical challenge. Herein, we present DISoptimizer, a machine learning-driven framework designed to optimize disinfection by identifying the optimal chlorine dose that ensures pathogen inactivation while minimizing trihalomethane (THM) formation. A standardized dataset was obtained by conducting simulated distribution system chlorination experiments. Microbial safety was ensured by maintaining the chlorine residual at a targeted level after 24 h, representing the delivery point of distribution system. DISoptimizer consists of a prediction module, designed for predicting chlorine consumption and THM formation, coupled with an optimization module that integrates multiple algorithmic strategies to identify the optimal chlorine dose. Computational simulations across diverse water quality conditions showed that DISoptimizer consistently maintained the desired chlorine residual level, while reducing THM formation by 17-40% compared with traditional chlorination methods. Experimental validations demonstrated the potential for real-world application. DISoptimizer not only provided early warnings of potential DBP risks through accurate THM prediction, but also address the challenge of minimizing DBP formation without compromising disinfection, safeguarding drinking water safety.

**Keywords:** Machine Learning, Disinfection Byproducts, Chlorine Residual, Drinking Water, Chlorination

## Advancing Illicit Connection Diagnosis of Urban Stormwater Pipes: Comprehensive Analysis with EEM Fluorescence Spectroscopy

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**Abstract.** Urban drainage systems are significant contributors to the issue of black-odorous water bodies. The current application of stormwater pipe inspection technologies faces substantial limitations, especially in industrial areas with diverse wastewater. This study introduced an innovative approach using excitation-emission matrix (EEM) fluorescence spectroscopy for rapid and accurate diagnosis, providing a new perspective for diagnosing illicit connections. In single wastewater-type areas like residential zones, the method achieved a remarkable 91.5% accuracy solely through

spectra observation and fluorescence peak intensity comparison, outperforming conventional $NH_3$-N-based techniques, which reached an accuracy of only 68.1%. For regions with complex wastewater scenarios, after EEM subtraction, the residual spectra can be roughly categorized into four distinctive categories based on characteristics. This provides a preliminary assessment and helps in initially identifying the types and sources of inflowing wastewater. Furthermore, the least squares (LS) method refines diagnosis results, offering calculated coefficients reflecting the probability and severity of suspected wastewater intrusion. Simulation experiments and field sample analyses validated the feasibility and accuracy of the EEM-based method, highlighting its advantages for diagnosing illicit connections in both single and mixed wastewater scenarios. The results can significantly narrow down the investigation scope and enhance the confirmation of wastewater sources, exhibiting promising application prospects.

**Keywords:** Stormwater Pipes, Illicit Connection, EEM Subtraction, Least Squares Method, Wastewater Traceability

## Intramolecular Hydrogen Bond Engineering of Covalent Organic Frameworks Accelerates Proton Transfer for Efficient $H_2O_2$ Electrosynthesis

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**Abstract.** The electrosynthesis of hydrogen peroxide (H2O2) presents a sustainable route to replace the energy-intensive anthraquinone (AQ) process, but its efficiency is often limited by sluggish water dissociation and proton transfer kinetics. Herein, we demonstrate a covalent organic framework (COF) featuring adjacent imine and AQ units (1,5-TfpAQ), which uniquely constructs an intramolecular hydrogen-bond (H-bond) between the protonated imine and the carbonyl oxygen of AQ that significantly accelerates proton transfer between the two moieties. The optimal 1,5-TfpAQ achieves a remarkable H2O2 production rate of 15.5 mol g−1 h−1 at approximately 120 mA cm−2 with a Faradaic efficiency (FE) up to 80.0% in 0.1 M KOH, simultaneously demonstrating exceptional operational stability. Combined experimental and theoretical studies elucidate that the intramolecular H-bond facilitates the formation of a weakly H-bonded water network at electrode surface, thereby promoting water dissociation and enabling rapid proton transfer. The sustainable proton supply favors the conversion of AQ into anthrahydroquinone (H2AQ), and subsequently decreases the energy barrier for the reduction of adsorbed oxygen (*O2) into *OOH intermediates. This work highlights the strategic construction of an intramolecular H-bond as the effective pathway for proton transfer, and establishes a fundamental design principle for advanced COF electrocatalysts.

**Keywords:** Covalent Organic Framework, Oxygen Reduction Reaction, Hydrogen Peroxide, Intramolecular Hydrogen-Bond, Proton Transfer

**Light-Enhanced PMS Activation by Nitrogen-Doped Biochar for Efficient Non-Radical Degradation of Benzo(a)pyrene**

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**Abstract.** The concentration of benzo(a)pyrene (BaP) in coking wastewater is typically high, and even after secondary biological treatment, the effluent often fails to meet the discharge limit (0.03 μg/L), posing a major challenge for wastewater discharge and reuse. To address this issue, this study developed a heterogeneous catalyst with a tunable catalytic pathway—nitrogen-doped biochar (NBC1)—and systematically investigated the performance and influencing factors of a light-assisted NBC1-activated peroxymonosulfate (PMS) system for BaP degradation. Material characterization confirmed the successful incorporation of nitrogen in the forms of pyridinic N, pyrrolic N, and graphitic N, which effectively modified the surface morphology of the catalyst. Under optimal conditions, the NBC1+PMS+Light system achieved a BaP degradation efficiency of 99.51%. Mechanistic investigations—including XPS, EPR, radical quenching, electrochemical analysis, and DFT calculations—demonstrated that nitrogen doping not only enhanced PMS adsorption and electron-donating capability but also altered the dominant catalytic pathway. BaP degradation proceeded primarily through a $^1O_2$-driven non-radical process, accompanied by $^{\bullet}OH$, $SO_4^{\bullet-}$, $O_2^{\bullet-}$, and direct electron transfer. GC–MS analysis identified 13 intermediates and proposed three potential degradation pathways, with toxicity gradually decreasing as mineralization progressed. Practical application tests further confirmed that the system efficiently removed BaP from coking wastewater, exhibited strong tolerance to common inorganic anions, and maintained 96% of its catalytic activity after three reuse cycles, indicating excellent stability and reusability. Overall, this work provides a promising strategy for developing efficient and sustainable treatment technologies for refractory organic pollutants.

**Keywords:** Nitrogen Doped Biochar, Persulfate, Benzo (A) Pyrene, Non-Radical Oxidation

**Acknowledgements:** This work was supported by Key R&D Program of Shanxi Province [202102090301006]; and "Yuezaki Young Scholars" Program of the Central University [2020YQHH03]; and Outstanding Youth Team Project of Central Universities [2023YQTD03]; and National Key R&D Program of China [2018YFC0406404].

## Video Presentation

### 5232: Effect of Climate Change on Morphological Divergence and Species Discrimination in Tropical Fish Species

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**Abstract.** Climate change is increasingly altering aquatic ecosystems, with potential consequences for fish morphology and species identification. This study aimed to investigate the effect of climate change on morphological divergence and species discrimination in tropical fish species. A total of 240 specimens representing two species (Clarias gariepinus and Oreochromis niloticus) were sampled across different habitats with contrasting environmental conditions. Morphometric measurements and geometric morphometric landmark analyses were conducted, while statistical methods including principal component analysis (PCA) and canonical variate analysis (CVA) were applied. The results revealed significant morphological divergence among populations, with PCA explaining 64.3% of total variance and CVA correctly classifying 88.7% of individuals into their respective species. Temperature and habitat variation strongly influenced body depth, head length, and caudal peduncle dimensions ($p < 0.01$), with species from warmer, shallower environments exhibiting deeper bodies and shorter heads compared to those from cooler, deeper habitats. These findings suggest that climate-driven environmental shifts are promoting morphological divergence that enhances species discrimination. The study concludes that morphological traits remain valuable indicators for monitoring the ecological impact of climate change on tropical fishes. It is recommended that conservation and management strategies incorporate climate-driven morphological monitoring into biodiversity assessments to improve resilience planning in vulnerable aquatic ecosystems.

