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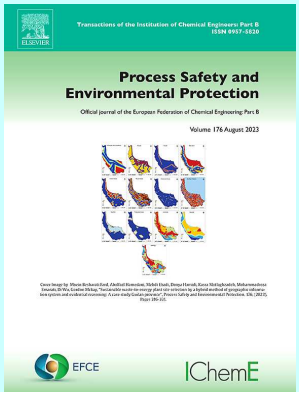

Lingmin Wu, Jinjun Deng, Hongsheng Liu, Hailin Yu, Huili Zhang, Yanbin Tong, Liqun Sun, Fankun Meng, Li Zhao. *Understanding synergistic mechanisms of silicate decorated polyaluminium chloride and organic polymer flocculation for enhancing polymer-flooding wastewater treatment*. Pages 1-10.

The efficient removal of oil droplets and particles from volumes of a stable emulsified oil-contaminated polymer-flooding wastewater has been an interesting yet challenging research topic within the oilfield. In this work, a highly efficient composite flocculant (PAC-PSi-PDMDAAC) was prepared by modifying activated silicic acid onto polyaluminium chloride (PAC) through Si-O-Al bond firstly and then combined with polydimethyldiallyl ammonium chloride (PDMDAAC) by physical blending, the preparation conditions and the flocculation parameters that influence of the turbidity removal and oil removal were experimentally investigated. The optimal conditions are shown as follows: pH= 3.04, PAC/PSi = 5:1, PAC/PDMDAAC = 1:0.3. The characterization of composites were analyzed by Fourier infrared (FTIR), Thermogravimetry (Tg) and Static light scattering (SLS). The results revealed that PAC underwent the addition of PSi and PDMDAAC to form high-polymeric species. In addition, the formation of more denser flocs in wastewater treatment was affirmed with scanning electron microscope (SEM) analysis. The flocculation experiments results showed that the maximum turbidity removal rate and oil removal efficiency for polymer-flooding wastewater could reached 98.3% and 91.3% at dosage of 120 mg/L, respectively, and its flocculation efficiency was much better than that of flocculants (PAC, PAC-PSi and PAC-PDMDAAC), which confirmed the synergistic enhancement of performance of PAC by PSi and PDMDAAC. However, the Zeta potential results indicated that the maximum Zeta potential value of PAC-PDMDAAC treatment was not beneficial for oil and particles removal, which indicated the adsorption bridging effect of lager aggregates played a most significant role in the flocculation process. And this newly synthesized PAC-PSi-PDMDAAC would be a promising flocculant for polymer-flooding oily wastewater treatment to reduce oil and particulate matters.

- **Keywords:** PAC-PSi-PDMDAAC; Inorganic-organic flocculant; Polymer-flooding wastewater; Synergistic effect; Bridging capacity

Hongfei Xu, Faisal Khan, Seungho Jung, Qingsheng Wang. *Probabilistic model for hydrate and wax risk assessment in oil and gas pipelines*. Pages 11-18.

Hydrates and wax are common hazards for oil and gas pipelines. The formation of hydrates and wax can lead to pipeline blockage, which may cause accidents incurring significant assets, safety, and environmental losses. The current study aims to develop a risk-based flow assurance model for hydrates and wax. The probabilistic models are developed to assess the likelihood of hydrate formation, hydrate blockage, and wax blockage. The proposed models use thermo-hydraulic data to estimate the probability of pipeline blockage hazards. The developed models are tested against the published studies and lab data. Application of the models is demonstrated using case studies. The models would help develop and implement pipeline design and intervention strategies to ensure a safer continued operation pipeline system.

- **Keywords:** Hydrate; Wax Blockage; Risk Assessment; Flow Assurance

Haoyuan Xu, Tao Wang, Yunlong Zhou, Mingxing Zhao, Wansheng Shi, Zhenxing Huang, Wenquan Ruan. *Insights into the phenol disinfectant on the methane performance from wastewater by mesophilic anaerobic digestion: Single and two stages analysis*. Pages 19-27.

In this study, the effect of different phenol disinfectant concentration on wastewater anaerobic digestion was indicated. The results indicated that the cumulative methane production decreased with the increase in the concentration of phenol disinfectant. The difference in the cumulative methane yield from disinfectants at concentrations of 0.04 mL/L, 0.2 mL/L, 0.4 mL/L and 0.8 mL/L was not significant ($P \geq 0.05$). However, the disinfectant concentration of 1.6 mL/L and 2.4 mL/L caused a decrease in methane yield by 69.98% ($P < 0.05$) and 100% ($P < 0.05$), respectively. The addition of phenol disinfectant led to the accumulation of volatile fatty acids (VFA), affected the secretion of extracellular polymeric substances (EPS) and the construction of anaerobic sludge. With the increase in disinfectant concentration, the activity of acetate kinase and coenzyme F420 were decreased. Furthermore, microbial community analysis indicated that the dominant bacteria were Firmicutes, Chloroflexi, Actinobacteria and Proteobacteria. The addition of disinfectant inhibited the growth of Methanosaeta and Methanobacterium. In addition, the high concentration of the disinfectant inhibited acidification and methanation process during the anaerobic digestion (AD) process and the inhibition was stronger in the methanation stage than in the acidification stage.

- **Keywords:** Phenol disinfectant; Anaerobic digestion; Methane production; Inhibition; Microbial communities

Wang Yuxin, Fu Gui, Lyu Qian, Li Xiao, Chen Yiran, Wu Yali, Xie Xuecai. *Modelling and analysis of unsafe acts in coal mine gas explosion accidents based on network theory*. Pages 28-44.

Coal mine accident prevention is a key issue affecting the safety of coal production in China. From accident analysis, it has been found that the interaction of unsafe acts of coal miners is the main cause of catastrophic accidents, and that ignoring the interrelationship between behaviors may lead to missing hidden chains of incidents as well as to a gross underestimation of behavioral risk. Therefore, to solve the above problems, it is of significant practical importance to explore unsafe acts in accidents as a collection and to analyse their evolution and development trends. The purpose of this study is to analyse the interrelationships and potential behavior patterns among unsafe acts in coal mine gas explosion accidents from the perspective of network modelling and to propose a modelling method for the mine accident unsafe acts network (MAUAN).

First, by mining the causes in 86 gas explosion accident reports, a MAUAN network composed of 95 unsafe-act nodes and 681 edges was determined. Second, by calculating the topology of the MAUAN, 3 key unsafe acts and 6 key behavior paths in the gas explosion accidents were determined. The research results show that 91% of unsafe acts in gas explosion accidents were violations. The lack of safety education and skills training for miners is the most influential unsafe act in gas explosion accidents, and the absence of operating procedures or prevention measures → failure to check gas concentration → risky operation without safety safeguards was the most critical link leading to the occurrence of gas accidents. Third, illegal mining practices have become another urgent problem today—in addition to gas accumulation and ignition source generation—with 83% of gas explosion accidents involving illegal mining. This study provides a reference for accident causation modelling and the identification of key causal factors from accident report data, and the results of the analysis provide a basis for decision making in coal mine accident prevention efforts to reduce future mining accidents.

- **Keywords:** Coal mine; Gas explosion accident; Unsafe act; Complex network modelling; Accident analysis

Jiao Qu, Jun Deng, Zhen-Min Luo, Yang Xiao, Chi-Min Shu. *Thermal reaction characteristics and microstructure evolution of aluminium nano-powder in various mixtures of oxygen and nitrogen atmosphere*. Pages 45-53.

Aluminium nano-powder has a small particle size, large specific surface area, and high surface energy, therefore when using it, the risk of fires or explosions is high. In this study, synchronous thermal analyser was used to determine the thermal reaction characteristics of aluminium nano-powder for various oxygen and nitrogen mixtures. The results showed that the oxidation behaviour of aluminium nano-powder could be considered to occur in four stages, according to the characteristic temperature points and polymorphic phase changes. Under experimental heating rates of 5, 10, 15, and 20 K/min, the mass gain and thermal effects of the samples were tested, and also for different oxygen concentrations of 9, 15, and 21 vol%. Changes in the microstructure of the samples were analysed. Oxide layer thickness was found to increase as temperature increased, and this trend was the same for mass change. Surface morphology images of the aluminium particles exhibited agglomeration, melting deformation, rupture, and fragmentation at the different pretreated temperatures of 500, 650, 800, and 900 °C. The results of this study could be used as a basis for exploring oxidation kinetics, and had significance for explosion-proofing technology, particularly with respect to aluminium nano-powder.

- **Keywords:** Characteristic temperature point; Polymorphic phase change; Thermal effect; Oxide layer thickness; Surface morphology

Faezeh Mirshafiee, Salman Movahedirad, Mohammad Amin Sobati, Reyhaneh Alaee, Sasan Zarei, Hamed Sargazi. *Current status and future prospects of oxidative desulfurization of naphtha: a review*. Pages 54-75.

Desulfurization of fuels is a critical process in oil refining due to the destructive effects of sulfur compounds on human health and the environment. Naphtha is an important middle distillate product, which is utilized as an automobile, engine, and jet-B fuel or blended with other fuel fractions. Therefore, the quality of the produced naphtha is essential in terms of sulfur content. Nowadays, hydrodesulfurization (HDS) is widely used in many refineries to remove the sulfur compounds from fuels. This method needs high temperature and pressure, higher investment costs, and in-situ hydrogen sources. The oxidative desulfurization (ODS) is recommended as a suitable alternative or

complementary process to HDS due to the mild reaction conditions and lack of hydrogen requirement. In recent years, the oxidative desulfurization of many real fuels such as diesel has been investigated. However, a few numbers of studies reported the oxidative desulfurization of naphtha fraction. Therefore, it is essential to address the ODS challenges for naphtha, especially in mini-refinery applications. In this study, the naphtha cuts and their compounds, the mechanism of ODS, classification and comparative analysis of different ODS methods, different types of oxidants/catalysts, and the kinetics of ODS reaction have been examined comprehensively. In addition, the effect of various parameters, such as temperature, pH, catalyst content, and oxidation time on the desulfurization efficiency is investigated. Finally, the research gaps in this field have been discussed, and suggestions for future studies in the field of oxidative desulfurization of naphtha have been proposed.

- **Keywords:** Oxidative desulfurization; Naphtha fraction; Oxidants; Sulfur; Kinetics

Xingyuan Miao, Hong Zhao, Zhaoyuan Xiang. *Leakage detection in natural gas pipeline based on unsupervised learning and stress perception*. Pages 76-88.

Natural gas pipeline leakage can cause serious financial losses to natural gas transportation and pose accidents to the environmental safety. Currently-used supervised learning methods heavily rely on sufficient pipeline failure historical data for their training. Therefore, we propose a novel detection approach based on unsupervised learning and stress perception for determining the leakage situation in pipelines. In this study, pipeline stress signals are first acquired based on residual magnetic effect. The relationship between residual magnetic and stress is built using improved sparrow search algorithm (ISSA) and extreme learning machine (ELM). Then, the Wasserstein generative adversarial network with gradient penalty (WGAN-GP) is deployed to learn suitable features from the stress signals under the pipeline normal condition, generating high-quality stress data features. Finally, the generated stress features are supplied to the Bayesian Gaussian mixture model (BGMM). And the weighted logarithm probability (WLP) is used as the health indicator for examining pipeline status. The results demonstrate that the relative error of residual magnetic stress model is controlled within 3 %, and the WLP value of fault samples is smaller than − 100, so that the proposed method can discriminate the normal and leak conditions as well as the risk and severity of leakage. This study provides a theoretical basis and new perspective for pipeline leakage detection.

- **Keywords:** BGMM; ISSA-ELM; Pipeline leakage detection; Residual magnetic effect; Stress perception; WGAN-GP

Hamid Shakibi, Navid Nedaei, Amir Hamzeh Farajollahi, Ata Chitsaz. *Exergoeconomic appraisement, sensitivity analysis, and multi-objective optimization of a solar-driven generation plant for yielding electricity and cooling load*. Pages 89-111.

Solar energy-driven generation units can assist in moderating energy-linked environmental issues. For this target, a new solar heliostat-based generation unit is suggested for electricity generation as the crucial product. A heliostat-based solar unit with a closed Brayton cycle and thermal energy storage unit is coupled with a Kalina cycle and an absorption refrigeration unit through a single-effect absorption chiller as an inimitable series of power plants. Exergy, economic, and energy investigations are carried out to scrutinize the efficiency of the introduced unit, and a thorough parametric evaluation is performed. Multi-aspect optimization is implemented to identify the optimum decision values, regarding four various scenarios, namely exergy performance/ sum unit cost of the product, exergy performance/ coefficient of performance,

NPV/exergy performance, and exergy performance/ cooling load. In this regard, The Grey Wolf Optimizer is the multi-objective optimization method, and TOPSIS, LINMAP, and Shannon entropy approaches assist the optimization procedure in acquiring the optimal solution in each scenario. The results indicate that the optimized exergy performance, coefficient of performance, and sum unit cost of the product are computed as 33.48 %, 0.817, and 3.44 $/GJ, respectively.

- **Keywords:** LINMAP; Multi-objective optimization; Response Surface methodology; Shannon entropy; Solar-driven KC-Brayton plant; TOPSIS

Dyg Siti Nurzailyn Abg Shamsuddin, Ahmad Faris Mohd Fekeri, Andanastuti Muchtar, Faisal Khan, Bee Chin Khor, Bee Huah Lim, Masli Irwan Rosli, Mohd Sobri Takriff. *Computational fluid dynamics modelling approaches of gas explosion in the chemical process industry: A review*. Pages 112-138.

Previous studies have revealed that major accidents in Chemical Process Industry (CPI) are most commonly due to explosions. Thus, analytical studies of explosion-related risk assessments are performed to predict the consequences of potential explosions. As physical experiments on explosions are very expensive, modelling and simulation techniques using theoretical models are becoming increasingly popular, allowing researchers to replicate the potential explosion scenarios. In this regard, computational fluid dynamics (CFD) models are more than appropriate. Although CFD simulations are widely applied, they have several weaknesses such as high computational costs as well as potential simulation inaccuracies due to inaccurate modelling steps. The weaknesses can be overcome with appropriate techniques such as model simplification, defining the appropriate method, grid design and boundary conditions. Many studies have reported different aspects and perspectives of explosion modelling and simulation techniques, but few evaluate the techniques across every different type of explosion. This subject is critical, as modelling steps and techniques directly affect the accuracy of simulation results. Hence, a review of the assumptions and simulation techniques that are used to reduce the computational costs associated with gas explosion modelling for each of the different explosion types is presented.

- **Keywords:** Chemical process industry; Explosion; Computational fluid dynamics simulation; Risk assessment; FLACS; Fluent

Hongliang Wang, Zhanguo Su, Azher M. Abed, Kaushik Nag, Ahmed Deifalla, Mohammad Marefati, Ibrahim Mahariq, Yanming Wei. *Multi-criteria evaluation and optimization of a new multigeneration cycle based on solid oxide fuel cell and biomass fuel integrated with a thermoelectric generator, gas turbine, and methanation cycle*. Pages 139-156.