**Keywords:** Climate Change, Morphological Divergence, Species Discrimination, Tropical Fish, Geometric Morphometrics

### 5240: Water Sustainability for Ecological Public Health in the Anthropocene

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**Abstract.** The disruptions of natural systems have imposed adverse consequential effects on human health, ecosystems and ecological public health worldwide. Water sustainability is one of the most vital natural resources that intricately connected to the evolving scientific conceptual framework of planetary health in this 21st century. The concept of planetary health recognizes that human well-being and Earth's life support systems are interdependent, necessitating water sustainability to address global ecological public health challenges such as climate change, biodiversity loss, and resource depletion. This paper focuses on the interconnectedness of planetary health and water sustainability in the Anthropocene. It involves analysing the arising global and ecological determinants of health, as well as the functioning of ecosystem services that are essential for maintaining clean air, water, and food to support sustainable health development. The impacts of water sustainability are closely associated with the integrity of the biosphere and planetary health systems, particularly in relation to global health systems from multiple perspectives. A web of dynamic interactions arises from the mediating effects of water depletion, which imposes diverse health trajectories, including the emergence and re-emergence of infectious diseases and global pandemics in this era of eco-environmental degradation and climate-mediated health risks. These challenges are especially pronounced in this new geologic epoch of the Anthropocene. The ultimate goal of this paper is to explore solution-oriented synergies between water sustainability and global ecological public health across generations. Planetary health education is therefore highly recommended as a cornerstone for fostering global partnership and transdisciplinary collaboration at this critical juncture in the Anthropocene.

**Keywords:** Water Sustainability, Ecological Public Health, Planetary Health Education

### 5288: Optimization and Design of Integrated Deepwater Drilling and Oil Pumping System for Shipwreck Residual Oil Recovery

Weiting Ning
*China Waterborne Transport Research Institute, China*

**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

### E5293: Assessment of Groundwater Quality and Irrigation Suitability in Selected Malaysian Aquifers Using Empirical Indices

Foo Chuan Hui
*Sultan Idris Education University, Malaysia*

**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

**5182: Mechanistic Investigation and Kinetics of Sodium Percarbonate-Induced Degradation of 2,4,6-Trichlorophenol in Groundwater Using Magnetite Catalysis**

Abubakar Aisha Gide
*Chengdu University of Technology, China*

**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

## Poster Presentations _ Part A

**5133: Efficient Inverse Estimation of Groundwater Contaminant Sources and Transport Parameters by Integrating Analytical Solutions with Bayesian MCMC**

Shiwing Chen
*Stantec Consulting Services Inc., Taiwan Branch*

**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

**5163: Understanding Flood Behavior in the Kashmir Himalayas Through Copula-Driven Models**

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**Abstract.** This research introduces a bivariate copula-based framework for flood frequency analysis at three key gauging stations, Asham, RM Bagh, and Sangam along the Jhelum River in Kashmir, India. This is the first study to use copula-based flood frequency analysis compared across these Jhelum stations and to report joint and conditional return periods. Flood characteristics, such as volume, duration and peak, were extracted using the annual maximum series method. Marginal distributions were selected using AIC, Kolmogorov–Smirnov, and Anderson–Darling tests, with CDF-based uncertainty analysis; The results illustrate that, based on maximal log-likelihood, minimal AIC/BIC, and corroborating uncertainty analysis, Clayton best fits both pairs at Asham, and Frank is optimal for volume–duration at RM Bagh and Sangam, and Gumbel best captures peak–volume at these stations. Joint and conditional return periods were calculated and graphically represented to evaluate flood severity. A significant correlation between flood volume and duration was observed at Asham, while weaker correlations were noted between peak and volume at the other stations. Moreover, joint return periods at Asham reach 100 years for peak flows of 170 to 200 $Mm^3$ per day with volumes of 1,500 to 2,000 $Mm^3$, and for volumes of 1,600 to 2,000 $Mm^3$ with durations of 30 to 45 days. At RM Bagh, the 100-year threshold occurs near peaks of 150 to 170 $Mm^3$ per day with volumes of 1,000 to 1,200 $Mm^3$ and for volumes of 1,200 to 1,500 $Mm^3$ with durations of 40 to 50 days; at Sangam, it occurs near peaks of 200 to 250 $Mm^3$ per day with volumes of 1,100 to 1,300 $Mm^3$ and for volumes of 1,000 to 1,300 $Mm^3$ with durations of 25 to 30 days, confirming Asham as the most at-risk location. These results emphasize the importance of strengthened flood risk management and demonstrate the practical utility of copula-based models in data-scarce, flood-prone regions.

**Keywords:** Bivariate Copula, Flood Frequency Analysis, Jhelum River Basin, Flood Management, Probabilistic Modelling

## 5172: Groundwater Response and Recharge Characteristics in the Haihe River Basin During the "23.7" Extreme Rainstorm Event

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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

## 5214: Integration of Satellite and Ground-Based Data to Assess Hydrological Droughts and Their Impact on Crop Yields in The Balkhash-Alakol Basin Under Climate Change

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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

## 5218: The Dual Role of Protozoa in Water Systems: Regulators of Microbial Communities and Public Health Risks

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**Abstract.** Protozoa are ubiquitous and ecologically significant microorganisms that play a pivotal role in the regulation of aquatic environments and the sustainability of water resources. As key components of microbial food webs, protozoa exert top-down control on bacterial populations through grazing, thereby influencing nutrient cycling, organic matter turnover, and the overall microbial community structure. Their selective predation not only prevents the excessive proliferation of pathogenic and opportunistic bacteria but also enhances water quality by maintaining microbial balance. In addition, protozoa contribute to the degradation of organic pollutants and the remineralization of essential nutrients such as nitrogen and phosphorus, processes that are fundamental for sustaining aquatic ecosystem productivity. Despite their ecological importance, protozoa can also serve as reservoirs or vectors for pathogenic microorganisms, including bacteria and viruses, raising concerns for public health, particularly in water reuse and wastewater treatment contexts. A comprehensive understanding of protozoan ecology is therefore essential for advancing water quality monitoring, optimizing treatment technologies, and ensuring sustainable management of water resources. This study aims to highlight the dual role of protozoa as regulators of microbial communities and as potential public health challenges, emphasizing their critical function in environmental protection and water security.

**Keywords:** Protozoa**,** Microorganisms**,** Environments, Microbial Community, Biodiversity, Pollution

## 5352: Evaluating the Effectiveness of Biochar in Reducing Nitrogen Leaching from Agricultural Soil in Nova Scotia

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**Abstract.** Biochar has emerged as a promising soil amendment to reduce nitrogen (N) losses from agricultural soils. This study evaluated the effectiveness of different biochar types and application rates in reducing nitrate and ammonium leaching from a Nova Scotia agricultural soil using column leaching experiments. Biochar application significantly ($p < 0.05$) reduced nitrate leaching from fertilized soils compared with the control. Poultry manure–derived biochars were more effective than wood-derived biochars, with high-temperature poultry manure biochar showing the greatest reduction. Increasing the application rate from 5 to 10 g $kg^{-1}$ soil did not significantly improve nitrate retention, except for MH biochar, which performed better at the higher rate. Wood-derived biochars slightly reduced ammonium leaching, while poultry manure–derived biochars tended to increase it over time. Overall, the findings highlight that biochar feedstock and production conditions strongly influence nitrogen leaching dynamics in agricultural soils.

**Keywords:** Biochar, Nutrient Leaching, Water Quality, Soil Amendment

## 5384: Inhibition of Antibiotic Resistance Genes by Indole-3-acetic Acid Mediated Root Exudates

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**Abstract.** Although the threat of antibiotic resistance genes (ARGs) in agriculture to human health has raised concerns, there is still a lack of effective and environmentally friendly measures to mitigate antibiotic resistance. Indole-3-acetic acid (IAA) and root exudates are environmentally friendly natural substances. However, the development of technologies harnessing their potential to suppress agricultural ARGs remains unexplored. Here, IAA mediated key root exudates, N-acetylserotonin and N-methyltryptamine, were found to effectively reduce ARGs in rhizosphere soil. They affected microbial community assembly and further shaped ARGs profiles. Additionally, they inhibited antibiotic-resistant bacteria, potentially suppressing the vertical transfer of ARGs. More importantly, N-acetylserotonin and N-methyltryptamine inhibited ARGs conjugative transfer through suppressing pili assembly and homologous recombination. Overall, IAA-mediated root exudates reduce ARGs in rhizosphere soil by influencing microbial community assembly and inhibiting ARGs transfer. This study provides inspiration for the development of technologies related to plant auxins and root exudates to reduce ARGs in agriculture.