Recently, due to increasing concerns about the reduction of fossil energies reserves and environmental crises, the development of more efficient and low-emission systems has become necessary. An alternative energy system should be able to improve the efficiency of energy production, have a reasonable investment cost and be environmentally friendly. The current research developed a multi-criteria evaluation method of a new multigeneration cycle (MGC) based on a solid oxide fuel cell (SOFC) and biomass fuel. In the planned MGC, the SOFC is fed by syngas from the biomass gasification process. To reduce environmental hazards, a fraction of the carbon dioxide was recycled for reutilization in the aforementioned process. A gas turbine and a thermoelectric generator (TEG) were employed to produce electrical energy and an absorption chiller was embedded to produce cooling. The output heat of the fuel cell was utilized for heating purposes. A part of the electricity produced was feed into the electrolysis cycle to

produce hydrogen. Excess hydrogen was combined with carbon dioxide released from the MGC in a synthesis cycle to reduce pollutant emissions by producing methane. A thermodynamic-conceptual, exergoeconomic and environmental evaluation of the MGC was developed. The optimization based on the genetic algorithm to maximize performance and minimize the cost of the MGC was also developed. The results obtained from the optimization indicate that the proposed MGC can compete with most biomass-driven systems. Besides, the amount of carbon dioxide released can be significantly reduced compared to conventional coal, natural gas and petroleum-driven power plants.

- **Keywords:** Multigeneration Cycle; Solid Oxide Fuel Cell; Biomass; Gas Turbine; Hydrogen Energy; CO2 reduction

Olusola Bamisile, Dongsheng Cai, Michael Adedeji, Mustafa Dagbasi, Jian Li, Yihua Hu, Qi Huang. *Thermo-enviro-exergoeconomic analysis and multi-objective optimization of a novel geothermal-solar-wind micro-multi-energy system for cleaner energy production*. Pages 157-175.

Renewable energy- based multigeneration systems have been proposed as a viable means of achieving a net-zero future as these systems can decarbonize the power and energy sector simultaneously. Although there has been significant development in this research field, the large sizes of the existing systems in literature are a major setback in the adoption/implementation of these systems. Furthermore, the unavailability of solar and wind energy during some hours daily makes solar or wind energy-based multigeneration systems undesirable in many applications. Considering the urgency/importance of attaining a net-zero emission future, this study presents a novel multi-energy system that can bridge the existing gaps in literature. Therefore, the thermodynamics, economic, and environmental analysis novel CO2-based geothermal micro-multi-energy system that is hybridized with a concentrated solar photovoltaic/thermal system and wind turbine is presented in this paper. The proposed energy system presents an innovative method that can be effectively used to decarbonize future energy production. The multi-energy system is modeled to produce electricity, refrigeration effect, space heating, hydrogen, and hot water. The economic study in this paper also analyzed the Levelized cost of electricity (LCOE), Levelized cost of cooling (LCOC), and Levelized cost of hydrogen (LCOH). A multi-objective optimization operation is also carried out on the modeled system in order to determine the optimal exergy efficiency and total product unit cost. The steady-state performance analyses showed that the overall energetic and exergetic efficiencies of the system are 48,61% and 88.31% and these efficiencies can be as high as 51.76% and 95.08% respectively when the system is optimized with reference to exergy efficiency. The LCOE, LCOC, and LCOH at the optimal total product unit cost are 0.04529 $/kWh, 0.004564 $/kWh, and 28.86 $/kg.

- **Keywords:** Energy/exergy analysis; Exergoeconomic analysis; Geothermal energy; Multigeneration system; Optimization

Anand Kushwah, Anil Kumar, Manoj Kumar Gaur. Optimization of drying parameters for hybrid indirect solar dryer for banana slices using response surface methodology. Pages 176-187.

Present research work focuses on applying response surface methodology (RSM) in optimization and modeling dried banana slices in a hybrid indirect solar dryer. The relationship of independent variables in terms of mass of banana slices (kg), drying chamber temperature (°C), water flow rate (L/hr), and geometry (cm2). Therefore, responses of interest or dependent variable consisting of moisture content (% db), energy consumption (kW/h), and shrinkage (%) utilization are concluded. A short drying period and energy consumption are seen as the optimizing drying parameters of banana

slices. Response surface methodology with central composite design (CCD) was applied to optimize the dependent variable. Experimentally observed data are adjusted by applying a second-order polynomial regression model. The predicted R2 in the range of 0.9828–0.9530, adjusted R2 value (0.9571–0.9974), and model F value (08.18) for banana slices were calculated. Optimal operational parameters are observed 89.99 ℃ (drying cabin temperature), 14.0 L/hr (water flow rate), 0.9998 (circular geometry), and 0.24004 kg (product mass). Optimum responses were 7.55% db (moisture content, MC), 5.54 kW/h (energy consumption), and 69.54% (shrinkage). Further, experiment was conducted at optimal operating conditions, and the results indicate good consistency between predicted and experimental data with a deviation of 3.14%, 2.16% and, 1.41% for the minimum moisture content (wb), energy consumption and, shrinkage, respectively.

- **Keywords:** RSM; Shrinkage; Banana; Energy consumption; Moisture content; Solar drying

Xianjun Du, Yu Peng. *Multi-objective pity beetle algorithm based optimal control of wastewater treatment process*. Pages 188-206.

Water is a critically scarce resource for industrial production and social life. The discharge of untreated wastewater into natural waters can pose a serious risk to human health. Most of urban wastewater treatment plants use biochemical methods, the most common of which is the biological reaction through activated sludge to degrade pollutants. Considering the public environmental protection and socio-economic needs, this paper establishes a wastewater treatment process (WWTP) optimization model considering the trade-off between effluent quality (EQ) and energy consumption (EC), and designs an dynamic optimal control framework based on a novel multi-objective evolutionary algorithm (MOEA) to track and control the key variables in the WWTP. The numerical experiments of multi-objective test functions show that the proposed MOEA has good convergence and distributivity. Simulation results based on the BSM1 platform show that the constructed framework can accurately adjust the set-points of controllers in time to improve the performance, which has broad application prospects in practical applications.

- **Keywords:** Evolutionary algorithm; Dynamic multi-objective optimization; Optimal process control; Pity beetle algorithm; Population prediction; Wastewater treatment process

Xuan Xing, Juan Tang, Shuo Yao, Hanzhi Chen, Tianyu Zheng, Juanli Wu. *Electrochemical regeneration of granular activated carbon saturated by p-nitrophenol in BDD anode system*. Pages 207-214.

Phenolic compounds have been widely used in metallurgy, petroleum, chemicals, textiles, dye printing and pharmaceuticals. These compounds are persistent, non-biodegradable and harmful for human healthy, whose emission should be restricted before their efficient treatment. Electrochemical regeneration of granular activated carbon (GAC) saturated with p-nitrophenol (p-NO2) has been investigated in Boron-doped Diamond (BDD) anode system. The dominated regeneration mechanism was mainly due to the electrostatic repulsion between negative polarized GAC located at cathode and deprotonated p-NO2 ions. Operating parameters including current density, regeneration time, pH value, electrolyte concentration and flow rate have been investigated systematically. Under the optimized experimental conditions, regeneration efficiency of GAC was as high as 81.6%, without significant declination after five-times adsorption-regeneration cycles. During the regeneration process, organic compounds of p-NO2, which was desorbed from GAC and released into electrolyte, was oxidized at BDD anode surface. Therefore, GAC regeneration and p-NO2 degradation were realized simultaneously. Effects of different anode materials on regeneration process was analyzed and BDD showed superior performance compared with PbO2, SnO2 and Pt anodes, which was attributed to different

intermediates formed at anode surface. In summary, GAC saturated with p-NO2 can be regenerated efficiently in BDD anode system with p-NO2 removed simultaneously. All these results demonstrated that electrochemical regeneration in BDD anode system has great potential for practical application.

- **Keywords:** Electrochemical regeneration; Granular activated carbon; p-nitrophenol; Boron-doped diamond

C. Karthick, Nanthagopal Kasianantham. *Experimental assessment of biobutanol degradation exposed to automotive components: A material compatibility approach*. Pages 215-228.

This study investigates the corrosive nature of gasoline engine parts such as piston, ring and valve exposed to various biobutanol ratios by static immersion method at different immersion durations. After immersion, variations in the surface morphology and elemental compositions of the metal samples were studied with the help of SEM and XRD results. The degradation in fuel characteristics such as density, viscosity and TAN were investigated as per the ASTM standards. According to the experimental findings, the piston sample is identified as least resistive than other components and resulted in more corrosive oxides. Among the various fuel blends, the degradation of fuel samples and corrosion rate of metals are comparatively higher for pure butanol and lower for gasoline (Bu0 <Bu20 <Bu50 <Bu100). The oxygen content that exists in the biobutanol chemical composition promotes the corrosiveness of the blends. To balance that, the OH functional group of biobutanol acts as a corrosion inhibition factor to restrict aggressive corrosion. Even though Bu100 ended with a higher corrosion rate, it can be used as a standalone fuel in gasoline because the results achieved were within the acceptable limit and has no severe influence on the failure of engine components due to corrosion.

- **Keywords:** Biobutanol; Flex fuel operation; Corrosion; Fuel degradation; Material compatibility

Haixia Li, Chen Li, Min Yan, Yinglong Wang, Zhaoyou Zhu, Peizhe Cui, Xin Li, Yanyue Lu. *Comprehensive analysis and energy efficient process design for separation of four high purity components from organosilicon system*. Pages 229-240.

The separation and purification of methyl-chlorosilanes play an important role in the organosilicon industry. NSGA-II algorithm was applied to the multi-objective optimization of traditional organosilicon distillation. In order to save energy, pinch technology and vapor recompression technology were introduced. Two heat integration enhancement schemes, which were heat integrated distillation process (HIDP) and vapor recompression assisted heat integrated distillation process (VRC-HIDP), were designed. The results show that the key to reducing energy consumption lies on the energy saving of M1/M2 separation column. Hence, the pressure-regulating heat integrated distillation process (PR-HIDP) and the vapor recompression assisted pressure-regulating heat integrated distillation process (VRC-PR-HIDP) were proposed. The pressure of M1/M2 separation column was increased to make better use of overhead steam to exchange heat for other columns in the PR-HIDP and VRC-PR-HIDP. The results show the gas emissions and total annual cost (TAC) of the four improved energy-saving schemes are reduced significantly. The VRC-PR-HIDP has the best economic and environmental performance, with TAC reduced by 44.46 % and gas emissions reduced by 70.96 % compared with the traditional distillation process (TDP).

- **Keywords:** Organosilicon distillation; Multi-objective optimization; Heat integration; Vapor recompression; Pressure regulation; Heat exchange network

Junkun Nie, Xiaojiao Yu, Yuchen Wei, Zongbin Liu, Jian Zhang, Zhong Yu, Yao Ma, Binghua Yao. *Interfacial charge transfer effects of α-Fe2O3/Cu2O heterojunction and enhancement mechanism of its photocatalytic oxidation*. Pages 241-258.

In order to construct Cu2O based heterostructures with high efficiency of interfacial charge transfer and clarify the enhancing mechanism of its photocatalytic performance for degrading antibiotics, and reveal the characteristics of band reconstruction and the photocatalytic reaction path, the α-Fe2O3/Cu2O heterojunction was established based on hydrothermal method. The crystal plane structure, morphological state, photoelectric conversion properties and photocatalytic degradation kinetics of α-Fe2O3/Cu2O heterojunction were revealed by XRD, XPS, UV-Vis, BET, SEM, TEM and RSM, and the reconstruction principles of bandgap formations of heterojunction were analyzed by the density function theory. The reaction intermediates of levofloxacin were distinguished with HPLC-MS/Ms, and the reactive sites and photocatalytic oxidation paths of levofloxacin were clarified from the frontier electron density calculation. It turned out that the constructed α-Fe2O3/Cu2O heterojunction emerged high energy (111) preferred crystal plane orientation and significantly enhanced the specific surface area and visible spectral excitation efficiency. The micromorphologies of Cu2O, M1-Cu2O, M2-Cu2O and M3-Cu2O crystals were cube, irregular polyhedron and approximate sphere, respectively. The introduction of Fe 3d hybrid orbital in α-Fe2O3/Cu2O heterojunction widened the band gap of Cu2O microcrystals, resulting in the migration of spectral absorption edging to high energy level and causing blueshift. Photogenerated superoxide radicals and hydroxyl radicals were the dominant active species for photocatalytic oxidation of levofloxacin. The removal rate of levofloxacin by α-Fe2O3/Cu2O heterojunction could still reach more than 70% after eight cycles and show high material durability. The ring opening reaction process and decarboxylic reaction of quinolone group and piperazine side chain were the main pathways for photocatalytic oxidation of levofloxacin. This study systematically revealed the interfacial charge transfer characteristics and photocatalytic reaction mechanism of α-Fe2O3/Cu2O heterojunction.

- **Keywords:** α-Fe2O3/Cu2O heterojunction; Photocatalytic activity; Levofloxacin; Density functional theory; Frontier electron density

Hongji Ren, Aijun Yin, Zongxian Dai, Xiaochun Liu, Zhibin Tan, Bo Zhang. *Parameter screening and optimized gaussian process for water dew point prediction of natural gas dehydration unit*. Pages 259-266.

Petrochemical equipment is characterized by continuity, large scale, complexity of processes, and critical operation conditions. Based on auto-collected monitoring parameters, online prediction of critical process parameters can be used to maintain high reliability of petrochemical equipment, which is generally unpractical due to interference parameters and the difficulty in establishing prediction models. In this paper, a process parameter online prediction method for petrochemical equipment is proposed. Firstly, sensitive parameters are selected applying gradient boosting decision tree (GBDT). Then optimized Gaussian process (GP) is utilized to develop a mapping model in order to inference process parameter from auto-collected parameters. Natural gas water dew point online prediction method for triethylene glycol (TEG) dehydration unit is investigated. The effectiveness of the proposed method is verified on production data of a natural gas dehydration station. The method proposed provides a promising solution for process parameter prediction for petrochemical processes as well as other similar scenarios.

- **Keywords:** Petrochemical equipment; Process parameters; Online prediction; Dehydration unit; Natural gas water dew point

Qirui Guo, Yuan Yao, Jiancheng Liu, Xuehua Zhang, Weizhong Shi, Jie Meng, Yuan Wang, Hui Wan, Guofeng Guan. *Surface engineering of γ-Al2O3 nanosheets with highly dispersed poly(ionic liquids) for selective CO2 adsorption*. Pages 267-276.

An efficient CO2 adsorbent (γ-Al2O3 @PAVIMBr) was constructed by means of graft copolymerization with mesoporous γ-Al2O3 nanosheets served as the host material and amino-functionalized imidazolium based poly(ionic liquids) (PAVIMBr) as the guest material. Thereinto, mesoporous γ-Al2O3 could provided abundant hydroxyl groups for loading PAVIMBr uniformly via chemical bonding interaction, while PAVIMBr was able to tailor suitable pore size and expose amino-groups adsorption active sites that was contributed to chemisorb with CO2. It was observed that the general topography of γ-Al2O3 @PAVIMBr composite was almost unchanged after PAVIMBr loaded, and its mesoporous structure and crystalline form was still maintained. Moreover, the content of PAVIMBr in our composite could be calculated from the TGA results before and after its grafting. The obtained γ-Al2O3 @PAVIMBr presented a good CO2 adsorption performance, its CO2 adsorption capacity increased obviously. Meanwhile, the CO2/N2 selectivity of γ-Al2O3 @PAVIMBr was 15.3 times higher than that of γ-Al2O3 at room temperature and the pressure of 100 kPa, while the CO2 uptake of γ-Al2O3 @PAVIMBr was almost 13 and 3 times higher than that of PAVIMBr and γ-Al2O3 at 10 kPa and 25 °C, respectively. It was mainly attributed to that the maintaining mesoporous channels in γ-Al2O3 @PAVIMBr could accelerate the CO2 diffusion, while chemisorption of those exposed adsorption active sites from loaded PAVIMBr could improve the adsorption performance at lower CO2 partial pressure and CO2/N2 selectivity of our composite. Furthermore, the excellent CO2/N2 selectivity, renewability and physicochemical stability of γ-Al2O3 @PAVIMBr might employ it as one of the potential CO2 adsorbents.