**Keywords:** Agricultural Antibiotic Resistome, Plant Auxin, Indole Derivatives, Conjugative Transfer, Multi-Omics Analysis

**Acknowledgements:** This work was funded by the National Key R&D Program of China (2021YFC3200602), the Key Research and Development Program of Ningxia Hui Autonomous Region of China (Grant No. 2023BEG02053), and the Shanghai Chengtou Water Group Co. Ltd. Scientific Research Reserve Project (No. KY.ZH.24.008).

## 5391: A Machine Learning Model for Predicting Coastal Water Quality

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**Abstract.** Coastal ecosystems are facing critical water quality deterioration, while the most convenient passage to the South China Sea, Beibu Gulf, has been under considerable pressure to its ecological environment due to rapid development and urbanization. In this study, we characterized the spatio-temporal change in the water quality in Beibu Gulf and proposed a machine learning approach to predict the water pollution level in Beibu Gulf on the basis of 5-year (2018–2022) observation data of ten water quality parameters from ten selected sites. Random forest (rf) and linear algorithms were utilized.

**Keywords:** Machine Learning, Perdicting, Water Quality

## 5393: Liquid Cobalt Enables Selective Polyvinyl Chloride Dechlorination and $H_2$ Evolution

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**Abstract.** Poly(vinyl chloride) (PVC) is one of the largest commodity plastics, yet its high chlorine content and corrosive off-gases render conventional thermal recycling inefficient and hazardous. Here we show that a cobalt-doped Ga–In–Sn liquid metal (LMCo) can couple deep dechlorination of PVC with low-temperature $H_2$ production. Density-functional screening identifies LMCo as an optimal compromise between strong adsorption of PVC fragments and near-thermoneutral stabilization of PVC-derived H*, predicting facilitated C–Cl activation and $H_2$ recombination. Experiments on real PVC confirm this design: at 300 °C LMCo converts 62.4% of all hydrogen in PVC (93.7% of convertible H) into $H_2$ while removing ~95% of chlorine as HCl, far outperforming undoped and other M-doped LMs. Thermogravimetry and in situ TG–FTIR show that LMCo shifts dehydrochlorination to markedly lower temperature and suppresses radical cracking, yielding off-gases dominated by HCl and $H_2$ instead of aromatics. Electron microscopy, XPS, solid-state $^{13}C$ NMR, Raman and IR spectroscopy reveal that PVC in contact with LMCo transforms into a dechlorinated,

$sp^2$-rich porous carbon shell around the liquid droplets. Electronic-structure calculations and ab initio molecular dynamics show that the d orbitals of atomically dispersed Co strongly hybridize with the Ga–In–Sn electron sea, creating interfacial states that polarize and weaken the PVC C–Cl and C–H bonds and stabilize PVC-derived H*, thereby lowering the overall dehydrochlorination/dehydrogenation barrier to ~0.72 eV. This work establishes M-doped liquid metals as a tunable platform for upgrading chlorinated plastics into clean $H_2$ and functional carbon materials.

**Keywords:** Poly(vinyl chloride) (PVC), Liquid Metal Catalyst, Co-doped Ga–In–Sn, Dechlorination, Hydrogen Evolution

## 5395: Source Control of Airborne Zoonoses via Welfare-Aligned Upper-Room UVGI and Multi-Scale Risk Modeling

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**Abstract.** Not Available.

## 5396: Temperature Dependence of Halogen Radical Reactivity with Dissolved Organic Matter

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**Abstract.** Not Available.

## 5353: Spatio-Temporal Dynamics of Nitrogen Cycling in Erhai Lake

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**Abstract.** Nitrogen (N) cycling is fundamental to lake ecosystems, yet its spatiotemporal dynamics in Erhai Lake remain unclear. This study employed metagenomic approaches to investigate N-cycling pathways across seasonal (dry/wet) and spatial (water/sediment) gradients, revealing systematic spatiotemporal patterns in the lake's N transformations. Results showed that the Organic Degradation and Ammonia Synthesis (ODAS) pathway consistently dominated the N cycle. Seasonal analysis revealed distinct temporal variations: in the water column, ODAS, Nitrogen Fixation (NF), and Dissimilatory Nitrate Reduction to Ammonium (DNRA) showed higher relative abundances during the wet season, whereas denitrification and Assimilatory Nitrate Reduction to Ammonium (ANRA) were more prominent during the dry season. Nitrification remained weak in both seasons. In sediments, ODAS, denitrification, and DNRA were predominant year-round, with a seasonal reversal between ANRA and nitrification, where ANRA exceeded nitrification in the dry season. Spatially, denitrification was the second most dominant pathway in both water and sediments during the dry season, while DNRA and NF activities were stronger in sediments. During the wet season, water column dynamics shifted significantly: NF became the second most dominant pathway and DNRA exceeded denitrification in intensity, while sediment intensities of denitrification, DNRA, and nitrification all surpassed those in the water column. These findings systematically characterize the spatiotemporal dynamics of N cycling in Erhai Lake, highlighting the consistent dominance of ODAS, clear seasonal succession of pathways, and distinct habitat partitioning of N transformations, providing new insights into the biogeochemical functioning of this important lake ecosystem.

**Keywords:** Spatiotemporal Dynamics, Nitrogen Cycling, Metagenomics

**Acknowledgements:** This research is supported by the National Key Research and Development Program of China (Project Nos. 2024YFD1700100), the Key Research and Development Program of Yunnan (Project Nos. 202003AD150015, 202303AC100016 & 202303AC100017), the Yunnan Fundamental Research Projects (Project Nos. 202301AT070001), and the Scientific Research Development Project of Dali University (Project Nos. KY2519104340).

## 5404: Development of a Detection Method for Per- and Polyfluoroalkyl Substances (PFAS) in High-Matrix Refinery Wastewater

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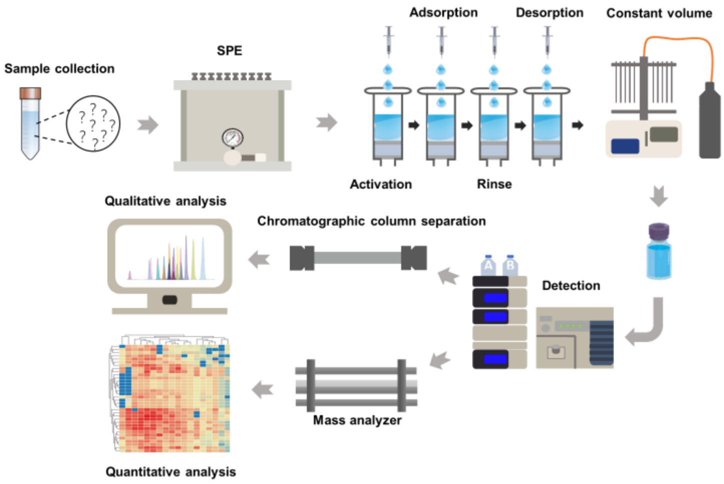
**Abstract.** Per- and polyfluoroalkyl substances (PFAS) are contaminants of increasing global concern due to their extreme persistence, capacity for bioaccumulation, and potential adverse effects on human health. The petroleum refining industry is a significant source of PFAS discharge, where the complex wastewater matrix—characterized by high organic content, salinity, and suspended solids—poses a

substantial challenge for accurate PFAS analysis. Conventional methods often suffer from inadequate sensitivity and complex pretreatment procedures, underscoring the need for a robust and reliable analytical approach. To address this, we developed and optimized a solid-phase extraction (SPE) coupled with ultra-performance liquid chromatography-tandem mass spectrometry (UPLC-MS/MS) method specifically for high-matrix refinery wastewater. The sample pretreatment protocol was critically designed to mitigate matrix interference. It involved sequential steps of vacuum filtration through a 0.45 μm PES membrane to prevent SPE cartridge clogging, liquid-liquid extraction with n-hexane to remove non-polar hydrocarbons, and pH adjustment to 3.0. For high-salinity samples (conductivity >5000 μS/cm), 5% (v/v) methanol was added to improve chromatographic performance. Samples were then enriched and purified using Oasis WAX SPE cartridges. After conditioning, a 500 mL sample was loaded, followed by washing with ammonium acetate buffer and ultrapure water. The analytes were eluted, concentrated under a gentle nitrogen stream, and reconstituted for instrumental analysis.