- **Keywords:** Poly(ionic liquids); γ-Al2O3 nanosheets; Composite; Graft copolymerization; Mesoporous; Selective CO2 adsorption

Jianan Chen, Zhu Huang, Anna Li, Ran Gao, Wenming Jiang, Guang Xi. *Numerical simulation of carbon separation with shock waves and phase change in supersonic separators*. Pages 277-285.

The current study evaluated a potential carbon separation method. Based on engineering thermodynamics, heat transfer and phase transition dynamics, a mathematical model is proposed to predict the phase change in high pressure supersonic flow, and a flue gas model after dehydration, desulfurization and denitration is established. The flow features with shock waves and spontaneous condensation in the supersonic separator are clarified, the influence of flow model on shock waves and flow features is quantified, and the energy recovery process with phase change is studied. The results show that flue gas enters the supercooled state near the throat, reaches Wilson point at x = 0.077 m, and the nucleation rate surges from 0 to 4.46 × 1020 m−3 s−1. When vapor molecules reach the surface of droplets, droplets grow, and latent heat is transferred from droplets to the vapor phase, resulting in condensation wave. A shock wave is generated at the diffuser inlet, and the flow and liquid phase parameters change abruptly after the shock wave. The single-phase model incorrectly predicted the separator refrigeration capacity, flue gas expansion capacity, location and intensity of the shock wave, and the maximum deviation is up to 65.5%. Excessive improvement of pressure recovery efficiency results in reducing the liquefaction capacity of the separator.

- **Keywords:** Flue gas; Carbon separation; Phase change; Shock wave; Supersonic flow

Hongwei Luo, Qianqian Cheng, Dongqin He, Jianqiang Sun, Jun Li, Xiangliang Pan. *Recent advances in microbial mercury methylation: A review on methylation habitat, methylator, mechanism, and influencing factor*. Pages 286-296.

In natural environments, inorganic mercury (Hg2+) can be converted to the neurotoxin methylmercury (MeHg) mainly via the microbial Hg methylation process with anaerobic microorganisms. This process is a cellular reaction, and is influenced by cellular activity of Hg methylating microorganisms and by cellular Hg2+ uptake. In the present article, we review research progress of Hg bio-methylation, which includes: sites for Hg bio-methylation, Hg methylating microorganisms, mechanisms of Hg bio-methylation, and factors affecting Hg bio-methylation. Microbial Hg methylation occurs in a variety of sites such as the freshwater and marine environments as well as some unrecognized habitats. Sulfate-reducing bacteria using sulfate as their terminal electron acceptors are a group of the most extensively studied Hg methylators, followed by iron-reducing bacteria. The cellular uptake of Hg2+ before methylation may proceed via passive and/or active transport. Most Hg methylators have a pivotal gene pair encoding proteins required for methylation process. The cellular activity and bioavailable Hg2+ concentration for methylation can be determined primarily by many environmental factors i.e., temperature, redox potentials, pH value, existence of dissolved organic matter (DOM) and sulfur-containing organic compounds. A comprehensive understanding of methylation habitat, methylator, mechanism, and influencing factor is urgently required and will provide guidance for regulating net MeHg production within natural environments.

- **Keywords:** Microbiology; Hg methylation; Bioavailability; Sulfide; Speciation

Yong Cao, Kanghua Gao, Bin Li, Lifeng Xie, Xuhai Pan. *Influence of vent size and vent burst pressure on vented ethylene-air explosion: Experimental and numerical study*. Pages 297-309.

This paper describes the numerical simulation of the vented explosion of ethylene-air mixtures. The influence of concentration, vent size, and vent burst pressure on the vented ethylene-air explosion is investigated by comparing simulation results and experiments. The different phases of external flame propagation are concluded by comparing the experimental photos and the simulation results. The external explosion process is captured by the high-speed camera and simulation. It is found that the unburned mixture expanded to the external atmosphere, which was ignited by the flame. The flow velocity, velocity vector, and turbulence kinetic energy are applied to analyze the mechanism of external flame propagation. The velocity vector is deflected to both sides of the flame front and the reverse flow velocity is captured in the external flow field. The change of ethylene concentration and the venting flow velocity is used to explain the relationship between the pressure rise, chemical reaction rate, and venting flow. Results show that the internal pressure for AV= 0.18 m2 is significantly greater than the internal pressure for AV= 0.55 m2 in this case. The smaller vent size results in higher flow velocity and turbulence kinetic energy inside of the vessel. The vent burst pressure growth promotes the acceleration of the flame front inside of the vessel. The variation curve of ethylene concentration and venting flow velocity has a similar law with different vent burst pressures. The experimental and simulated results can provide technical and theoretical support for the design of gas explosion prevention in the field of process safety and risk engineering.

- **Keywords:** Vented explosion; Ethylene; Numerical simulation; Flame; Pressure

Abdolvahhab Fetanat, Mohsen Tayebi. *Industrial filtration technologies selection for contamination control in natural gas processing plants: A sustainability and maintainability-based decision support system under q-rung orthopair fuzzy set*. Pages 310-327.

The challenges of sustainability and maintainability to implement the industrial filtration technologies in the natural gas industry necessitate a systematic and practical assessment. With the target of balance between the issues in the context of sustainability and maintainability policies, criteria (principles) including economic, environmental, social, and maintainability aspects are taken into consideration. This work aims at developing a novel hybrid decision support system (DSS) namely q-rung orthorpair fuzzy set-based MAIRCA (Multi-Attributive Ideal-Real Comparative Analysis). The proposed DSS is applied to prioritize industrial filtration technologies considering the sustainability and maintainability principles. These technologies are considered for controlling contaminants produced by the natural gas industry in Iran. The prioritization of the considered technologies is obtained from the most to least preferred as: Cyclo-filter, Cyclone separator, Backwash, Gravity separator, and Basket strainer, respectively. The Cyclo-filter technology is selected as the preferable alternative. The adaptability of this technology with the regional and local states of the study area has assisted to make it the most suitable technology. The decision-making framework can help to give a new and practical insight for the policymaking in the field of process energy and environmental systems especially in the natural gas industry to control contamination.

- **Keywords:** Industrial filtration technologies; Maintainability; MAIRCA; Natural gas processing plant; Q-rung orthopair fuzzy set; Sustainability

Bo Jiang, Yunshu Zhang, Cong Li, Jiaqi Guo, Chunmeng Sun. *Zero-valent iron loaded on N-doped biochar fabricated by one-step pyrolysis of K2FeO4 and coffee grounds as a persulfate activator for Bisphenol A degradation*. Pages 328-338.

Nanoscale zero-valent iron loaded on N-doped biochar (nZVI/NBC) is a novel catalyst for activating peroxydisulfate (PDS) toward efficient degradation of endocrine disruptors in water. In this study, spent coffee grounds were modified by K2FeO4 and then transformed into nZVI/NBC by one-step pyrolysis. The nZVI/NBC modified with 0.3 mol/L K2FeO4 displayed an excellent PDS activating performance, and the specific surface area and average pore width of this nZVI/NBC were 277.19 m2/g and 2.47 nm, respectively. Bisphenol A (BPA) as a typical endocrine disruptor can be efficiently degraded by nZVI/NBC/persulfate advanced oxidation process. The optimum dosage of nZVI/NBC was 0.1 g/L, and the optimum PDS concentration was 20 mM. pH (3−9) had little effect on BPA degradation. In addition, the presence of Cl− had a facilitating effect on BPA degradation, while CO32− and HPO42− had strong inhibitory effects. nZVI/NBC had long-term stability in that the activation rate remained stable after five cycles and 90 days of storage in air and natural light. This study also investigated the activation mechanism of PDS by nZVI/NBC and concluded that radical (•OH, SO4•−, and O2•−) and non-radical (1O2) processes were simultaneously presented under the synergistic catalysis of ZVI and N. The formation of metastable PDS intermediates on the surface of biochar substantially enhanced the adsorption of PDS/BPA and the electron transfer process. Finally, the degradation pathways of BPA were speculated based on nine identified intermediates. Overall, this study described a rapid and green method for nZVI/NBC fabrication, which simultaneously achieved the recycling of spent coffee grounds and the degradation of endocrine disruptors in water.

- **Keywords:** Zero-valent iron; Spent coffee grounds; K2FeO4; Peroxydisulfate activation; Bisphenol A

Mohammad Zaid Kamil, Faisal Khan, S. Zohra Halim, Paul Amyotte, Salim Ahmed. *A methodical approach for knowledge-based fire and explosion accident likelihood analysis*. Pages 339-355.

An accident database is an excellent data source if appropriately leveraged along with domain expertise. However, a proper framework and tools are required to extract data from a database. The current work aims to develop such a framework by systematically introducing a unique approach to integrate three techniques. First, Natural Language Processing (NLP) is used to extract causal and contributing factors from an accident database. Second, an Interpretive Structural Model (ISM) establishes the interrelationship and hierarchy of the extracted factors. Third, a probabilistic method for quantitative reasoning and accident analysis is employed. This integrated approach is applied to the US Chemical Safety and Hazard Investigation Board (CSB) oil and refining (downstream) incident database to develop a generalized accident causation model. The model provides insight into the factors responsible for accidents (i.e., commonalities among casualties), interactions, and accident pathways. It can also be used to develop strategies for preventing accidents. The model is tested on ten scenarios from the CSB and verified on six incidents from the IChemE database. The results are promising in establishing the model's efficacy in predicting adverse events. Sensitivity analysis shows that management of change and lack of procedure and training have the highest sensitivity towards fire and explosion, and therefore need proper attention. This approach will be an essential tool for Safety 4.0, enabling process safety in the digitalization process.

- **Keywords:** Lessons learnt; Process safety excellence; Natural language processing; Interpretive structural modelling; Bayesian network; Safety 4.0

Shuaiqi Yuan, Genserik Reniers, Ming Yang, Yiping Bai. *Cost-effective maintenance of safety and security barriers in the chemical process industries via genetic algorithm*. Pages 356-371.

Chemical plants face safety hazards and security threats that may induce catastrophic scenarios. Safety and security barriers are employed widely to protect chemical plants from accidental and intentional undesired events and mitigate consequences. Managing safety and security barriers effectively and economically is a research topic with practical significance. The analysis of undesired event scenarios, including both accidental and intentional adverse scenarios, and assessing associated safety and security barriers are critical regarding cost-efficient barrier maintenance. This study proposes a novel approach for optimizing safety and security barrier maintenance strategy considering economic constraints. This approach consists of three steps: scenario building and barrier identification, barrier modeling, and determining optimal barrier maintenance intervals. In the proposed approach, accident scenarios in terms of safety and physical security are constructed using the extended bow-tie diagrams. After associated safety and security barriers are identified, a system simulation model is developed to conduct barrier modeling based on MATLAB/Simulink simulations, in which the barrier maintenance, the impacts of human and organizational barriers, and the correlations between barriers caused by shared components are considered. Finally, a combination of cost-effectiveness analysis (CEA) and genetic algorithm (GA) is employed to support the decision-making on barrier maintenance optimization. An illustrative case is employed in this study to validate the feasibility of the proposed approach.

- **Keywords:** Barrier maintenance; Cost-effectiveness analysis; Integration of safety and security; Barrier modeling; Genetic algorithm; Chemical industry

Muneer Ahmad Malla, Anamika Dubey, Ashwani Kumar, Shweta Yadav. *Unlocking the biotechnological and environmental perspectives of microplastic degradation in soil-ecosystems using metagenomics*. Pages 372-379.

Microplastics are ubiquitous and continue to migrate and transform. The potential hazards of microplastics to the environment and organisms, including humans, have attracted great concerns worldwide. Microplastics enter the soil ecosystems via different sources such as mulch degradation, plastic landfills, organic fertilizer, transport, etc., and occur widely with a significant spatial difference. Microplastics interact with the physicochemical properties of soil and negatively impact plants, animals and environmental health. More than 400 bacterial species have been identified as potential plastic degraders, but little is known about these organisms' structure, dynamics, and functional abilities in plastic-contaminated environments. Here, in this review, we have highlighted the distribution and transportation of microplastics in terrestrial environments. We then discussed the synergistic efficacy of soil and earthworm-gut microbiomes towards the effective degradation of microplastics and highlighted the role of metagenomic approaches in assessing the diverse plastisphere.

- **Keywords:** Micro-plastics; Earthworms; Bioturbation; Microbiome; Degradation

Fengye Zhang, Yaojun Zhang, Panyang He, Hao Chen, Jiangyu Gao, Jiale Liang. *Multifunctional granulated blast furnace slag-based inorganic membrane for highly efficient separation of oil and dye from wastewater*. Pages 380-391.

Superhydrophilic and underwater superoleophobic metal-based mesh membranes exhibit high flux, high separation efficiency, low energy consumption, and facile continuous oil/water separation. However, their separation performance for oil/water emulsions and organic pollutants is very poor. In this study, graphene oxide (GO)-modified granulated blast furnace slag (GBFS)-based geopolymer paste was coated onto a stainless-steel mesh to prepare an inorganic geopolymer membrane (GO/GBFSGM). A sample containing 0.25 % GO (0.25GO/GBFSGM) demonstrated the highest flux of 10,520.25 kg·m−2·h−1 and high separation efficiencies (>98 %) for various oil/water mixtures and oil-in-water emulsions under gravity-driven conditions. In addition, the 0.25GO/GBFSGM sample possessed excellent pollution resistance, cycling stability, mechanical stability, and alkali, salt, and heat resistances. Importantly, it exhibited unique physical rejection and electrostatic adsorption properties for organic dye molecules owing to the three-dimensional network gelling structure of the geopolymer. The adsorption rate of a 10 mg/L methylene blue solution by 0.25GO/GBFSGM exceeded 91 % within 4 h. This study proposes a "treating waste with waste" concept, i.e., the utilization of GBFS solid waste for the preparation of multifunctional inorganic membranes that can effectively separate oil and dye from wastewater with tremendous economic, environmental, and social benefits.

- **Keywords:** Granulated blast furnace slag; Graphene oxide; Geopolymer; Inorganic membrane; Oil/water separation; Dye adsorption

Mohammad Ali Hatefi, Hamid Reza Balilehvand. *Risk assessment of oil and gas drilling operation: An empirical case using a hybrid GROC-VIMUN-modified FMEA method*. Pages 392-402.

The failures of drilling operation in oil and gas fields may cause big economic losses owing to several technical consequences such as safety incidents, machinery damages, environmental impacts, etc. To prevent unwelcome events in drilling activities, it is necessary to assess and reduce the potential related risk factors. Hence, the present

paper offers a framework to diagnose and analyze drilling operation risk factors in one of the Iranian gas field, located in the south area of the country. The proposed methodology consists of four main stages: providing knowledge sources, risk identification, general risk analysis, and estimation of wellbores overall risks. This framework helps to ensure the successfully performance of drilling companies, and to access safety standards. An improved version of the FMEA method (Failure Mode and Effects Analysis), named as modified FMEA, is suggested by adding risk controllability criterion. Further, a generalized version of the ROC method (Rank Order Centroid) is developed. This method is used to estimate the weights of any ranked entities. Moreover, a new idea called VIMUN (Vital, Important, Medium, Unimportant, and Negligible) is proposed to deal with weighting problems when there are many number of entities to be weighted. A hybrid of the modified FMEA, GROC, and VIMUN methods is used for evaluating the risk factors in the field, and for determining the level of overall risk of each wellbore. The results show that the lost circulation of drilling fluid caused by high density of natural fractures in formation, and lack of advanced technology has the highest priority, and is the most serious failure in drilling operation in the field under study. The failures at the next ranks are drilling rig fire & explosion, well blowout, and wellbore instability. Using the proposed methodology, 36 wellbores in the field are grouped into five classes according to their levels of risk. The robustness of the results was confirmed by carrying out a sensitivity analysis.