Chromatographic separation was achieved on a C18 column using a methanol/ammonium acetate gradient, and detection was performed via MS/MS in MRM mode. The method was rigorously validated, demonstrating excellent linearity ($R^2$ > 0.999) for all 18 target PFAS over a range of 1-100 μg/L. The limits of quantification (LOQs) were exceptionally low, ranging from 0.81 to 4.79 ng/L. Method accuracy and precision were confirmed through spike-recovery tests (70-134% ) with RSD below 20%.




In conclusion, the developed SPE-UPLC-MS/MS method effectively overcomes the matrix challenges of refinery wastewater, providing high sensitivity, accuracy, and robustness for monitoring trace-level PFAS, thereby fulfilling a critical need for environmental monitoring in the petroleum industry.

**Keywords:** PFAS, Detection Method, Refinery Wastewater

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## Poster Presentations _ Part B

### 5196: Evaluation of Ferric Chloride Applicability in Drinking Water Treatment Processes

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**Abstract.** In this study, the coagulation efficiency of ferric chloride was evaluated through batch-scale experiments using a jar tester and pilot-scale experiments using a horizontal-flow sedimentation basin, in order to assess its applicability in actual water treatment processes. The experimental results showed that ferric chloride achieved comparable turbidity and TOC removal rates at only 50–80% of the dosing levels typically required for aluminum sulfate. In samples with high concentrations of cyanobacteria (372,900 cells/mL) at pH levels above 9, ferric chloride demonstrated excellent coagulation performance—achieving 98.5% turbidity reduction and 48.8% TOC removal—without the use of a pH adjuster. Additionally, organic matter analysis using LC-OCD revealed that ferric chloride exhibited high removal efficiency across a wide range of organic fractions, from high-molecular-weight biopolymers to low-molecular-weight acids and neutrals. While ferric chloride may induce color in treated water, this is largely due to particulate matter (fine flocs) when dosed within the appropriate range of 40–60 ppm (v/v), and is expected to be largely controlled by subsequent rapid filtration processes. Furthermore, the corrosion index (LI) of settled water treated with ferric chloride ranged from moderate to strong (-1.71 to -2.61), which is less severe compared to the consistently strong corrosivity (< -3.00) of both raw and treated water at Plant B. This suggests that using corrosion-resistant materials for chemical injection piping and related infrastructure could effectively mitigate any corrosion concerns.

**Keywords:** Drinking Water Treatment, Cyanobacteria Bloom, Coagulant, Ferric Chloride

### 5197: A Study on the Behavior and Control of Odorants in Drinking Water Treatment Processes

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**Abstract.** This study investigated the removal characteristics and behavior of odor-causing organic compounds in water treatment processes to establish an odor management strategy for drinking water treatment plants. Ten odorants—Dimethyl

trisulfide (DMTS), 2-Methylbenzofuran, 3-Hexenylacetate, 2-Isopropyl-3-methoxypyrazine (IPMP), β-Cyclocitral (CCC), 2-trans-4-trans-Decadienal (DCDEN), trans-2-Decenal, 2-Isobutyl-3-methoxypyrazine (IBMP), β-Ionone (ION), and 2,4,6-Trichloroanisole (TCA)—were analyzed using SPME-GC/MS. DMTS and DCDEN were completely removed by chlorination (2 ppm, 30 minutes), but IPMP, IBMP, CCC, and TCA were not effectively removed by chlorination or ozonation alone. PAC (Powdered Activated Carbon) and BAC (Biological Activated Carbon) were effective for removing most odorants. In raw water from the Nakdong River (Mulgeum site), β-Cyclocitral was detected at 463±613 ng/L (ranging from 11 to 2,439 ng/L), and β-Ionone at 78±85 ng/L (non-detectable to 442 ng/L); the other eight odorants were not detected. β-Cyclocitral showed the highest correlation ($r^2 = 0.7825$) with cyanobacterial cell count, while β-Ionone showed a low correlation ($r^2 = 0.2008$) with *Microcystis*. At the Hwamyeong Water Treatment Plant, the sedimentation process achieved an average cumulative removal of 52.4% for β-Cyclocitral and 64.2% for β-Ionone. Both compounds were undetectable after post-ozonation and BAC treatment.

**Keywords:** Odorants, β-Cyclocitral, β-Ionone, Drinking Water Treatment Process

## 5215: $FeCl_3$- and $MnSO_4$-Modified Sewage Sludge Biochars for Heavy Metal Ion Adsorption in Semiconductor Wastewater

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**Abstract.** The expansion of the semiconductor industry has created an urgent need for the effective treatment of semiconductor wastewater. Due to the intricate nature of semiconductor manufacturing processes, the resulting wastewater is characterized by a complex mixture of organic chemicals and heavy metals, with copper (Cu) and nickel (Ni) being the most prevalent and challenging contaminants. The environmental risks associated with these pollutants have driven the exploration of advanced treatment technologies. Among these, adsorption is widely recognized for its efficiency and simplicity. However, the widespread application of traditional adsorbents such as activated carbon is hindered by their high production costs, necessitating the development of cost-effective alternatives. Biochar, a carbonaceous material derived from the pyrolysis of biomass, has attracted significant attention due to its economic viability and favorable adsorption properties, including a porous structure and high surface area. While a wide range of feedstocks has been investigated for biochar production, research on sewage sludge-derived biochar remains relatively underexplored. This study addresses this gap by synthesizing biochar from sewage sludge and enhancing its adsorption performance through modification techniques.

Various strategies exist for modifying biochar to improve its adsorption capacity, including chemical activation, thermal treatment, and impregnation with functional agents. Among these, modification using metal salts has emerged as a promising approach to improve surface properties and introduce active binding sites for heavy metals. In this study, ferric chloride ($FeCl_3$) and manganese sulfate ($MnSO_4$) were selected as the modifying agents to prepare two types of metal salt-modified biochars. These salts were chosen for their ability to generate iron and manganese oxides/hydroxides on the biochar surface, thereby increasing the availability of functional groups and enhancing metal ion affinity. Biochar was prepared via pyrolysis at temperatures ranging from 400°C to 800°C for 180 minutes. The physicochemical properties of unmodified and Fe/Mn-modified biochars were characterized using Brunauer-Emmett-Teller (BET) surface area analysis and field emission scanning electron microscopy (FE-SEM). Fourier transform infrared spectroscopy (FT-IR) was employed to analyze changes in surface functional groups induced by modification. Adsorption experiments targeting Cu(II) and Ni(II) ions were conducted under isothermal conditions, and residual concentrations were measured using inductively coupled plasma optical emission spectrometry (ICP-OES). The preliminary results suggest that increasing pyrolysis temperature improves the pore structure of biochar, which in turn enhances adsorption performance. Furthermore, both $FeCl_3$- and $MnSO_4$-modified biochars exhibited superior adsorption capacities compared to the unmodified biochar. These improvements are attributed to the combined effects of enhanced pore development and the deposition of iron and manganese species, which introduce additional active sites and promote ion exchange mechanisms, as supported by spectroscopic and morphological analyses. Overall, the findings indicate that Fe- and Mn-modified biochars are promising candidates for heavy metal remediation in wastewater treatment. Future research will focus on validating these results under real wastewater conditions, optimizing modification protocols, and exploring synergistic effects of multi-metal salt treatments to broaden the scope of applications.

**Keywords:** Adsorption, Biochar, Semiconductor Wastewater, Sewage Sludge

**Acknowledgements:** This research was supported by the Graduate School Specialization Project for Carbon Neutrality, funded by the Korea Ministry of Environment (MOE) through the Korea Environmental Industry & Technology Institute (KEITI).

## 5236: Enhanced Underground Pipeline Leakage Detection via Deep Denoising of Mel Spectrograms and Efficient CNN Classification

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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

**5262: A Review of Urban Flood Risk Analysis Methods and the Impacts of Flood on Power Supply and Drainage Infrastructure Systems**

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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

**5265: Controlled Phosphorus Release from Encapsulated Microalgae Biochar for Sustainable Agriculture**

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**Abstract.** Phosphorus (P) is essential for plant growth, and its incorporation into fertilizers is vital for contemporary agricultural practices. This study aimed to investigate the potential of potassium (K)-modified microalgal biochar as a slow-release phosphorus fertilizer. Microalgae (*Arthrospira platensis*) underwent co-pyrolysis at two distinct temperatures (500 and 550°C) with organic potassium compounds ($CH_3COOK$ and $C_6H_5K_3O_7$). This process enhanced the bioavailability of P compared to unmodified biochar. The total phosphorus (TP) content in the biochar was measured using a modified dry ashing method and bioavailability was assessed using 2% citric acid (CA), 2% formic acid (FA), and water solubility tests. The Hedley sequential extraction further confirmed this by demonstrating an increase in the readily available P fraction after K-modification. However, water-soluble results indicated that approximately 95% of phosphorus was released within 16 hours. Now to improve nutrient use efficiency and mitigate ingredient loss during transport and soil application, the biochar was encapsulated in sodium alginate beads, with calcium chloride serving as the cross-linking agent, which appears to be a beneficial approach. This finding suggests that biochar encapsulation could significantly enhance fertilizer use efficiency, functioning as an effective slow-release fertilizer, and that microalgae modified with specific organic compounds hold promise as slow-release phosphate fertilizers for agricultural applications.

**Keywords:** Biochar, Microalgae, Phosphorous Fertilizer, Phosphorous Fractionation, Slow-Release Fertilizer

## 5291: Constructing Confinement of Cobalt Nanoparticles Tip-Encapsulated in Carbon Nanotubes for Boosting Fenton-Like Catalysis

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**Abstract.** Cobalt-based heterogeneous catalysts are known to efficiently activate peroxymonosulfate (PMS) for emerging contaminant elimination, but limited mass transfer and loss of metal site still severely restrict their decontamination performance. Herein, we proposed a ZIF-67 derived catalyst (Co@CNT-NC) with cobalt nanoparticles (Co NPs) tip-encapsulated within carbon nanotubes (CNTs). The encapsulated Co NPs was not only more conducive to PMS activation, but also the introduction of CNTs created a confined nano-space to improve the mass transfer of reactants, thereby promoting contaminant degradation. Additionally, Co NPs were protected from corrosion by the CNTs, ensuring their stability. Comprehensive mechanism exploration identified HO• as the primary reactive species in the Co@CNT-NC/PMS system. Density functional theory (DFT) calculations further revealed that the confinement of Co NPs within CNTs enhances PMS adsorption, facilitates electron transfer, and lowers the free energy required for radical generation. Furthermore, a continuous catalytic device equipped with Co@CNT-NC-loaded membrane was also carried out to explore the application performance, achieving sustained 100% removal in the treatment of 5 L of atrazine (ATZ) wastewater, and efficient real hospital wastewater. This study offers a promising approach for developing heterogeneous catalysts that enhance Fenton-like catalysis, making them suitable for water treatment applications.

**Keywords:** ZIF-67, Carbon Nanotubes, Peroxymonosulfate, Nanoconfinement, Density Functional Theory Calculations

**Acknowledgements:** This work was supported by the Natural Science Basic Research Program of Shaanxi Province (2024JC-YBMS-126 and 2024JC-YBMS-375).

## 5292: Si–O Doped Layered Carbon-based Catalyst Boosts Nonradical Oxidation Pathways via Peroxymonosulfate Activation for Refractory Organic Pollutants Removal

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**Abstract.** Traditional Carbon-based catalysts often suffer from limited catalytic activity and stability in peroxymonosulfate (PMS) activation for pollutants degradation. In this study, a Si–O doped layered carbonaceous catalyst (Si/C@PDA) was

synthesized using natural vermiculite as the hard template, enabling the efficient PMS activation for ultrafast degradation of tetracycline (TC) ($k_{obs-TC}$ = 0.228 $min^{-1}$). The Si/C@PDA/PMS system demonstrated strong resistance to environmental matrix interference by enhanced singlet oxygen ($^1O_2$) generation and electron transfer processes (ETP). The experimental and density functional theory results prove that the Si–O site induced the cleavage of adsorbed PMS to promote the generation of $^1O_2$ though the self-decomposition of peroxymonosulfate anion radical ($SO_5^{\bullet-}$) and the disproportionation of superoxide radical ($O_2^{\bullet-}$). Meanwhile, the Si–O site also served as the electron transfer bridge facilitating electron migration from the pollutants to the Si/C@PDA/PMS*. In addition, the Si/C@PDA/PMS system integrated with membrane filtration technology achieved continuous degradation of TC with nearly 100% removal efficiency under a low oxidant dosage (0.1 mmol/L PMS). This work underscores the pivotal role of Si–O doping in modulating active sites to selectively promote nonradical pathways, thereby promoting effective pollutant degradation in complex water matrices and offering strategic insights for developing nonradical-dominated carbon-based catalysts.

**Keywords:** Carbon-based Catalysts, Si–O Doped, Peroxymonosulfate, Singlet Oxygen, Density Functional Theory Calculations

**Acknowledgements:** This work was supported by the Natural Science Basic Research Program of Shaanxi Province (2024JC-YBMS-126 and 2024JC-YBMS-375).

## 5308: AI-driven Prediction of Pre-ozonation Dose and Sensor Combination Optimization: An Approach Toward Smart Drinking Water Treatment Plants

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**Abstract.** Pre-ozonation is widely used in drinking water treatment plants to stabilize raw water quality. However, determining the appropriate ozone dose remains challenging due to its sensitivity to variable source-water characteristics and environmental conditions. In this study, machine learning (ML) models were developed using more than 210,000 real operational records from a full-scale plant in the Han River Basin to predict pre-ozonation dose in real time. Four ML families were evaluated, among which Random Forest (RF) ($R^2 > 0.96$) and CatBoost (CAT) ($R^2 > 0.97$) yielded the highest predictive performance, demonstrating robustness against fluctuations in online monitoring data. Feature importance analyses consistently identified temperature as the most dominant variable, while conductivity exhibited the lowest influence. Since increasing the number of sensors inevitably leads to higher

instrumentation costs and maintenance burdens, a systematic sensor-combination optimization was conducted by fixing temperature, excluding conductivity, and varying auxiliary inputs. The results demonstrated that using temperature alone was insufficient ($R^2 < 0.5$), whereas adding geosmin increased $R^2$ above 0.85 for both models, highlighting its operational relevance despite its relatively lower ranking in linear correlation analysis. Geosmin appeared in all of the top-performing sensor sets, confirming its substantial contribution to prediction accuracy. Moreover, both RF and CAT achieved near-optimal performance ($R^2 \approx 0.95$) using only three to four auxiliary variables-specifically alkalinity, turbidity, and geosmin in combination with temperature-indicating that additional sensors beyond this point provided diminishing returns. From a practical perspective, these findings demonstrate that real-time AI-driven pre-ozonation control can be achieved with a lightweight and cost-effective sensor configuration, offering guidance for the design and implementation of smart water treatment systems.

**Keywords:** Pre-Ozonation, Smart Water Treatment, Machine Learning

**5326: Pressure Fluctuation-Driven Transmission of Pathogen-Laden Aerosols in Building Drainage Systems: Mechanisms, Risks, and Mitigation Strategies**

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**Abstract.** Pressure fluctuations within building drainage systems represent a critical yet often underestimated public health risk, serving as the principal physical mechanism driving the reverse transmission of pathogen-laden aerosols into indoor environments. This review systematically elucidates the causal relationships and underlying mechanisms linking transient pressure changes—induced by activities such as fixture discharge—to the aerosolization and subsequent invasion of microbial pathogens from drainage pipelines into occupied spaces. A key focus is placed on the failure of water trap seals due to positive pressure transients, which facilitates the direct release of contaminated aerosols, as well as the ingress of sewer air under negative pressure conditions. The analysis further explores how aerosolization dynamics influence the survival and transmission efficiency of diverse pathogens, addressing factors such as the environmental persistence of non-enveloped viruses and the biofilm-forming propensity of pathogenic bacteria. The efficacy of innovative engineering controls—including active air admittance valves and pressure attenuation devices—is evaluated for their ability to mitigate risk by dynamically balancing pressure differentials and interrupting pathogen-specific transmission pathways. By integrating insights from aerosol science, building fluid dynamics, and environmental microbiology, this synthesis provides a robust theoretical foundation and technical framework for

advancing plumbing code revisions and developing targeted intervention strategies to minimize airborne disease transmission.