- **Keywords:** Gas field; Oil and gas wellbore; Overall risk; Weight assignment; Generalized rank order centroid

Junhuan Lei, Zhaoping Meng, Libo Tan, Yuheng Wang, Di Wu. *Experimental study on stress-dependent permeability of coal samples with different salinities of water in coal*. Pages 403-414.

The stress sensitivity and water sensitivity of coals are key factors restricting the productivity of coalbed methane (CBM) wells. In this study, stress sensitivity experiments with different salinities and X-ray diffraction (XRD) tests were conducted with coal samples from the Zhaozhuang (ZZ), Sihe (SH), and Xishan coalmine (XS) in the Qinshui Basin to analyse the correlation between permeability and the coupling of salinity and effective stress. To reveal the revolution of coal permeability under the coupling of salinity and stress, the permeability damage rate (PDR), the stress sensitivity coefficient (αk), and the water sensitivity index (IW) were introduced to evaluate the stress sensitivity and water sensitivity. The results showed that the permeability varied with the effective stress following a negative exponential function and was positively correlated with salinity within a certain range. When the salinity increased from 0 ppm to 5000 ppm, the stress sensitivity decreased; when the salinity increased from 5000 ppm to 10,000 ppm, the stress sensitivity remained constant, and the water sensitivity increased with increasing effective stress. Finally, a mathematical model for predicting coal permeability that considered the impacts of stress and salinity was established, and the control mechanism of stress and salinity on permeability was revealed.

- **Keywords:** Coal reservoir; Permeability; Stress sensitivity; Water sensitivity; Coupled model

Akanksha Chauhan, Anita Sudhaik, Pankaj Raizada, Aftab Aslam Parwaz Khan, Arachna Singh, Quyet Van Le, Van-Huy Nguyen, Tansir Ahamad, Sourbh Thakur, Pardeep Singh, Abdullah M. Asiri. *Enhancement strategies for ZnSe based photocatalysts: Application to environmental remediation and energy conversion*. Pages 415-435.

In recent times, the increase in the growth of population and industries has become a major issue for environmental resources and energy. The foremost reason behind

environmental pollution is the discharging of hazardous pollutants like antibiotics, pesticides, dyes, phenols, and heavy metal ions into the water, which cause the lack to access to pure water. The photocatalysis method, obtained from solar energy can surely be helpful for the improvement of the environment. Recently, Zinc selenide (ZnSe) is a noteworthy and admirable photocatalytic material that belongs to the II-VI group with a direct energy gap of 2.67 eV. Due to ZnSe good photocatalytic properties, it is a useful photocatalytic material in environmental remediation. The present review illustrated the structural and optoelectronic properties of ZnSe with theoretical studies. The density functional theory (DFT) computation was used to validate the structural characteristics and optoelectronic properties. Various modification strategies like doping, conventional heterojunctions, and Z-scheme heterojunctions have been illustrated which enhanced the photocatalytic activity of ZnSe. These strategies lower the recombination rate and enhance the photoinduced charge carrier separation and migration efficacy. Similarly, photocatalytic applications of ZnSe in pollutant degradation, Co2 reduction, H2 evolution, and Cr(VI) reduction have been highlighted with its photocatalytic mechanism. Finally, the review ended with a conclusion and emerging future challenges in the field of ZnSe photocatalysts for water purification.

- **Keywords:** Photocatalysis; ZnSe photocatalyst; Photocatalytic degradation; CO2 reduction; Cr (VI) reduction

Fryad S. Mustafa, Kosar Hikmat Hama Aziz. *Heterogeneous catalytic activation of persulfate for the removal of rhodamine B and diclofenac pollutants from water using iron-impregnated biochar derived from the waste of black seed pomace*. Pages 436-448.

Waste reutilization in environmental remediation is highly desired as a new strategy in the scientific community for environmental applications. Industrial biowaste has been used significantly to produce biochar, which can be used in environmental remediation. In this study, a low-cost iron-impregnated modified biochar (FeBS800) was successfully prepared using a one-step pyrolysis method with waste black seed pomace as a "waste-to-resource" strategy and applied to activate peroxydisulfate (PDS) for the degradation and mineralization of rhodamine B (RhB) and diclofenac (DCF) in water. The physicochemical properties of the FeBS800 catalyst were investigated by various characterization analytical methods. The developed FeBS800 catalyst exhibits excellent catalytic activity and good stability in PDS activation. In the FeBS800/PDS system, the degradation efficiency within 10 min reached up to 98.2 % and 88.3 %, while the mineralization efficiencies within 30 min reached 48 % and 68.7 % for 20 mg/L RhB and DCF, respectively, with slight iron ions leaching of less than 3 mg/L. The optimum removal conditions of the FeBS800/PDS system were found to be 1.5 g/L catalyst dose and 10 mM PDS initial concentration at circumneutral pH solution. Moreover, the radical quenching experiment revealed that the main reactive oxygen species (ROS) responsible for the pollutants' degradation in FeBS800/PDS system are in the order of 1O2 > •OH > O2•- > SO4•-, while singlet oxygen plays a leading role. The degradation kinetics of both pollutants (RhB and DCF) were well-fitted to the pseudo-first-order model. Furthermore, a possible mechanism pathway of PDS activation for generation ROS in the FeBS800/PDS system was proposed. Overall, the research results suggested that the modified FeBS800 could have a promising potential in activating PDS for the removal of refractory organic pollutants from water.

- **Keywords:** Diclofenac; Rhodamine B; Advanced oxidation process; Modified biochar; Persulfate activation; Water treatment

Satyendra, Saisaurabh Kishor Asoria, Ritesh Vijay. *In-situ drain treatment types and technologies for flowing wastewater: A comprehensive review*. Pages 449-463.

The flowing wastewater in the drains joins water-bodies in untreated conditions causing a serious risk of pollution and diseases due to organic enrichment and nutrient. An in-situ drain treatment is doable and practical solution for sewage flowing through drains without displacing or disturbing the drain structure and the utilization of physical and biological processes in an aerobic environment. In-situ remediation techniques are easier to construct, operate, and administer than conventional sewage treatment plants because they don't require additional space and energy. A comprehensive review of in-situ drain treatment is carried out in this paper, with a particular focus on bioremediation and phytoremediation techniques as an effective solutions to treat the sewage/wastewater in the drain, itself. Review paper also suggests the further research and resource recovery from the in-situ drain treatment support economic development along the drains. As most cities are growing fast with sewage generation and insufficient treatment facilities, in-situ drain treatment is an immediate and sustainable solution to control pollution from drain to water bodies.

- **Keywords:** Wastewater; Drain; In-situ treatment; Resource recovery; Wetland plants

R. Muneeswari, K.V. Swathi, G. Sekaran, K. Ramani. *A real time integrated approach for the treatment of petroleum industry oily waste through ancillary carbon metabolism and biocatalytic cascade induction*. Pages 464-478.

Recalcitrant hydrocarbons contamination by petroleum oil sludge (POS) disposal from the petroleum refining industry is a major environmental issue. Insufficient biomolecules (biosurfactant and degradative enzymes) production and passive metabolic transformation lead to more prolonged and incomplete bioremediation process. Herein, integration of ancillary carbon metabolism and biocatalytic cascade induction facilitated faster microbial growth, increased supply of precursors for macromolecule production and activated enzymatic degradation cascade. The agricultural by-product, rice husk found to be the suitable ancillary carbon source and elemental analysis of Carbon, Hydrogen and Nitrogen (CHN), Fourier transform infrared spectroscopy (FT-IR) and X-ray photoelectron spectroscopy analyses confirmed the microbial assimilation of the co-substrate. Divalent metal cations such as Cu2+, Fe2+ and Zn2+ were screened as essential enzyme activators, thereby induce the enzymatic degradation of POS. The integrative system exhibited the maximum aliphatic and aromatic hydrocarbons degradation of 96% and 92% during semi-pilot scale treatment (1 Kg of POS). Further, the functional annotation of the genome using Carbohydrate-active enzymes (CAZymes) provided specific insight into the genomic potential of E.xiangfangensis STP-3 in the concomitant metabolism of complex carbohydrates towards the enhanced enzymatic degradation of POS. These findings demonstrated that integrating ancillary metabolism and biomolecular machinery induction provides a sustainable POS clean-up strategy.

- **Keywords:** Petroleum oily sludge treatment; Ancillary carbon; Biomolecules; Cationic enzyme activators; Carbohydrate metabolism

Oscar D. Pedrayes, Rubén Usamentiaga, Daniel F. García. *Fully automated method to estimate opacity in stack and fugitive emissions: A case study in industrial environments*. Pages 479-490.

Fugitive emissions are those that are unplanned, i.e., they do not come out of a stack. These emissions are usually disperse and difficult to locate. By estimating the opacity of

fugitive emissions they can be controlled or even prevented, helping to comply with environmental regulations. Most opacity estimation methods are based on stack emissions, which are straightforward, as they are always located in the same area. All methods in the literature for emission opacity estimation require a human operator to select the regions to be used as a reference. In this work, deep learning networks are proposed to improve the quality and automation of this process by selecting the regions completely and automatically. Furthermore, a new fugitive emission opacity estimation method is proposed. This method, called SBPB, is compared with other relevant methods in the literature, offering a solution with an average F1-Score metric 5 % higher than other methods on two real datasets with over 4000 images in total. This method provides a robust solution for fugitive emissions.

- **Keywords:** Deeplab; Deep learning; Pollution; Semantic segmentation; Smoke

Yingying Shao, Chao Tian, Wenjia Kong, Yanfeng Yang, Weiyi Zhang, Yanqiu Shao, Tao Zhang, Ziyang Lou, Ying Zhu. *Co-utilization of zinc contaminated soil and red mud for high-strength ceramsite: Preparation, zinc immobilization mechanism and environmental safety risks*. Pages 491-497.

In this research, high strength ceramsite was sintered by zinc contaminated soil and red mud. In addition, the influence of sintering temperature and red mud addition on ceramsite properties and Zn immobilization were investigated, and the Zn immobilization mechanisms were determined. The X-ray diffraction (XRD) analysis, scanning electron microscopy (SEM-EDS), and BCR sequential extraction technique were used to determine the crystal phases, microstructures, and Zn immobilization. Under the optimum synthesis conditions (sintering temperature of 1150 °C and the red mud addition of 5%), the sintered ceramsite exhibited a Zn loss rate of 10.31%, Zn leaching concentration of 0.13 mg/L (performed by rotating vibration device), bulk density of 1052.6 kg/m3, 1 h water absorption of 1.06%, and cylindrical compressive strength of 27.06 MPa, implying that the ceramsite obtained under this conditions not only meets the Chinese National Standards and has no environmental risk. High temperature and the addition of red mud were beneficial to the immobilization of Zn in ceramsite. The main immobilization mechanism of Zn in ceramsite was the formation of ZnFexAl2−xO4 spinel and the encapsulation of glass phase. Thus, Zn can be immobilized effectively by ceramsite prepared from zinc contaminated soil and red mud at high temperature.

- **Keywords:** Zinc contaminated soil; Red mud; Ceramsite; Heavy metals loss; Immobilization mechanisms

Qingqing Rui, Qing Ye, Jinlong Li, Yao Wang, Azhi Yu. *Investigation on energy-saving extractive distillation for recovering ethanol and 1,4-dioxane from wastewater*. Pages 498-512.

Energy-saving extractive distillation for separating ethanol and 1,4-dioxane from the industrial effluent is proposed. From the point of COSMO-SAC model and thermodynamic insights, appropriate entrainer is screened. Ethylene glycol (EG) is chosen in direct extractive distillation process. Subsequently, it is observed that increasing the pressure can make the azeotropic point of ethanol and 1,4-dioxane disappear. Thus, both EG and dimethyl sulfoxide (DMSO) are used as entrainers in indirect extractive distillation (IED) process. The entropy generation of different sections of each column is analyzed. And then, heat integration and heat pump technologies are used to reduce more energy consumption. The comparison results show that the total annual cost (TAC), total energy consumption, CO2 emissions and entropy generation of IED process with DMSO as entrainer (IED-DMSO) is smaller than those processes with EG as entrainer. The IED-DMSO process in combination with heat integration performs best, the TAC is reduced by

41.96%, energy consumption is reduced by 50.28%, CO2 emissions is decreased by 50.28% and entropy generation is decreased by 57.46% comparison with the IED-EG process.

- **Keywords:** Extractive distillation; Entrainer selection; Energy-saving; Heat integration

Nasma Bouchelkia, Hichem Tahraoui, Abdeltif Amrane, Hayet Belkacemi, Jean-Claude Bollinger, Abdelkrim Bouzaza, Abdelhalim Zoukel, Jie Zhang, Lotfi Mouni. *Jujube stones based highly efficient activated carbon for methylene blue adsorption: Kinetics and isotherms modeling, thermodynamics and mechanism study, optimization via response surface methodology and machine learning approaches*. Pages 513-535.

Water contaminated by methylene blue (MB) dye was treated with activated carbon based on locally collected jujube stones. This activated carbon was characterized by physico-chemical methods after preparation and chemical activation. Response surface methodology (RSM) was used to maximize the MB uptake a dependent variable in Box-Behnken Design (BBD) with the initial concentration of methylene blue (400–700 mg/L), adsorbent dosage (0.6–1.6 g/L), contact time (30–540 min), pH (7−11) and temperature (20–50 °C) as independent variables. Then, the database created by BBD was further modeled using Gaussian Process Regression coupled with Bagging (Bootstrap Aggregation_Bag) and Dragonfly optimization algorithm (GPR_DA_Bootstrap). The results of the optimization analysis using the GPR_DA_Bootstrap model are shown to be superior to those of the BBD model. The experimental validation of the optimal conditions of the GPR_DA_Bootstrap model (X1 = 700 mg/L, X2 = 0.6 g/L, X3 = 540 min, X4 = 11, and X5 =50 °C) led to an MB uptake (501.01 mg/g) significantly higher than that of BBD (456.00 g/g). In addition, the very low error between the experimental and the predicted values given by the GPR_DA_Bootstrap model (8.64 mg/g) compared to that of the BBD model (22.19 mg/g), should be highlighted. This clearly shows the efficiency and the performance of the GPR_DA_Bootstrap model on the one hand; as well as the effectiveness of activated carbon prepared from jujube stones (PJAC) as a low-cost adsorbent on the other hand.

- **Keywords:** Activated carbon; Bootstrap Aggregation_Bag; Box-Behnken design; Dragonfly algorithm; Gaussian Process Regression; Methylene blue adsorption

Na Zhang, Bingjun Wang, Deguo Yue, Dawei Pan, Haijiao Wang, Jiangtao Li, Yang Zhang. *Waste liquid-added regeneration activator to enhance the pore structure and compressive strength of geopolymer-foam-fiber: A sustainable strategy of kenaf fiber pretreatment and reuse*. Pages 536-544.

Developing good pore structure, high-strength inorganic insulation materials derived from fiber-reinforced foaming geopolymer, is desirable for several applications. In this paper, a low-cost, eco-friendly, and high-efficiency method was proposed for processing alkali-treated kenaf fibers (TKF) and metakaolin geopolymer into lightweight yet strong bulk structure geopolymer-foam-fiber (GFF). The composites were produced using H2O2 as foaming agent. The waste liquid of TKF and activator (NaOH and Na2SiO3) were mixed and considered as the regenerating activator. Disordered TKF and regenerating activator with higher viscosity play a crucial role in the mechanical and pore structure of the composites. The results showed that when the foaming agent content increased, the compressive strength of composites decreased. The record-high compressive strength of geopolymer-foam (GF) increased by 1.1–2.1 times and 1.2–2.7 times for ambient temperature and 50 ℃, respectively. GFF with homogeneous pore distribution and high porosity were successfully fabricated by introducing TKF. Therefore, the thermal

conductivity and compressive strength were in the ranges of 0.118–0.248 W/(m·k) (comparable to GF) and 1.6–19.9 MPa (1.1–2.6 times increase compared with GF), respectively. This low-cost and no-waste production of geopolymer foam material can enhance the utilization of agricultural waste and the development of inorganic insulation materials.

- **Keywords:** Thermal conductivity; Compressive strength; Fiber reinforcement; Recyclable method

Xu Kang, Chaolin Li, Wanqing Ding, Yuhao Ma, Shuhong Gao, Xu Zhou, Yidi Chen, Wenzong Liu, Guangming Jiang. *Optimization of operating conditions in the biological enzymes for efficient waste activated sludge dewatering*. Pages 545-552.

The sludge dewaterability is essential for waste activated sludge (WAS) treatment and disposal in wastewater treatment plants (WWTPs). The biological enzyme conditioning process is a promising method to enhance the dewaterability of WAS. In this study, the optimal conditions in terms of pH, temperature, bio-enzyme dosage, and treatment time for five kinds of biological enzymes (α-amylase, cellulase, acidic protease, neutral protease, and alkaline protease) were investigated. Among them, α-amylase and neutral protease showed good performance in conditional optimization experiments. After biological enzyme conditioning, the sludge supernatant of proteins, polysaccharides, and SCOD contents increased. The sludge water content (Wc) decreased, while the capillary suction time (CST) increased. The optimal conditions for α-amylase were pH 6, 45 ℃ of temperature, 30 mg/g TSS of dosage, and 3 h of treatment time, under which the lowest Wc can reach 68.67%. The optimal conditions for neutral protease were pH 6.5, 40 ℃ of temperature, 30 mg/g TSS of dosage, and 2 h of treatment time, under which the lowest Wc can reach 69.82%. Using biological enzymes is an environmentally friendly conditioning process for efficient WAS dewatering. The optimization of operating conditions in the biological enzymes conditioning process may be beneficial to WAS dewatering and further disposal in actual WWTPs.

- **Keywords:** Sludge conditioning; Sludge dewaterability; Biological enzyme; Optimization; Operating condition

Mingjiang Xie, Jianli Zhao, Xianjun Pei. *Maintenance strategy optimization of pipeline system with multi-stage corrosion defects based on heuristically genetic algorithm*. Pages 553-572.

To ensure the high reliability of the pipeline system, it is necessary to take group maintenance actions. This work proposes an optimal group maintenance approach based on a heuristically genetic algorithm to attain the system-performing goal while minimizing overall costs with assured system reliability. Multi-stage corrosion defects and multi-level risk areas are considered in this novel approach. The proposed method can sufficiently avoid pipeline failures by considering the multi-level probability of failure constraints. The methodology is illustrated by taking the 60-segment pipelines with multiple corrosion defects as an example. Numerical studies show that the proposed methodology can find an optimized maintenance strategy with a lower cost compared with the unified batch maintenance strategy. In addition, an optimal dynamic maintenance model is proposed and compared with the static model when the environment of the pipelines varies. Sensitivity analyses of the physical parameters of the phenomenon and the tuning parameters of the data-driven model show that the method has good effectiveness, compatibility, and universality.

- **Keywords:** Multi-stage corrosion; Genetic algorithm; Optimization; Multi-risk area; Maintenance strategy

Yogeswaran Jagadeesan, Shanmugapriya Meenakshisundaram, Keerthi Raja, Anandaraj Balaiah. *Sustainable and efficient-recycling approach of chicken feather waste into liquid protein hydrolysate with biostimulant efficacy on plant, soil fertility and soil microbial consortium: A perspective to promote the circular economy*. Pages 573-583.

The study aims to promote plant growth, soil fertility and soil microbiota using a combination of Bacillus pumilus AR57 and chicken feather protein hydrolysate (CFPH). The bacterium-mediated CFPH (5 % v/v) was found to be the optimum biostimulant concentration that showed significant maize plant (Zea mays L.) growth and enhanced its phytochemical contents (3.7 folds chlorophyll, 1.3 folds protein, 2.3 folds carbohydrate). The addition of CFPH to soil eventually showed a remarkable increase in the soil fertility and microbial community (heterotrophic, 42.23 ×106 CFU/g, nitrogen fixers, 2.45 ×104 CFU/g, phosphate solubilizers, 0.48 ×104 CFU/g and potassium solubilizers, 0.33 ×104 CFU/g). Bacillus sp. is considered the universal cell factory and secretory machine of bioactive peptides. B. pumilus AR57 positively influenced plant growth as a biofertilizer and may develop an adaptive immunity against plant pathogens. The CFPH exhibited an excellent shelf-life of protein stability (719 μg/ml) on the 10th day when stored at 4 °C. Conclusively, the Chick 'n' Farm, our in-house, unprocessed biostimulant, emerged as an effective alternative biostimulant and biofertilizer that replaces the existing chemical fertilizers and enriches the soils' biotic and abiotic factors that will play an inevitable role in the sustainable agriculture and circular economy.

- **Keywords:** Bacillus pumilus; Chicken feather protein hydrolysate; Zea mays; Biostimulant; Soil fertility; Soil microbiota

Sadia Ilyas, Rajiv Ranjan Srivastava, Hyunjung Kim. *Cradle-to-cradle recycling of spent NMC batteries with emphasis on novel Co2+/Ni2+ separation from HCl leached solution and synthesis of new ternary precursor*. Pages 584-595.

Herein, a cradle-to-cradle recycling of post-consumer NMC batteries has been demonstrated with a focused separation of cobalt over nickel by applying the ionic liquid, trihexyl(tetradecyl)phosphonium bis-2,4,4-(trimethylpentyl)phosphinate. At the optimized condition of: 0.8 mol·L−1 ionic liquid, 3.0 mol·L−1 Cl− ions, equilibrium pH value ~5.0, and organic-to-aqueous ratio 2/3, > 99% cobalt was extracted in the organic phase with a separation factor of 1097. Approximately 99% cobalt from the loaded organic was stripped back in 2.0 mol·L−1 HCl solution, yielding high-pure CoCl2·xH2O crystals after crystallizing the stripped solution. Subsequently, ~99% of nickel from the Co-depleted raffinate was extracted over lithium using 0.32 mol·L−1 acetophenone at an organic-to-aqueous ratio of 1 and equilibrium pH ~5.3. Nickel stripped in 2.0 mol·L−1 H2SO4 was crystallized to yield high-pure NiSO4·6H2O crystals. Further, Li-bearing raffinate was subjected to carbonate precipitation at a higher pH (~12) and CO32−:Li+ ratio of 1.2. All the recycled products were further employed to the stepwise synthesis of a new ternary precursor, exhibiting similar electrochemical behaviour (with 149 mAh·g−1 capacity) and found compatible with the precursor prepared using virgin materials. The sustainable process index value determined to be 0.0006 cap·t−1 for the overall recycling process indicated that the process is suitable for sustainable development.

- **Keywords:** Spent Li-ion batteries; Critical raw materials; Resources recycling; Cathode precursor synthesis

Shuang Liu, Jishuang Jiang, Mingyue Yin, Yaoqi Zheng, Caixu Wang, Lilong Yan. *Promoting performance of Anammox by iron loaded sludge biochar with hydrothermal carbonization (HTC-Fe-BC) addition*. Pages 596-607.

Anaerobic ammonia oxidation (Anammox) treatment cannot always achieve optimal efficiency due to its sensitivity to environmental conditions. The nitrogen removal efficiency of Anammox reactors with different iron loaded sludge biochar modified by hydrothermal carbonization (HTC-Fe-BC) addition dose of 0, 2.5 and 5.0 g/L (named BC0, BC1 and BC2) were analyzed. The effects of adding HTC-Fe-BC on the performance of Anammox reactor, extracellular polymeric substances (EPS), microbial community and functional genes were investigated. The results showed that the addition of HTC-Fe-BC could reduce the environmental sensitivity of Anammox reactor, the removal efficiency of total nitrogen increased from 51.20 (BC0) to 70.83 % (BC2), and the activity of Anammox sludge improved by 49.58 %. HTC-Fe-BC increased the activity of Anammox sludge by promoting the secretion of protein, humic acids and cytochrome c in EPS and alleviated the inhibitory effect by mediating the Anammox electron transfer process. After EPS removal and enzymatic hydrolysis, the activity of Anammox sludge in BC2 decreased by 61.38% and 79.80 %, respectively, significantly higher than the reduced values of BC0. Further, the relative abundance of Candidatus_Brocadia in Anammox reactors supplemented with HTC-Fe-BC was increased by 35.56–55.56 % compared to the control group, as were the relative abundances of the key functional genes connected to N transformation. These results deepened the understanding of the potential mechanism by which HTC-Fe-BC improved the efficiency of Anammox system.

- **Keywords:** Anammox; HTC-Fe-BC; Extracellular polymeric substances; Electron transfer; Microbial community; Functional genes

Mina Dolatshah, Ali Akbar Zinatizadeh, Sirus Zinadini, Hadis Zangeneh. *A new UV-grafted photocatalytic membrane for advanced treatment of biologically treated baker's yeast (BTY) effluent: Fabrication, characterization and performance evaluation*. Pages 608-622.

In this study, a superior hydrophilic polyethersulfone (PES) membrane modified with L-Lysine (C, N codoped)-TiO2/WO3 (LTW) photocatalyst is presented to endow self-antifouling properties and amelioration of the membrane performance in versatile wastewater treatment. ATR-FTIR spectra, FESEM, 3D AFM images, and water contact angle (WCA) measurement indicated that successful connection of LTW photocatalyst on PES membrane surface led to improved membrane properties like hydrophilicity and surface roughness. The PES/LTW membranes demonstrated significant enhancement in water permeability (49.79 L/m2.h) and antifouling feature (flux recovery rate (FRR) of 96.96 %). The optimal membrane (M-2, 0.03 wt%) with the highest hydrophilicity, pure water flux (PWF), and fouling resistance, was used to evaluate the filtration performance in a cross-flow setup. Response surface methodology (RSM) was utilized to model and optimize the filtration process. The effects of three influential variables, including operating pressure (P, 3–5 bar), feed COD concentration (C, 500–1500 mg/l), and effect of irradiation on four responses, i.e., flux (L/m2.h), FRR (%), dye removal efficiency (%), and COD removal efficiency (%) were assessed in a continuous regime using nanofiltration of biologically treated baker's yeast (BTY) effluent. The optimum conditions were found to be 693 mg/l of feed COD concentration and 4.44 bar of operating pressure under visible light irradiation. The experimental data compared to the predicted ones indicated a good agreement that confirms the validity of the models describing the performance of the photocatalytic membrane.

- **Keywords:** Surface modified membrane; TiO2-based photocatalytic membrane; Self-antifouling; Modeling and optimization

Hong Ji, Renjie Lu, Ke Yang, Juncheng Jiang, Zhixiang Xing, Jie Guo. *Experimental study on methane explosion suppression by heptafluoropropane drived modified ABC powder*. Pages 623-635.

The accidental methane explosion accident will not only pose a serious threat to the safety of industrial processes, but also cause serious environmental pollution with excessive carbon emissions and greenhouse effect. Therefore, this paper has studied the inhibition effect of modified ABC powder driven by heptafluoropropane on methane explosion. Multiple methane explosion suppression experiments were carried out using a 3.2 L horizontal experimental pipeline under various working condition. The experimental results demonstrate that the modified ABC powder has a certain inhibitory effect on methane explosions, but the explosive suppression effect of the powder improves when heptafluoropropane is used as the driving gas. When 3~4 % heptafluoropropane is used as the driving gas, the flame is obviously inhibited. The deformation degree of flame shape is the largest at 4 % concentration. The flame totally folds inward at this point, forming an uneven finger flame. When 4 % concentration of heptafluoropropane drives the powder, there is a critical value of the concentration of the powder, which is 0.06 g/L. According to the characterization results, the average particle size of the modified ABC powder is less than 5 μm. It has good dispersibility and pyrolysis effect and is not easy to agglomerate. Under the driving action of heptafluoropropane, the powder will form aerosol, which can fully contact and react with the flame. The inert gas around the powder will reduce the forward speed of the flame and ensure that the flame and powder can fully contact and react. The combination of the two has a good synergistic effect and can effectively inhibit methane explosion.

- **Keywords:** Heptafluoropropane; Modified ABC powder; Flame propagation; Methane explosion suppression; Explosion pressure

Aosong Wei, Jianping Li, Minjie Shan, Wenjie Lv, Jianqi Chen, Pengbo Fu, Yanping Liu, Weichun Xu, Li Dai, Hualin Wang. *Removal of chlorine, microparticles and water from high-viscosity liquids by a sand filter coupling hydrocyclone*. Pages 636-646.

Separation energy consumption in industrial production accounts for 10–15 % of global energy consumption. Nonthermal separation represented by sand filtration can open a new door to separation energy savings. Traditional sand filters cannot be regenerated completely, which limits their efficiency. A sand filter coupling hydrocyclone (SFCH) was proposed to enhance regeneration. The performance of SFCHs with different separation particle sizes was systematically analyzed, as indicated by turbidity, water, and chlorine in a pilot-scale experiment. The larger the sand particle size of the SFCH was, the longer it took to reach saturation. The efficiency and cycle were balanced by combining SFCHs with particle sizes of 1–2 mm and 0.5–1 mm. The average turbidity, water and chlorine decreased from 793 NTU, 1439 mg/L, and 126 mg/L to 155 NTU, 389 mg/L, and 88 mg/L, respectively, with a cycle of 88 h. Under the same conditions, the effluent turbidity of the SFCH was half of that of the original disc centrifuge, which indicates that the life of the downstream alumina bed was doubled. Almost 260 t/year alumina consumption can be reduced in a 200,000 tons/year-capacity petroleum resin plant, saving 600,000 USD/year, mainly due to the extension of the service life of the alumina bed.

- **Keywords:** Petroleum resin; Nonthermal separation; Process transformation; Energy saving

A. Carter, S. Imtiaz, G.F. Naterer. *Review of interpretable machine learning for process industries*. Pages 647-659.

This review article examines recent advances in the use of machine learning for process industries. The article presents common process industry tasks that researchers are solving with machine learning techniques. It then identifies a lack of consensus among past studies when selecting an appropriate model given a prescribed application. Furthermore, the article identifies that relatively few past studies have considered model interpretability – a "black-box" challenge holding back machine learning's implementation in more high-risk industrial applications. This interdisciplinary field of engineering and computer science is still reasonably young. Additional research is recommended to standardize methods and establish a strategic framework to manage risk during adoption of machine learning models.

- **Keywords:** Machine learning; Process industries; Risk management; Model interpretability

Kun Zhou, Yifan Tong, Xintong Li, Xiaoran Wei, Hao Huang, Kai Song, Xu Chen. *Exploring global attention mechanism on fault detection and diagnosis for complex engineering processes*. Pages 660-669.

Considering about slow drift and complicated relationships among process variables caused by corrosion, fatigue, and so on in complex chemical engineering processes, an Industrial Process Optimization ViT (IPO-ViT) method was proposed to explore the global receptive field provided by self-attention mechanism of Vision Transformer (ViT) on fault detection and diagnosis (FDD). The applications on data sampled from both a real industrial process and the Tennessee Eastman (TE) process showed superior performance of the global attention-based method (IPO-ViT) over other typical local receptive fields deep learning methods without increasing sample and computation requirements. Moreover, results on six different variants in combing local, shallow filtering and global receptive field mechanisms unravel that the local attention explosion, the information alignment, and the expression capability are three major challenges for further improving on industrial applications of complex deep learning network structures.