**Keywords:** Drainage Systems, Pathogen-Laden Aerosols, Pressure Fluctuation

## 5332: A Novel Strategy for Simultaneous Removal of Hardness, Suspended Solids and Organics from Fracturing Wastewater: Efficiency, Mechanism and Application

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**Abstract.** The coexistence of high hardness, turbidity, and organic matter in oilfield fracturing wastewater presents significant challenges for its reuse and the efficiency of conventional treatment methods. The accumulation of hardness-causing ions, suspended solids (SS), and organic pollutants complicates treatment processes, reducing both efficiency and sustainability in wastewater management. A practical solution is essential to enable large-scale reuse of oilfield wastewater while minimizing environmental impacts. This study introduced an innovative nucleation crystallization pelleting (NCP) process for the simultaneous removal of hardness, organic matter, and SS from wastewater. The method employed pre-added seeds with active sites, facilitating the deposition of $Ca^{2+}$ and $Mg^{2+}$ as $CaCO_3$, $Mg(OH)_2$, and $Mg_{0.03}Ca_{0.97}CO_3$ via $Na_2CO_3$ and NaOH addition. Organic matter was removed by co-precipitation and surface complexation, while SS adhered to the particle surface due to hydrodynamic action. Under optimal conditions (4200 mg/L $Na_2CO_3$, 1400 mg/L NaOH, 7.5% seed filling rate, and 80 m/h up-flow velocity), the three-stage NCP system achieved removal efficiencies of 95.6% for total hardness, 90.1% for TSS, and a 31.1% reduction in COD, with effluent hardness consistently remaining below 300 mg/L. These results satisfied the requirement that the total concentration of $Ca^{2+}$ and $Mg^{2+}$ ions in the field-prepared fracturing fluid remains below 150 mg/L. The process demonstrated stability across three reuse cycles, confirming the seeds' reliability, efficiency, and reproducibility. A pilot-scale NCP system with a treatment capacity of 50 $m^3$/h was developed, and 120 hours of continuous operation demonstrated stable effluent quality. Dense pellets (~1.2 mm) formed during the treatment required no additional processing. The findings confirmed that the NCP system effectively and reliably treats oilfield fracturing wastewater, achieving substantial removal of hardness, SS, and organic pollutants. The formation of dense pellets without generating sludge underscored its practicality for large-scale applications. This study offers a scalable and sustainable solution to wastewater treatment challenges, paving the way for broader adoption of NCP technology in industrial settings.

**Keywords:** Cucumber, Pathenocarpic, Growth, Yield, Seasons

## 5333: Efficient Organic Removal from Hypersaline Reverse Osmosis Concentrates Through a Hybrid Microbubble Ozonation-Coagulation Process: A Two-Stage Removal Procedure Caused by Two-Sided Effect of Salinity

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**Abstract.** Removal of organic matter in hypersaline reverse osmosis concentrate (ROC) poses significant challenges. In this study, the hybrid microbubble ozonation-coagulation (HOC) process was established for actual hypersaline ROC treatment from energy chemical industry. In this HOC process, the hypersaline environment facilitated the formation of microbubbles, which enhanced ozone mass transfer and ensured an adequate dissolved ozone concentration. Efficient organic removal was achieved through a two-stage procedure: a rapid-removal stage dominated by coagulation (≤ 30 min) and a slow-removal stage dominated by ozone oxidation (> 30 min). Moreover, salinity exhibited two-sided effect on oxidation and coagulation in the HOC process. In the first stage of the treatment process, the alkaline conditions in hypersaline environment promoted oxidation and coagulation through increased •OH production and polymerized Al species generation. However, as the pH decreased owing to coagulant hydrolysis, excessive anions in hypersaline environment inhibited both oxidation and coagulation processes by quenching •OH and promoting large floc generation in the second stage. Furthermore, the two-stage organic removal mechanism was elucidated from the perspectives of oxidative transformation and floc entrapment. In the first stage, high-coagulability organics were directly removed through enhanced coagulation. Meanwhile, low-coagulability organics were oxidized into high-coagulability structures, which were removed via coagulation. In the second stage, organic matter was mainly removed through molecular ozone oxidation, while the coagulation process was inhibited. This study unveiled the two-sided effect of hypersaline environment on oxidation and coagulation, and provided new approaches for enhanced organic removal in the ozone-based process for hypersaline wastewater.

**Keywords:** Hypersaline Reverse Osmosis Concentrate, Hybrid Microbubble Ozonation-Coagulation Process, Mass Transfer Enhancement, Coagulation, Two-Sided Effect

**Acknowledgements:** This work was supported by the National Natural Science Foundation of China (52422002, 52170052, 52230001), Natural Science Basic Research Program of Shaanxi (2024JC-TBZC-15), the Project of Qinchuangyuan Platform "Scientist + Engineer" Team of Shaanxi Province (2023KXJ-120).

**5401: Response of Supersaturated TDG Distribution Characteristics to Thermal Stratification in a Cascading Large Deep Reservoir**

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**Abstract.** Not available.

## Poster Presentations _ Part C

**5260: Pre-Assessment of Microplastic Pollution in Pasig River: Occurrence, Distribution and Type**

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**Abstract.** To avoid issues with similarity index, the abstract will be updated once the full paper is published.

**5270: Integrating Biodiversity into Ecosystem Service Assessment for Constructed Wetlands**

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**Abstract.** Global water systems are under increasing stress from urbanization and climate change highlighting the need for sustainable management strategies. Constructed wetlands (CWs) are among the most established nature-based solutions implemented for water treatment and climate mitigation. Biodiversity is central to sustaining these outcomes. However, biodiversity monitoring in CWs is often disconnected from performance evaluations that mainly focus on pollutant removal. A major challenge is the absence of structured monitoring frameworks and indicators linked suited to the unique design and functional goals of CWs. To address this gap, a Biodiversity-Based Ecosystem Service Index Framework for CWs was developed to link biodiversity with ecosystem service delivery. The structure is structured into two service-based indices: a Water Quality Regulation Index (WQI) and a Climate Regulation Index (CRI). The WQI encompasses nutrient cycling and pollutant degradation, while the CRI encompasses carbon sequestration and gas fluxes. Indicators span microbial, soil, and water datasets to connect biodiversity with functional outcomes. The framework was applied to two constructed wetlands in South Korea. Results showed microbial Shannon diversity ranging from 4.3 to 7.3 and

phylogenetic diversity between 2922 and 5528, reflecting diverse microbial communities. Soil organic carbon values were higher at inflow soils, ranging from 1.9 to 2.2 percent, and declined toward outflow soils, ranging from 0.3 to 0.8 percent, demonstrating carbon turnover along wetland flow paths. This study demonstrates how biodiversity data can be translated into standardized service-based indices, embedding biodiversity into performance assessment, aligning with global efforts to address the challenges of the climate crisis.

**Keywords:** Bioindicators, Ecological Assessment, Nature-based Solutions, Soil-Microbe Interactions.

**Acknowledgements:** This study was supported by the Korea Environmental Industry and Technology Institute's Wetland Ecosystem Valuation and Carbon Absorption Value Enhancement Technology Development Project funded by the Ministry of Environment (2022003630005).

## 5274: Estimation of Runoff Quality for Designing Green Infrastructure Functions in Large-scale Underground Stormwater Storage Facilities

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**Abstract.** Urban stormwater drainage systems are experiencing difficulties in maintaining their flood prevention functions due to high impervious surface ratios and abnormal climate conditions. Major cities worldwide are introducing policies for the construction of large-scale underground storage facilities to temporarily store stormwater runoff generated during peak flow periods as a measure to mitigate urban flooding. However, design concentrations of inflow water are required for environmentally friendly design that ensures ease of maintenance of underground storage facilities. Therefore, this study was conducted to analyze water quality data from urban stormwater drainage systems both domestically and internationally, characterize the water quality of stormwater runoff occurring after first flush, and propose design inflow concentrations for large-scale underground storage facilities. Approximately 50–80% of the total pollutant load was discharged during the first flush period. The design inflow concentration ranges for water entering underground storage facilities after first flush were found to be: BOD 10-60 mg/L, COD 25-150 mg/L, TSS 30-300 mg/L, TN 2-12 mg/L, TP 0.2-1.5 mg/L, Zn 0.10-0.40 mg/L, Cu 0.05-0.20 mg/L, and Pb 0.02-0.05 mg/L. Underground storage facilities can reduce 30-60% of influent TSS, TP, and metals through sedimentation mechanisms, but their removal efficiency

for dissolved pollutants and microorganisms is limited. The results of this study can be utilized to induce environmentally friendly design by pre-managing inflow water to underground storage facilities and to establish cost-effective maintenance management standards.