- **Keywords:** Self-attention; Convolutional Neural Network; Fluorochemical Engineering Processes; Tennessee Eastman process; Deep learning; Process safety

Jingxiang Liu, Guan-Yu Hou, Weiming Shao, Junghui Chen. *A supervised functional Bayesian inference model with transfer-learning for performance enhancement of monitoring target batches with limited data*. Pages 670-684.

To increase the monitoring performance of the batch process with serious nonlinearity, uneven-length, and limited-data issues, a supervised transfer-learning based functional Bayesian inference method is developed in this study. The raw uneven-length batch data are firstly transformed into functional data by choosing appropriate orthogonal wavelet basis functions (WBFs). Using the approximation coefficients representing the latent features that are inherent to the raw data, a Gaussian process model and a Bayesian inference method are applied based on the coefficients in each source batch process and the established models are transferred to enhance modeling performance for the target process with limited batches. In the proposed functional method, the unfolding operation is not needed for preprocessing, avoiding distortion of the raw data structure. With the compact support property of WBFs, within-batch detection can be implemented effectively to recognize faults earlier. The advantages of the proposed model are verified using a numerical case and an industrial polytetrafluoroethylene process.

- **Keywords:** Batch process; Functional Bayesian inference; Gaussian process; Limited data modeling; Transfer learning

Yanqing Cong, Lingjie Ye, Shiyi Zhang, Qiuyu Zheng, Yi Zhang, Shi-Wen Lv. *Efficient degradation of emerging contaminant by newly-constructed Ni-CoO yolk-shell hollow sphere in the presence of peroxymonosulfate: Performance and mechanism*. Pages 685-693.

Constructing hollow structure is an effective strategy to boost the activity of heterogeneous catalysts in peroxymonosulfate (PMS) activation. Herein, a newly-designed Ni-CoO yolk-shell hollow sphere was first synthesized by a step-by-step method. Interestingly, the etching treatment of NH3·H2O endowed Ni-CoO sphere with hollow yolk-shelled structure, which was beneficial for the increase of specific surface area and the full exposure of active sites. The calcination treatment reduced the charge transfer resistance and enhanced the redox ability of Ni-CoO, further improving its catalytic activity. As expected, 93.1% of diclofenac sodium (DCF) could be rapidly degraded within 5 min over developed Ni-CoO-3/PMS system, and removal efficiency of TOC was as high as 73.3%. Significantly, redox couples of Co3+/Co2+ and Ni3+/Ni2+ were responsible for PMS activation based on radical pathways (namely SO4•−, OH• and O2•−). As the typical radical pathway, 1O2 was also involved in DCF degradation. More importantly, Ni-CoO-3-PMS* complexes mediated the direct electron transfer between DCF and PMS. Furthermore, Ni-CoO-3/PMS system with great stability had excellent practical application prospect in actual wastewater treatment. In short, current work not only offered a high-efficiency catalyst for PMS activation, but also shared some insights into the research on advanced oxidation processes.

- **Keywords:** Yolk-shell hollow structure; Drug residues; Peroxymonosulfate activation; Electron transfer

Kangkai Xu, Jinqiu Hu, Laibin Zhang, Yiyue Chen, Shangrui Xiao, Jiancheng Shi. *A risk factor tracing method for LNG receiving terminals based on GAT and a bidirectional LSTM network*. Pages 694-708.

LNG terminals are important transfer stations for LNG storage, processing, and outbound transmission which involve intensive manual operation and safety management activities. Traditional safety evaluation methods can provide "cause-effect" information when investigating the traceability of incorrect manual operation. However, manual analysis and summarizing risk factor causality is time-consuming and labor-intensive, and there are inaccuracy problems. Usually, HAZOP meetings require safety, electrical, mechanical, instrumentation and other engineers to brainstorm and summarize the risk factors of LNG receiving terminals. This process is laborious and time-consuming, and there is no guarantee that the person will be able to record it completely every time. In this paper, a graph attention network (GAT) and bidirectional Long and Short-Term Memory Network (LSTM) deep integrated learning model is proposed. The model can automatically extract risk factor causal relationships. After starting with a risk factor text, the number type features and syntactic dependency graph features of the input text are fused to enhance the causal relationship traceability of incorrect personnel operation. Taking the unloading and storage processes as examples, in terms of the effect of automatic extraction risk factors, the integrated algorithm model improves the extraction accuracy by up to 7.1% compared with a single algorithm. In addition, the correct extraction rate of different cause-effect relationships increases by 21.57%, while the integrated algorithm considers sentence matching, improves the granularity of cause-effect information based on the traditional method, expands the root cause of risk factors, and the traceability results are consistent with on-site accident event results. At the same time, it is more conducive to accurately managing incorrect manual operations. In the model training sample size sensitivity analysis, the algorithm has a superior correct causal label extraction rate for

different sample sizes when the number of hidden layer stacking layers is K= 2, which solves the problem of model adaptation for the text volume of LNG terminal risk factors.

- **Keywords:** LNG unloading system; Personnel misoperation; Traceability of risk factors; Automatic causality extraction; Features enhancement

Danial Nobakht, Reza Abedini. *A new ternary Pebax®1657/maltitol/ZIF-8 mixed matrix membrane for efficient CO2 separation*. Pages 709-719.

In this study, a novel high-performance mixed matrix membrane (MMM) based on poly(ether-b-amide) was fabricated in which the synthesized ZIF-8 nanoparticles embedded into a maltitol-modified Pebax®1657. Maltitol (as an inexpensive low molecular weight additive) provides a good CO2 affinity. Moreover, an existence of selective affinity in ZIF-8 nanoparticles toward CO2, enhances the CO2 permeability and its selectivity over other penetrants. The synthesized ZIF-8 nanoparticles were added (0–10 wt%) into the Pebax/maltitol (20 wt%) matrix to prepare the Pebax/maltitol/ZIF-8 MMMs. Field Emission Scanning electron microscopy (FESEM) was applied to evaluate the MMM morphology, where excellent dispersion was shown. Thermogravimetric analysis (TGA) was used to determine the thermal properties of prepared membranes. The TGA results indicated that the decomposition temperature of membranes raised as the ZIF-8 loading increased within the Pebax matrix. Differential scanning calorimetry (DSC) implied the disruptive role of MOF on polymer chain mobility which reduces the overall crystallinity and increases the glass transition temperature of MMMs. The analysis of gas permeability at 30 °C and 10 bar revealed that Pebax/maltitol (20 wt%)/ZIF-8 (10 wt%) membrane showed the highest CO2 permeability of 429.57 Barrer. In addition, the highest selectivity values of 69.31 and 26.59 for CO2/N2 and CO2/CH4 separation, respectively; obtained by Pebax/maltitol (20 wt%)/ZIF-8 (5 wt%) at 30 °C and 10 bar. Finally, the performance of Pebax/maltitol (20 wt%)/ZIF-8 (5 wt%) membrane was able to surpass the Robeson upper bound for the CO2/N2 separation and Robeson prior bound for CO2/CH4 one.

- **Keywords:** Pebax®1657; Maltitol, ZIF-8; Mixed matrix membrane; CO2 separation

Cheng Peng, Xuan Zhao, Xiaowen Ji, Jinhong Wu, Weiyu Liang, Huihui Song, Wei Zhang, Xuedong Wang. *Mixed bacteria passivation for the remediation of arsenic, lead, and cadmium: Medium optimization and mechanisms*. Pages 720-727.

Lead(Pb), cadmium(Cd), and arsenic(As) are highly bioaccumulative and hazardous to human health. In this study, the effectiveness and mechanism of mixed bacteria applied to Pb, Cd, and As complex contaminated soil were investigated. According to the one factor per time (OFT) method, the optimal medium consisted of 10 g/L corn pulp dry powder, 10 g/L glucose, 3.8 g/L dipotassium hydrogen phosphate, 0.5 g/L sulfate, 1 g/L trisodium citrate at pH 7.2. The gradient test showed that the key fermentation process conditions were the optimal inoculum level of 1% and incubation temperature of 37 ℃. Then the mixed bacteria agent was used to treat the Pb(II), Cd(II), and As(III) contaminated soil. The adsorption amounts of Pb(II), Cd(II), and As(III) by the mixed bacteria were 10.39 μg/g, 1.65 μg/g, and 67.03 μg/g, respectively. The X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), scanning electron microscope (SEM), and X-ray photoelectron spectroscopy(XPS) analyses showed that the remediation mechanism of three metals by mixed bacteria involved in extracellular polymer adsorption, biomineralization, and oxidation. This study would provide a potential remediation method for the multi-heavy metal polluted soil.

- **Keywords:** Mixed bacteria; Bacillus; Optimization; Heavy metal; Bioremediation

Lu Wang, Yanan Zhao, Xi Chen, Rui long, Zhichun Liu, Wei Liu. *Experimental study on the effects of salt solution pH on the performance of reverse electrodialysis stack*. Pages 728-737.

Reverse electrodialysis (RED) is a promising way of harvesting salinity gradient energy (SGE). The seawater or industrial wastewater may have various pHs. Here the RED performance involving sodium salt solutions with different ion valence ratios including anions of Cl-, SO42-, and PO43- is experimentally investigated in symmetric and asymmetric pH configurations. In the symmetrical pH configuration, increasing the solution pH significantly weakens the energy conversion performance for the 1:1 and 1:3 salts; for the 1:2 salt, the power density and energy conversion efficiency increase and then decrease with increasing pH due to the coupling effects of OH- on the ion transportation through AEMs and CEMs. In the asymmetric pH configuration, increasing the pH of the low concentration solution decreases the power density and energy conversion efficiency. As the pH of the high concentration solution increases, the output power and energy conversion efficiency decrease and then increase for the 1:1 salt due to the coupling effects of the ion transmembrane concentration difference and OH- on the ion migration of IEMs; for the 1:2 salt, the output power and energy conversion efficiency increase and then decrease; for the 1:3 salt, OH- inhibits the hydrolysis of Na3PO4 and anion migration, leading to the lowered output power density and energy efficiency.

- **Keywords:** Reverse electrodialysis; Salinity gradient energy; Solution pH; Energy conversion

Chao-Qiang Wang, Ze-Yuan Wang, De-Ming Huang, Qi-Cong Huang, Yu Chen, Huan Zhang, Zhong-He Shui. *Recovery and recycling core of phosphogypsum: Characteristic hazardous elements risk assessment and analysis*. Pages 738-756.

Phosphogypsum(PG) is a solid waste produced by wet-process phosphoric acid. However, the heavy metals and other pollutants contained in PG have not been controlled in the process of resource utilization, and there are potential risks to the ecological environment and human health. In this paper, the basic physical and chemical properties (XRD, XRF, FTIR,TGA and XPS) and heavy metal pollution of four samples from four PG accumulation areas in China were studied. The study found that the microstructure of different samples of PG was not much different, but there were some differences in heavy metal content. The characteristic heavy metals in PG were determined as "As, Cd, Cr and Hg" by comprehensive evaluation methods of different characteristic heavy metals. At the same time, it was found that the valence of heavy metals in PG was related to the process of wet-process phosphoric acid. The harm of gypsum to the environment was mainly caused by heavy metal elements of As, Cd, Cr, Hg. Using the risk exposure model recommended by the United States Environmental Protection Agency, it was found that there were carcinogenic risks for adults and children in soil intake due to As and Cr pollution. Also, the characteristic heavy metals in PG were determined as "As(As3+, As5+), Cd, Cr(Cr3+, Cr6+) and Hg(Hg2+)". Carcinogenic and non-carcinogenic risks caused by oral intake. Therefore, considering that this was closely related to the long-term accumulation of PG, heavy metals in PG enter the human body through the soil, which causes serious harm to human health. Combined with the above results, the hazard prevention and control model of PG comprehensive utilization was scientifically established from three aspects of hazard identification, risk analysis, and hazard characterization, and the risk control value of PG was determined according to the use scenario of PG. Therefore, this study can provide adequate support for PG's sustainable, efficient, safe, and environmentally friendly utilization.

- **Keywords:** Phosphogypsum; Utilization; Heavy metal; Eco-environmental; Risk assessment

Xueliang Zhu, Xuhai Pan, Hao Tang, Xilin Wang, Yucheng Zhu, Lian X. Liu, Juncheng Jiang, Tao Chen. *Breakup regime of flashing jet under thermal nonequilibrium and mechanical forces and its relationship with jet characteristics during depressurized releases of superheated liquid*. Pages 757-770.

Accidental superheated liquid emissions into the atmosphere yield two-phase releases. The resulting flashing jet, driven by thermal nonequilibrium and mechanical forces, breaks up into massive droplets, fostering beneficial conditions for fire, explosion, and toxic diffusion. In this work, a 20 L tank was built to examine two-phase flow behaviors during depressurized releases of superheated liquids via a high-speed camera and phase Doppler anemometry. Different breakup regimes of flashing jet and dimensionless groups that effectively represent thermodynamic (RpJa) and mechanical (WevOh) driving effects were determined. Based on the interaction between the two effects, quantitative criteria to distinguish different regimes were developed. The accompanying jet characteristics, including jet angle (θ), area fraction (fA), droplet diameter (dSMD), and droplet velocity (ud), and their relationship with jet breakup were revealed. Results show that non-flashing (NFB), partially flashing (PFB), and fully flashing (FFB) breakups coincide with RpJa(WevOh)1/7 < 41, 41 ≤RpJa(WevOh)1/7 < 223, and 223 ≤RpJa(WevOh)1/7, respectively. For small-sized nozzles (d≤3 mm), θ2 and fA2 increase within 41 ≤RpJa(WevOh)1/7 < 558 and then keep stable. The difference for large-sized nozzles resides in 223 ≤RpJa(WevOh)1/7 < 558 (early FFB regime), where θ2 and fA2 decrease slightly due to the enhanced droplet evaporation. In 41 ≤RpJa(WevOh)1/7, dSMD2 decreases and ud2 increases, but at an extremely low rate within 558 ≤RpJa(WevOh)1/7.

- **Keywords:** Superheated liquid; Two-phase release; Thermal nonequilibrium; Mechanical force; Flashing jet; Breakup

Qi Mao, Haiqing Wang, Ming Yang, Jason Hu. *Inference algorithms for the useful life of safety instrumented systems under small failure sample data*. Pages 783-790.

Safety instrumented systems(SIS) have been widely used in petroleum and chemical plants to detect and respond to dangerous events and prevent them from developing into accidents. The in-service time of SIS does not exceed its useful life is one of the crucial assumptions of IEC functional safety standards. The testing method recommended in the IEC standard is essentially a chi-square testing, where the testing effect is proportional to the sample size and, therefore, not suitable for testing the type of data distribution under small samples. In this paper, a rapid inference method of useful life (RIUL) is proposed to: i) determine whether the distribution type of failure data is exponential under small samples with the help of Anderson-Darling testing, and ii) use the Bayesian sequential testing method for estimating the useful life. The sequential posterior odds ratio testing is introduced to test the equipment failure rate one by one. The proposed RIUL approach is applied to the liquid-level protection circuit of the hot high-pressure separator. The engineering simulation results show that compared with IEC standard methods, the proposed method can be performed with fewer failure data, providing a theoretical basis for reasonable maintenance and replacement of equipment.

- **Keywords:** Safety instrumented systems; Useful life; Reliability; Small samples; Failure rate

Tonni Agustiono Kurniawan, Mohd Hafiz Dzarfan Othman, Xue Liang, Hui Hwang Goh, Kit Wayne Chew. *From liquid waste to mineral fertilizer: Recovery, recycle and reuse of high-value macro-nutrients from landfill leachate to contribute to circular economy, food security, and carbon neutrality*. Pages 791-807.

As nutrients shortage that will occur by the next decade could limit global fertilizer production, there are growing needs to recover macro-nutrients such as P and N from landfill leachate, which its generation and treatment have become global environmental issues. This work critically reviews the applicability and the performance of physico-chemical treatments for nutrient recovery from landfill leachate. This article also identifies recent progress and bottlenecks of nutrient recovery from landfill leachate, while providing an overview of how to apply a circular economy paradigm in the nexus of water–food–energy. Due to their ability to recover P and N from landfill leachate, specific attention is given to struvite precipitation, adsorption, and ammonium stripping. Their technological strengths and bottlenecks of each technique are evaluated based on a literature survey of 145 papers (1981–2022). By integrating anaerobic digestion and other nutrient recovery technologies, it is possible for water utilities to provide both renewable energy and nutrients, while contributing to a circular economy, global food security, and carbon neutrality. To attain a sustainable landfill management, the selection of appropriate technology for nutrient recovery from the liquid waste needs to consider the properties of waste stream, recovery performance, discharge standard, impacts, and cost-effectiveness. Overall, this work has consolidated new knowledge between technological development and demand-driven valorization.

- **Keywords:** Ammonium stripping; Climate change; Landfill; Nutrient recovery; Struvite precipitation

Yanhong Guo, Houcheng Zhang, Jingyuan Xu, Mohsen Bahrami. *Evaluation on the waste heat recovery potential of thermoacoustically-driven cryocoolers for solid oxide fuel cells*. Pages 771-782.

Heat accumulation significantly affects the long-term stability of solid oxide fuel cell (SOFC) during operation. Harvesting the waste heat for additional applications can provide dual benefits. A novel hybrid system coupling a thermoacoustically-driven cryocooler (TDC) to a SOFC is proposed, aiming to recover the released waste heat for additional cooling production. Performance indicators assessing the hybrid system are derived by considering a variety of irreversible losses, from which the generic performance properties for such a hybrid system are determined. In comparison to a standalone SOFC system, the effectiveness and advantage of the combined system are shown. It is found that the maximum power density, the corresponding energetic efficiency and the exergetic efficiency of the proposed hybrid system are improved compared to that of the standalone SOFC system. Extensive parametric studies indicate that an increase in working temperature, working pressure of the SOFC, engine stage number or cooling temperature in the TDC improve the proposed system performance, while increasing the heat transfer coefficient worsens the performance.

- **Keywords:** Solid oxide fuel cell; Thermoacoustically-driven cryocooler; Heat management; System integration; Parametric analysis

Chaonan Pan, Ran Zhao, Jin Zhou, Junqiu Wu, Liqin Wang, Yufeng Chen, Zimin Wei, Liming Jia. *Elucidating the positive influence of calcined clay on the retention of carbon components during chicken manure composting*. Pages 808-816.

Composting is an efficient way of recycling wastes, serious mineralization will lead to loss of organic carbon components in the biodegradation process, which will affect the quality of composting products. Calcination technology was adopted to improve the ability of clay minerals to adsorb and retain organic carbon components, and was applied to chicken manure composting. Five treatments (control group (CK), calcined montmorillonite (M-), montmorillonite (M), calcined illite (I-) and illite (I)) were executed. The results indicated that calcined clay minerals significantly reduced organic carbon loss (CK: 57.22%, M-: 54.56%, M: 56.86%, I-: 52.39% and I: 56.08%) and most of them in the form of humic acids. Therefore, the properties of carbon components were more stable, and ultimately improved quality of final compost products. Meanwhile, the network complexity, interactions and contribution of core bacteria involved in the formation of organic carbon were enhanced in the calcined clay minerals treatments through microbial analysis. Moreover, a series of statistical informatics analysis verified that specific structure of calcined clay minerals could indeed retain organic carbon by enhancing role of core bacteria and physicochemical factors. Therefore, this article revealed mechanism of calcined clay minerals retained organic carbon and proposed rational recommendations for practice of composting.

- **Keywords:** Agricultural wastes composting; Organic carbon components; Calcination technology; Retention; Bacterial community

Yan Cao, Mahdi Ghadiri. *Numerical evaluation of the ozonation process in a hollow fibre membrane contactor*. Pages 817-823.

This work presents comprehensive mathematical modelling employed to describe the ozone (O3) mass transfer in the hollow fibre membrane contactor (HFMC) system. Using the model, impacts of operating parameters and membrane specification such as gas phase and liquid flow rates, porosity-to-tortuosity and membrane length on the dissolved ozone at the reactor outlet as well as ozone concentration distribution were simulated. Also, experimental data were used to validate the created simulation model and it was observed that there is reasonable agreement between experimental results and modelling output in terms of dissolved ozone at the reactor outlet at various water flow rate and initial ozone concentration. Based on the simulation outputs, the gas flow rate as well as porosity (ε)-to-tortuosity (τ) do not have impact on the dissolved ozone at reactor outlet while there was slight increase in the ozone outlet concentration with the enhancement of membrane length. Furthermore, the main resistance for ozone mass transfer was liquid phase and it was indicated that the gas phase and membrane subdomain resistance is lower for ozone mass transfer due to higher ozone diffusion coefficient in the gas phase.

- **Keywords:** Membrane; Modelling; Ozone; Simulation

Le Gao, Wanqing Ding, Jingjing Xi, Shuhong Gao, Xu Zhou, Yidi Chen, Kang Song, Xinrui Mao, Renjie Tu, Guangming Jiang. *Effects of different nitrogen/phosphorus ratios on the growth and metabolism of microalgae Scenedesmus obliquus cultured in the mixed wastewater from primary settling tank and sludge thickener*. Pages 824-833.

Microalgae has great potential in wastewater treatment and resource utilization, but few studies have explored the impact mechanism of pollutants on its biochemical compositions. In this study, the effects of different ratios of nitrogen to phosphorus (N/P)

on microalgae Scenedesmus obliquus grown in the mixed wastewater from primary settling tank (PSW) and sludge thickener (STW) were investigated. The optimum N/P ratio for the growth of S. obliquus was determined by nutrient utilization rates and the growth curve. On this basis, the effects of different N/P ratios on its biochemical compositions were explored, and reasons were further analyzed by proteomics. Results showed that at N/P=18, the growth of S. obliquus was optimal (OD680=2.34). And dry weight, lipid production, and chlorophyll-a accumulation were highest (1.70 g·L-1, 0.49 g·L-1, 7.43 mg·L-1), whereas protein production was lowest (0.10 g·L-1). Proteomic results showed that the metabolic activities of S. obliquus cells were the most active at N/P=18. Productivity processes were involved in protein up-regulation, producing more energy. Furthermore, lipid metabolism and fatty acid synthesis pathways were strengthened. The ribosome synthesis activity was significantly enhanced, but the protein content was low, which might attribute to the energy generated by the production activity for other activities.

- **Keywords:** Microalgae; Wastewater from primary settling tank; Wastewater from the supernatant of sludge thickener; Nitrogen to Phosphorus ratios; Proteomics

Muhammad Jahanzaib, Shambhavi Sharma, Ahtesham Bakht, Jaeseok Heo, Duckshin Park. *Analyzing the effectiveness of air curtain in reducing particulate matter generated by human-induced slipstream*. Pages 834-841.

Air curtains are frequently used as separation barriers to reduce the transfer of dust, heat, and smoke between two areas. When people travel from one location to another, they bring dust and airflow with them, known as slipstream. To limit the spread of toxins inside any indoor environment, it is critical to understand the human-induced slipstream. The usefulness of air curtains in preventing human-induced slipstream movement is investigated in this study. We also used an air curtain to monitor airflow, dust flow, and particulate matter transfer from a contaminated zone to a cleaner zone in the chamber. A dust sensor and a particulate matter sensor were used to assess real-time monitoring of dust and PM2.5,10 particles created, as well as the human-induced slipstream. The experiment was performed at a different position (horizontal, vertical, wedge) of the air curtain unit (ACU) and different vane angles (10°−15°, 15°−30°, 30°−45°) with the human walking and without as well. The maximum efficiency for horizontal was 47% at 30°− 45°, for wedge position, it was 74% at 15°− 30°, and for the vertical, it was 81.4% at 30°− 45° angles. Maximum efficiency was found at 81.4% with vertical direction at 30°− 45°. This can help to achieve maximum PM reduction in commercial and public offices.

- **Keywords:** Air curtain unit; Human induced slipstream; Indoor Environment; Real-time monitoring

Ankur Kumar, Trina Podder, Vinay Kumar, Probir Kumar Ojha. *Risk assessment of aromatic organic chemicals to T. pyriformis in environmental protection using regression-based QSTR and Read-Across algorithm*. Pages 842-854.

Hazardous aromatic compounds have a high probability of entering the surrounding environment, posing a threat to humans and other habitats. It is, thus, necessary to estimate the toxicity of these chemicals as a preventive measure before being marketed. The present study involves the development of in silico-based predictive 2D-QSTR models using a PLS regression approach for the exploration of the structural features responsible for the toxicity of T. pyriformis using simple and easily interpretable 2D descriptors employing a dataset containing 892 chemicals. The developed model was extensively validated by evaluating the model's reliability and predictability using

internationally accepted external and internal validation metrics. We have also used the "Intelligent Consensus Predictor" tool and Read-Across software, which shows better results for test set compounds as compared with individual PLS models. We have also validated the models using a set of 383 external set compounds which are not used for the development of models. The results suggested that molecules with aliphatic aldehyde groups are much more toxic to the protozoan whereas chemicals containing C–N fragments at the topological distance 3 & 4, polar and alcoholic groups are less toxic to the protozoan. In conclusion, the developed QSTR and Read-Across models might be extremely beneficial as guides for researchers to estimate the toxicity profile of novel compounds against T. pyriformis.

- **Keywords:** Aromatic organic compounds; Toxicity; Tetrahymena pyriformis; 2D-QSTR; ICP; Read-Across

Lobzang Chorol, Sunil Kumar Gupta. *Evaluation of groundwater heavy metal pollution index through analytical hierarchy process and its health risk assessment via Monte Carlo simulation*. Pages 855-864.

Heavy metals in water are detrimental to both human health and the environment. This study delineated the assessment of heavy metal contamination using AHP-based HPI and their associated health risk through Monte Carlo simulation. Triplicate samples of ground water were collected from 28 locations in Leh town (Ladakh) for the two seasons, i.e., summer and winter. The study revealed higher concentration of chromium (40–179 μg/L), Cadmium (5–12 μg/L), and Iron (90–2060 μg/L) beyond their permissible guideline values (IS 10500). The seasonal effect on the ground water quality was not pronounced due to cold desert region and the concentration were comparatively higher in summer than winter. AHP-HPI analysis of groundwater using AHP based modified criteria weights demonstrated higher accuracy than the conventional methods of HPI determination. The study revealed that about 96.43% of samples fall under highly polluted category which may be attributed to high concentration of Cr, Cd, Fe and Mn which showed strong Pearson correlation with AHP-HPI and thus, were mostly responsible for deteriorating the groundwater quality of the region. Multi-exposure pathways risk analysis using Monte Carlo simulation revealed that 95th percentile of carcinogenic risk in children (5.54E −03) was about 3 times higher than adults (2.38E-03). The non-carcinogenic risk was evaluated using quantification of Hazard Index (HI) which followed the order of Cr > Mn > Cd > Fe > Ni > Zn. The sensitivity analysis revealed that concentration of metal was major influential factors followed by body weight and exposure duration causing overall health risk.

- **Keywords:** Analytical hierarchy process; Heavy metals; Monte Carlo simulations; Carcinogenic risk; Sensitivity analysis

Junhua Liu, Yunjian Xu, Yingmo Zhu, Wen Yin, Danhua Fan, Guangxuan Yan, Syed Turab Raza, Zhiyun Lu, Zhe Chen. *Enhanced soil methane oxidation in both organic layer and topsoil during the succession of subtropical forests*. Pages 865-876.

Although (sub)tropical forests account for 10–20% of the atmospheric methane (CH4) uptake by soils, the study of soil CH4 oxidation rates and the controlling factors during the chronosequences of forest succession remains poorly understood. The objectives of this study were to characterize the vertical distribution patterns and dynamics of CH4 oxidation among the early-, mid-, and late-successional stages of subtropical forests, and to investigate the main drivers of soil CH4 fluxes. Three successional forests soils were collected and the ambient and potential CH4 oxidation rates, the related enzymes as well as the key soil parameters were determined in the laboratory. The soils at mid- and late-successional stages functioned exclusively as a CH4 sink while the soil at early-

succesional stage was either a CH4 source or sink. Soil CH4 oxidations showed significant vertical distributions along with the successional gradients. The highest rate of ambient CH4 oxidation was observed in the A-horizon of the mid-successional stage (forest age ~ 100 years), increased by 26-fold compared to the early successional stage, while the highest rate of potential CH4 oxidation was detected in the O-horizon of the late-successional stages (forest age > 300 years), which increased the CH4 oxidation by 29% and 21% respectively compared to the early- and mid-successional stages. Soil CH4 oxidation enhanced with decreasing of soil nitrite and nitrate content but weakened with declining of soil moisture at the successional chronosequence. Collectively, subtropical forests have the potential to increase the soil sink capacity for CH4 oxidation along the successional gradient, and thereby providing the negative feedbacks to ecosystems under climate changing.

- **Keywords:** Methane oxidation; Forest succession; Chronosequence; Nitrogen availability; Methane monooxygenase activity; Subtropical forest

Rasoul Raei, Iman Izadi, Marzieh Kamali. *Performance analysis of up/down counters in alarm design*. Pages 877-885.

Alarm systems, as a layer of protection, play a critical role in process safety. Modern alarm systems, however, pose a challenge in the process industry due to alarm floods, missed alarms, and a large number of false, nuisance, and chattering alarms. In this paper, we propose up/down counter configurations as a technique to improve the quality of univariate alarm systems. Mathematical models are developed based on the Markov chain to study the performance of up/down counters and analytical expressions for performance indices (the false alarm rate, missed alarm rate, and expected detection delay) are derived. The results are confirmed using Monte Carlo simulation and the utility of the proposed technique is demonstrated through examples. This proposed up/down counter is specifically compared to delay-timers as a common and well-studied alarm configuration technique.

- **Keywords:** Process safety; Alarm systems; Alarm management; Up/down counters

M.S. Almanzalawy, M.F. Elkady, S. Mori, A.E. Elwardany. *The role of acetone for cleaner combustion in diesel engine*. Pages 886-897.

The effects of acetone on the combustion, performance and emission characteristics of a diesel engine were investigated. This study focused on the advantages, disadvantages and limitations of using acetone in a diesel engine. Acetone as an oxygenated additive with a carbonyl functional group was blended with diesel fuel at different concentrations. The engine was operated at a constant speed of 2000 rpm and different loads. Low concentrations of acetone reduced the coefficient of variation (COV) and slightly increased the peak pressure and the heat release rate (HRR) at most loads. The emissions of CO and NOx were reduced besides a slight enhancement in the engine performance. Relatively high concentrations significantly increased the COV at both idle and full loads and depressed the peak pressure and HRR at full load. Acetone with relatively high concentrations caused instabilities in the diesel engine operation.

- **Keywords:** Acetone; Diesel engine; In-cylinder pressure; Misfire; Stability

Yihui Liu, Shikang Xie, Yuanjing Chen, Shi Chen, Gongduan Fan, Junge Xu, Yingmu Wang. *Metagenomic analysis reveals the influence of pH and hydraulic loading on thiosulfate-driven denitratation: Insight into efficient performance and microbial mechanism*. Pages 898-907.