**Keywords:** Urban Flooding, Post-First Flush Runoff, Large-Scale Underground Storage Facility, EMC, Environmentally Friendly Design

**Acknowledgements:** This research was conducted with funding from the Ministry of Environment and support from the Korea Environmental Industry & Technology Institute's Wetland Ecosystem Value Assessment and Carbon Absorption Value Enhancement Technology Development Project (2022003630005).

## 5275: Evaluation of Heavy Metal Reduction Efficiency and Phytoremediation Performance of *Salix gracilistyla* in Multi-Metal Contaminated Soils

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**Abstract.** Heavy metal contamination in soil severely limits plant growth and poses ecological risks. This study evaluated the tolerance and metal reduction capacity of *Salix gracilistyla* Miq., a native willow species in Korea, under single and combined heavy metal stresses. Artificially contaminated soils were prepared with four gradient levels of Pb (400–3200 mg $kg^{-1}$), As (25–200 mg $kg^{-1}$), and Cd (20–160 mg $kg^{-1}$), as single (Pb, As, Cd) and mixed treatments (Pb×As, Pb×Cd, As×Cd, Pb×As×Cd).

Survival rate markedly declined in high-concentration Pb and As treatments (≥1600 mg $kg^{-1}$ and ≥100 mg $kg^{-1}$, respectively), whereas Cd-treated plants maintained 75–100% survival across all concentrations, indicating strong Cd tolerance. Both shoot length and dry biomass decreased with increasing contamination, most prominently in As and Pb×As treatments, while Cd treatments showed relatively stable growth.

Metal accumulation analysis revealed that Pb primarily accumulated in roots (BCF = 0.22, TF = 0.21), indicating a root-immobilizing characteristic, while Cd exhibited higher translocation potential (BCF = 0.48, TF = 0.47). Arsenic showed limited mobility with low TF values (<0.2). In mixed treatments, metal interactions altered uptake patterns, with Cd absorption varying by ±30% compared with single treatments. These findings demonstrate that *S. gracilistyla* possesses strong survival capacity and selective Cd uptake and translocation abilities under multi-metal stress, suggesting its potential as a promising candidate for phytoremediation of Cd-dominant contaminated soils.

**Keywords:** *Salix Gracilistyla*, Phytoremediation, Heavy Metal Tolerance, Metal Accumulation, Translocation Factor (TF), Bioconcentration Factor (BCF), Combined Metal Contamination

**Acknowledgements:** This study was supported by the Korea Environmental Industry and Technology Institute's Wetland Ecosystem Valuation and Carbon Absorption Value Enhancement Technology Development Project funded by the Ministry of Environment (2022003630005).

## 5276: Evaluating the Potential of Constructed Wetlands as a Nature-Based Solution for Antibiotic Resistance Management

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**Abstract.** has led to the emergence of antimicrobial resistance (AMR), posing a serious public health concern. Livestock wastewater is one of the major sources of antibiotic discharge, yet the implementation of advanced treatment technologies in conventional wastewater treatment plants is often limited due to high costs and technical constraints. This study aimed to evaluate the effectiveness of a constructed wetland, nature-based solution (NbS), in reducing antibiotics and antibiotic resistance genes (ARGs) in livestock wastewater. The study site is a constructed wetland located in Seongju-gun, Gyeongsangbuk-do, Republic of Korea, established in 2016 to provide secondary treatment for effluent from a livestock wastewater treatment plant. Water samples were collected from the influent, within the wetland, and at the effluent outlet. Antibiotic concentrations were analyzed using liquid chromatography–mass spectrometry (LC-MS/MS), while ARG abundance was examined through shotgun metagenomic sequencing. Removal efficiencies for Ampicillin (8–33.5 ppb), lincomycin (174.4–205.9 ppb), and carbamazepine (2.2–2.8 ppb) ranged from 14.5% to 100%. In contrast, ciprofloxacin, norfloxacin, sulfamethoxazole, and trimethoprim exhibited higher concentrations in the effluent than in the influent, suggesting their persistence within the wetland. The ARG analysis showed that genes associated with quinolone resistance were present in relatively low proportions, while tetracycline-related ARGs accounted for 32.1% of the total detected ARGs, despite the absence of tetracycline compounds in the chemical analysis. This discrepancy suggests that the presence or concentration of antibiotics in water may not always correspond to the abundance of their associated resistance genes. Moreover, this result suggests that high antibiotic concentrations may not always lead to a high prevalence of corresponding ARGs, and vice versa. Therefore, assessing antimicrobial resistance risks requires an integrated approach that combines both chemical data (antibiotic concentrations) and genetic data (ARG profiles) to obtain

a more accurate and comprehensive understanding of AMR dynamics in constructed wetlands.

**Keywords:** Constructed Wetland, Antibiotics, Antibiotics Resistance Gene, Antimicrobial Resistance

**Acknowledgements:** This study was supported by the Korea Environmental Industry and Technology Institute's Wetland Ecosystem Valuation and Carbon Absorption Value Enhancement Technology Development Project funded by the Ministry of Environment (2022003630005).

## 5367: Research Advancements on Agricultural Non-Point Source Pollution in Major Lake and Reservoir Watersheds of China: Status, Sources, Monitoring, and Prospects

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**Abstract.** Agricultural non-point source pollution (ANPSP) has become a global environmental issue due to its widespread dispersion, difficulty in treatment, and delayed impact. Compared with point source pollution, the monitoring, pollution load accounting, and management of non-point source pollution have proven to be more challenging, particularly at the watershed scale. To comprehensively assess the current status of control and monitoring of ANPSP in watersheds and formulate new monitoring schemes, this paper reviews the specific situation and research status of ANPSP in major lake and reservoir watersheds of China and specifically analyzes the sources of ANPSP in four main dimensions, including farmland cultivation sources, livestock and poultry breeding sources, aquaculture sources, and rural domestic sources. On this basis, we also describe the current technical deficiencies for monitoring ANPSP in key watersheds. This review also puts forth a comprehensive three-dimensional monitoring network, termed “sky-air-land-lake,” and elucidates the present status of monitoring and assessment in each dimension. This study has a positive role and theoretical value in further strengthening ANPSP control technology, improving the quality of the rural ecological environment, and enhancing the output value of cultivation and breeding.

**Keywords:** Agricultural Non-Point Source Pollution, Watershed Scale, Monitoring and Model Evaluation, Major Lakes and Reservoirs

## 5370: Sustainable Cr(VI) Electroplating Rinsing for Efficient Wastewater Recovery and Stable Coating Quality

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**Abstract.** The rinsing process in conventional chromium electroplating generates large volumes of Cr(VI)-containing wastewater and also causes corrosion of plated parts due to the presence of impurity ions in the wastewater. To address this issue, this study proposes an online separation system that integrates the corrosion control of plated parts with the efficient recovery of resources from Cr(VI)-containing rinse wastewater. By optimizing the rinsing configuration and flow rates, the concentration of impurity ions is reduced by 46.23%, significantly lowering part corrosion by 70.4%. Through selective anion exchange and gradient concentration, Cr(VI) is purified from an initial concentration of 477.7 mg/L to below China's discharge standard (0.1 mg/L) and concentrated for the production of high-purity sodium chromate (purity 98.87%, recovery efficiency 98.47%). The resulting chromium-free effluent is treated using NF/RO, achieving 58.15% acid recovery and 81.2% water recovery. Techno-economic analysis (TEA) and life cycle assessment (LCA) show that the cost of this process is US$1.21 per cubic meter of wastewater, which is only 1/12 the cost of conventional reduction-precipitation methods, and it features a 67.25% lower global warming potential. This work offers a sustainable and cost-effective solution for the circular utilization of Cr(VI) rinse wastewater and the stability of electroplated coatings.

**Keywords:** Chromium-Containing Rinse Wastewater, Countercurrent Rinsing, Corrosion Reduction, Membrane Technology, Resource Recovery

## 5380: Photoelectrocatalytic Conversion for Wastewater to Hhigh-value Chemicals and Energy

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**Abstract.** Wastewater is a potential resource warehouse, and converting wastewater into treasures is significant in addressing the environmental and energy crisis. The solar-driven photoelectrocatalytic (PEC) process is considered a promising technology because it can utilize solar light for driving chemical conversion. However, previous studies on the PEC process have mainly focused on wastewater purification and water splitting, overlooking its potential for chemicals (fine products, ammonia, hydrogen peroxide, and metal resources) extraction and energy (hydrogen and electricity) recovery. Thus, a review of in-depth understanding and state-of-the-art account on multifunctional PEC-coupled processes that aim to integrate wastewater treatment and resource conversion is desired. This review offers an overview of PEC-coupled processes for the recovery of valuable resources from wastewater. First, several typical wastewaters are pointed out and their potential for resource utilization is assessed separately. Next, the wastewater treatment mechanism and the recovery model of valuable resources in the PEC wastewater treatment system are recalled. Then, the recent progress is comprehensively overviewed and discussed in the PEC conversion of various wastewaters into high-value chemicals and energy. Finally, the main challenges and future perspectives for PEC wastewater resourcing are presented. This review points the path for PEC technology to address the solar-wastewater-energy nexus and offers evolutionary opportunities for future generations of waste-to-chemicals/energy conversion processes.

**Keywords:** Photoelectrocatalytic Process, Wastewater Treatment, Resource Conversion, Chemicals and Energy Recovery

## 5381: Decoding the Divalent Cation Effect on Sulfidation of Zero-Valent Iron: Phase Evolution and FeSx Assembly

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**Abstract.** The decontamination ability of sulfidated zero-valent iron (S-ZVI) can be enhanced by the effective assembly of iron sulfides (FeSx) on neglected heterogeneous surfaces by liquid-phase precipitation. However, S-ZVI preparation with the usual pickling is detrimental to orderly interfacial assembly and leads to an imbalance between electron transfer optimization and electron storage. In this work, S-ZVI was prepared in solutions containing trace divalent cation, and it removed Cr(VI) up to 323.25 times higher than ZVI. This result is achieved by surface sites protonation of divalent cations regulating the phase evolution on the ZVI surface and inducing FeSx chemical assembly. Regulation of divalent cation and S(-II) content further promotes FeSx targeted assembly and reduces electron storage consumption as much as possible. The barrier for FeSx assembly is found to lie at the ZVI interface rather than in the deposition between FeSx. Chemical assembly at heterogeneous interfaces is a pre-requisite for the ordered assembly of FeSx. In addition, S-ZVI prepared in simulated groundwater showed extensive preparation pH and universality for remediation scenarios. These findings provide new insights into the development of in-situ sulfidation mechanisms with particular implications for S-ZVI applied to soil and groundwater remediation by the regulation of heterogeneous interfacial assembly.

**Keywords:** Sulfidated Zero-Valent Iron, Divalent Cations, Phase Evolution, Fesx Assembly, Electrokinetics-Permeable Reactive Barrier

### 5385: Enhanced •Cl Generation by Introducing Electrophilic Cu(II) in $Co_3O_4$ Anode for Urine Treatment

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**Abstract.** Urine is a nitrogen-containing waste, but can be used as an attractive alternative substrate for $H_2$ recovery. However, conventional urea oxidation reaction is subject to complex six-electron transfer kinetics and requires alkaline conditions. Herein, an efficient method of enhancing •Cl generation by introducing electrophilic Cu(II) into $Co_3O_4$ nanowires anode was proposed, which realized the highly efficient TN removal and $H_2$ production in urine treatment under neutral conditions. The key mechanism is that the electrophilic effect of Cu(II) attracts electrons from the oxygen atom, which causes the oxygen atom to further attract electrons from Co(II), reducing the charge density of Co(II). Electrophilic Cu(II) accelerates the difficult conversion step of Co(II) to Co(III), which enhances the generation of •Cl. The generated •Cl efficiently converts urea to $N_2$, while the electron transport promotes $H_2$ production on the CuO@CF nanowires cathode. Results showed that the steady-state concentration of •Cl was increased to about 1.5 times by the Cu(II) introduction. TN removal and $H_2$ production reached 94.7% and 642.1 μmol after 50 min, which was 1.6 times and 1.5 times that of $Co_3O_4$ system, respectively. It was also 2.3 times and 2.1 times of $RuO_2$, and 3.3 times and 2.5 times of Pt, respectively. Moreover, TN removal was 11.0 times higher than that of without •Cl mediation, and $H_2$ production was 4.3 times higher. More importantly, excellent TN removal and $H_2$ production were also observed in the actual urine treatment. This work provides a practical possibility for efficient total nitrogen removal and hydrogen recovery in urine wastewater treatment.

**Keywords:** Urine Treatment, $H_2$ Production, TN Removal, •Cl Generation,

Electrophilic Cu(II), Co(II)/Co(III) Conversion

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## 5394: Reversed $I_1Cu_4$ Single-atom Sites for superior Neutral Ammonia Electrosynthesis with Nitrate

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**Abstract.** Electrochemical ammonia ($NH_3$) synthesis from nitrate reduction (NITRR) offers an appealing solution for addressing environmental concerns and energy crisis. However, most of the developed electrocatalysts reduce $NO_3^-$ to $NH_3$ via a hydrogen (H*)-mediated reduction mechanism, which suffers from the undesired H*-H* dimerization to $H_2$, resulting in unsatisfactory $NH_3$ yields. Herein, we demonstrate that reversed $I_1Cu_4$ single-atom sites, prepared by anchoring iodine single atoms on Cu surface, could realize superior NITRR with an unprecedented $NH_3$ yield rate of 4.36 mg $h^{-1}$ $cm^{-2}$ and a Faradaic efficiency of 98.5% under neutral condition via a proton-coupled electron transfer (PCET) mechanism, far beyond those of the traditional Cu sites ($NH_3$ yield rate of 0.082 mg $h^{-1}$ $cm^{-2}$ and Faradaic efficiency of 36.5%) and most of the traditional H*-mediated NITRR electrocatalysts. Theoretical calculations revealed that I single atoms can regulate the local electronic structures of adjacent Cu sites in favour of stronger O-end-bidentate $NO_3^-$ adsorption with dual electron transfer channels, and suppress the H* formation from $H_2O$ dissociation, thus switching the NITRR mechanism from H*-mediated reduction to PCET one. This study offers novel single-atom electrodes for electrochemical ammonia synthesis with nitrate wastewater, and sheds light on the importance of switching catalytic mechanism in improving the performance of electrochemical reactions.

**Keywords:** Reversed Single-Atom Configuration, Non-Metal Single Atom, Electrocatalytic Nitrate Reduction, Ammonia Synthesis, Proton-Coupled Electron Transfer Mechanism

## 5397: Formation of Odorous By-Products during Chlorination of Algae Organic Matter: Evolution, Mechanism, and Key Precursors

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**Abstract.** Not Available.

## 5140: Stochastic Multi-Criteria Decision-Making for Improved Reservoir Operations

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**Abstract.** Reservoir operations involve complex decision-making processes that balance conflicting objectives, such as water supply, flood control, hydropower generation, and environmental sustainability. Traditional deterministic Multi-Criteria Decision-Making (MCDM) methods often fail to capture the uncertainties inherent in reservoir management. This study introduces an integrated SMAA-MCDM framework that account for uncertainties in criteria weights and performance scores. The five key evaluation metrics—Rank Acceptability Index (RAI), Central Weight Vectors (CWVs), Holistic Acceptability Index (HAI), Rank Uncertainty Degree (RUD), and Risk of Errors in Decision-Making (REDM)—are used along with four uncertain weight scenarios (missing, deterministic, uniform, and normally distributed). The results demonstrate the effectiveness of stochastic MCDM in improving the resilience of reservoir operations under uncertainty and reducing the risk of suboptimal decisions. This study contributes to the field by offering a more reliable and adaptive decision-support tool for water resource managers facing uncertain climatic and hydrological conditions.

**Keywords:** Stochastic MCDM, Reservoir Operations, Decision-Making Under Uncertainty, Rank Acceptability Index, Water Resource Management

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