This study evaluated the performance of thiosulfate-driven denitratation (TDD) systems. The results demonstrated that a cycle time of 4.00 h was adequate for NO3--N removal and NO2--N accumulation (average NO3--N removal efficiencies (NREs): 95%; average NO3--N accumulation efficiencies (NAEs): 79%) under pH range of 6.50–9.50. According to metagenomic research, the enrichment of dominant denitrifiers is essential for the pH responsiveness of the TDD system. Furthermore, interspecific microorganism cooperation and the potential selective advantage of NO3--N reducing bacteria over NO2--N reducing bacteria contributed to a higher NO2--N accumulation efficiency. In addition, the results revealed that the reduction in hydraulic loading time (HRT) improved metabolic activities (i.e., energy metabolism). Overall, this study broadened the application potential of the TDD system and enhanced the understanding of microbial niches and the metabolic potential of autotrophic denitrification from electron transfer and metagenomic insights.

- **Keywords:** Nitrite accumulation; Partial denitrification; Metagenomic sequencing; Functional microorganism; Potential interspecies cooperation

Si-qi Jiang, Chun-chen Nie, Shun-xiang Shi, Yong-qiang Zhao, Xiang-guang Li, Chao-zhu Deng, Lu Yang, Ling Zhang, Xiang-nan Zhu. *Enhancements of dissociation of electrode materials in spent lithium-ion batteries by low-temperature heating pretreatment*. Pages 908-920.

The recycling of spent lithium-ion batteries (LIBs) is considered one of the prominent areas of interest in the global community owing to its economic interests and environmental protection. The existence of binder in batteries makes it difficult in the dissociation of electrode material from the fluid collector. This has prompted the need to develop an innovative means of dissociation. In this study, low-temperature heating with low-energy consumption is proposed to enhance the efficiency of dissociation. To determine the ideal heating temperature, the pyrolysis properties of electrode materials and binders were examined by the TG. The dissociation characteristics were analyzed by the grade of the collector (copper, aluminum) and the size composition of crushed electrode material. The surface morphology and element distribution of electrode material and the fluid collection were examined using SEM-EDS. The heating results shows that 500 ºC is the efficient low-temperature which is only slightly higher than the decomposition temperature of the PVDF. The SEM examination reveals that the electrode material's looser structure following heating makes it simpler for the electrode material to fall off of fluid-collecting surfaces, which intensifies dissociation. After heating, the crushing products of the anode and the cathode with size of − 0.074 mm increased by 5.94 % and 38.88 % respectively, the grade of the copper anode and the aluminum cathode in + 2 mm increased by 5.55 % and 38.92 % respectively.

- **Keywords:** Spent lithium-ion batteries; Low-temperature heating; Efficient dissociation; Low-energy drive; PVDF removal

Youquan Yuan, Zhuo Chen, Jingjie Feng, Chonglin Wang, Bingkai Wang, Sizhen Liang, Ran Li. *Research on the dissipation framework and dissipation coefficient prediction model of the supersaturated dissolved gas in solid media containing water*. Pages 921-934.

Supersaturation of dissolved gas in water will cause fish to suffer from gas bubble diseases and even death. Therefore, it is imperative to illustrate the dissipation process of dissolved gas and then seek measures to remit the negative effects of dissolved gas

supersaturation on fish. Generally, adding solid media (SM) to water has proven to be an effective and economical way to remove supersaturated dissolved gas from aquaculture water. While, the supersaturated dissolved gas dissipation framework in solid media containing water was still unclear. In this paper, combined with laboratory experiments and research available in the literature, the dissipation framework of dissolved gas was proposed along with the calculation of the liquidgas interfacial transfer mass, solid wall adsorption mass, porous media adsorption mass, and inner dissipation mass. The solid wall adsorption coefficient was found to follow a power function of the contact angle, and the porous adsorption coefficient logarithmically increased with the specific surface area. It was found that the inner dissipation coefficient exponentially increased with increasing total dissipation coefficient. Utilizing an approximation algorithm method, a model for the prediction of the dissipation coefficient was established. The research reported in this paper could contribute to enriching the research field of supersaturated dissolved dissipation and is significant for ecological and environmental protection.

- **Keywords:** Supersaturated dissolved gas; Solid media; Dissipation framework; Dissipation coefficient; Prediction model

Zhiliang Cui, Guoren Xu, Banu Ormeci, Jiayin Hao. *Enhanced adsorption of copper and cadmium by magnetic biochar with a high specific surface area prepared from penicillin mycelial dreg via K2FeO4 fabrication*. Pages 935-945.

In this study, a novel magnetic material (MPC800) was synthesized from penicillin mycelial dreg via K2FeO4 fabrication. The characterization results demonstrated that Fe3O4 particles were successfully loaded on the surface of MPC800, which provided independent functional sites, with high surface area accompanied by strong magnetic separation performance. The removal capacities of Cu2+ and Cd2+ on MPC800 in the single-metal system reached 93.28 mg/g and 69.20 mg/, respectively, at 25 °C and pH 5.0, which were 12.31 and 19.60 times higher than those before activation. The sorption of Cu2+ and Cd2+ on MPC800 fitted well to the pseudo-second-order model and Langmuir isotherm model. In the binary-metals system, the sorption of Cu2+ on MPC800 was slightly affected. At the same time, the uptake of Cd2+ was severely inhibited, indicating that competitive adsorption occurred between the two metal ions, and the adsorption preference of Cu2+ was better than that of Cd2+ on MPC800. Furthermore, MPC800 was highly effective in metal ion solutions prepared with natural water and has an excellent recycling capacity.

- **Keywords:** Penicillin mycelial dreg; K2FeO4 activation; Magnetic biochar; Cu2+/Cd2+ adsorption; Competitive adsorption

Tao Hai, Ibrahim B. Mansir, Asmaa khudhair yakoop, Hasan Mulki, Ali E. Anqi, Ahmed Deifalla, Yong Chen. *Integration of wind turbine with biomass-fueled SOFC to provide hydrogen-rich fuel: Economic and CO2 emission reduction assessment*. Pages 946-959.

Addressing the energy crisis and global warming issues would entail urgent development of efficient and environmentally-benign power generation systems to mitigate the future clean energy policies. The biomass-driven SOFC systems are considered in this regard as pioneer technologies to supply clean power, particularly for decentralized applications. However, enough biomass availability and supply is a main challenge to run these systems. In current research to reduce biomass consumption, the biomass-driven SOFC is hybridized with wind turbines to produce pure hydrogen via a PEM electrolyzer. Produced hydrogen is added to the anode of SOFC to enrich the hydrogen content of the synthesis gas fuel. Feasibility assessment of proposed hybrid SOFC/wind turbine structure is examined considering first and second laws. Then, comprehensive economic

and environmental appraisals are considered to inspect trade-offs between increased costs (associated with wind turbine and electrolyzer) and increased power as well as decreased CO2 emission. Finally to determine the optimal conditions for proposed system operation, triple-objective optimization via genetic algorithm is implemented. Obtained results have revealed exergy efficiency enhancement by 7.3% and CO2 emission reduction by 13.0 %, via incorporation of wind turbine. These technical and environmental performance enhancements are achieved at the expense of around 6.4 % increase in unit electricity cost, due to the increment of capital expenditures associated with the wind turbine and water electrolyzer. From parametric analysis, it is found that, the proposed framework yields lower electricity price and CO2 emission under higher cell temperatures and lower fuel utilization factors.

- **Keywords:** Solid oxide fuel cell; Wind turbine; Biomass; Hydrogen; Tri-objective economic optimization

Jing Yang, Run Huang, Xuan He, Xiaodong Lv, Renlin Zhu, Huixin Jin, Xue Deng. *Research for the recovery of Zn and Pb from electric arc furnace dust through vacuum carbothermal reduction*. Pages 960-970.

Isothermal kinetic methods were used to investigate reduction process in the Zn and Pb during the vacuum carbothermal reduction of electric arc furnace dust (EAFD). During the experiments, the volatilization ratios of Zn and Pb in EAFD increased with the increase of temperature and holding time, which was 96.29 % and 83.91 % for Zn and Pb respectively at a temperature of 1000 °C and holding time of 60 min. The main phase changes of Zn and Pb in the reduction process were ZnFe2O4 → ZnO → Zn and PbSO4 → PbO → Pb, and the generated Zn and Pb gases escaped and were collected via condensation. In the kinetic study, the volatilization of Zn was controlled by three-dimensional diffusion (Jander) with an apparent activation energy of 19.97 kJ/mol, whereas the volatilization of Pb was controlled by the interfacial chemical reaction with an apparent activation energy of 85.68 kJ/mol. The results show that higher purity of valuable metals Zn and Pb could be obtained, laying a theoretical foundation for the treatment of EAFD pollution.

- **Keywords:** Electric arc furnace dust; Vacuum carbothermal reduction; Zn; Pb; Isothermal kinetics

Siti Fatihah Ramli, Hamidi Abdul Aziz. *Potential use of tin tetrachloride and polyacrylamide as a coagulant-coagulant aid in the treatment of highly coloured and turbid matured landfill leachate*. Pages 971-982.

The effectiveness of using natural coagulants as flocculants and tetravalent metal salts as coagulants in the treatment of landfill leachate remains debatable. The main aim of this study is to assess how well the polymer polyacrylamide (PAM) could interact as a coagulant, coagulant aid or flocculant with the tetravalent metal coagulant tin tetrachloride (SnCl4) in the removal of contaminants from leachate. Thus, this study examined the performance of a mix of the rare four-valence metal SnCl4 as a coagulant and compared it with the organic-based coagulant and flocculant PAM (molecular weight of 3.46 × 104 Da and zeta potential of −57.9 mV). Optimal rapid/slow mixing and settling times were evaluated by performing a standard jar test. The optimal rapid mixing rates for SnCl4 and PAM were 220 rpm and 120 rpm, respectively. At these speeds, 98.4% reductions of colour and 98.7% of SS were obtained by using SnCl4 as opposed to 35.1% and 15.3% reductions for colour and SS, respectively, by using PAM. The best slow mixing speed for both coagulants was 60 rpm, with 98.4% and 98.6% reductions of colour and SS, respectively. Whereas PAM resulted in a 40.4% reduction in colour and an insignificant reduction in SS. SnCl4 performed better in colour and SS treatment at a faster settling time (40 min) than PAM, which required a settling time of 45 min. The optimal conditions for the application of SnCl4 as the sole coagulant were pH 8 and 10

000 mg/L SnCl4. Under these conditions, SnCl4 resulted in almost complete reductions in colour and SS. However, PAM was ineffective when applied as the sole coagulant. When 100 mg/L PAM was introduced as a coagulant aid, the dosage of SnCl4 decreased to 6000 mg/L. At this dosage, SnCl4 caused 94.3% and 95.9% reductions in colour and SS, respectively. After treatment, the settling rate and sludge volume index also significantly increased to 0.61 cm/min and 84.2 mL/g, respectively. Therefore, SnCl4 and PAM could be used together to remove pollutants effectively.

- **Keywords:** Solid waste, coagulation-flocculation; Leachate; Sludge, charge neutralization

Lu Zhang, Xiangyang Sun. *Food waste and montmorillonite contribute to the enhancement of green waste composting*. Pages 983-998.

Composting is currently the best strategy to dispose of green waste (GW) containing substantial quantities of lignocelluloses that prolongs composting time and yields unstable compost. This study aimed to evaluate the effects of food waste (FW, at 0%, 35%, and 55%) and montmorillonite (M, at 0%, 10.5%, and 15.5%) as the composting amendments on the physicochemical and microbial characteristics of compost in two-stage composting of GW. Changes in temperature, bulk density, C/N ratio, carbon dioxide emission, organic matter, humic substances, lignocellulosic substances, microbial numbers, and phytotoxicity were assessed during GW composting. The results demonstrated that combining FW and M exhibited positive effects, and 35% FW and 15.5% M obtained the best results in all compost characteristics. The optimum extended thermophilic period, enhanced lignocellulose decomposition, and generated a stable and mature product in only 21 days. Consequently, the best final compost was mature (C/N ratio: 7.01, HAs/FAs ratio: 3.14, and NH4+-N/NO3−-N ratio: 0.10), nutrient-rich (N: 4.89%, P: 2.01%, and K: 0.92%), and no phytotoxic (germination index: 145%). This study unveils the effects of FW, M, or a combination of FW and M on compost characteristics. The study therefore increases the understanding of the sustainable disposal of an important solid waste.

- **Keywords:** Composting; Food waste; Germination index; Green waste; Montmorillonite

Norafneeza Norazahar, Daashna Suppiah. *The shift work affecting sleep pattern and social well-being of workers: The food manufacturing industry in Selangor, Malaysia*. Pages 999-1009.

Many industries operate or run 24 h and seven days a week with downtime only for maintenance and repair in manufacturing facilities. This continuous operating trend allows for a higher production volume since the industry has relentless pressures on cost containment to maintain profit margins. However, the practice poses high risks of occupational injuries or major accidents. Shift working hours could lead to various safety and health and significantly impact the workers' well-being. Based on this fact, this paper presents a correlation analysis of shift works with sleep patterns, fatigue, and work injuries in food manufacturing plants, specifically in Malaysia. A survey using a set of questionnaires was conducted on two food manufacturing industries in Selangor, Malaysia. The industry operates continuously with a pre-planned downtime due to market globalization, industrialization transformation, and the rising demand for food. The companies in the food manufacturing industry held frequent internal and external audits to ensure the food quality was not being compromised and adhered to the local acts and regulations. To ensure the company runs continuously, the companies practice slow rotation schedules of shift work systems, where workers change to a new shift every three months. The companies have three working shifts per day, namely the morning shift (7.00 am to 3.00 pm), the afternoon shift (3.00–11.00 pm) and the night shift (11.00 pm to 7.00 am). Based on the statistical analysis, many workers prefer the day

shift over the afternoon and night shifts. Sleep patterns and fatigue are significantly correlated with work-related injuries. Due to shift work, the workers tend to have fewer sleep hours, resulting in poor sleep patterns, which could increase the possibility of work injuries. In conclusion, workers' physical, mental and social well-being in any industry should be promoted and maintained to the highest degree.

- **Keywords:** Human factors; Human fatigue; Safety; Shift work; Spearman correlation

Biswajit Dehingia, Hemen Kalita. *Facile, cost-effective and mechanically stable graphene-melamine sponge for efficient oil/water separation with enhanced recyclability*. Pages 1010-1022.

Water contamination due to the accidental release of oil spills and the discharge of industrial wastes into water bodies is considered an ecological disaster worldwide. At present, it is imperative to establish a low-cost method for the efficient separation of oils from water to address this problem. Here, a facile and cost effective approach to fabricate graphene modified melamine sponge (MS) is reported (rGO-MS) for efficient oil/water separation. The pristine MS is dip coated with graphene oxide (GO) followed by post treatment with thiourea to obtain the final rGO-MS with enhanced hydrophobic behavior. The water contact angle of the prepared rGO-MS is about ~145°, which signifies its excellent hydrophobic character. The prepared rGO-MS shows excellent mechanical integrity with no significant deformation in its shape after applying load on it for 500 cycles. Only 10% of deformation occurred after 100 cycles of the pressing-releasing cycle by hand. The rGO-MS shows excellent absorption capacity for various oils such as soybean oil, kerosene, petrol, diesel, mustard oil and organic solvents such as acetone, ethanol, chloroform, toluene and DMF (Dimethylformamide). The rGO-MS has an absorption capacity in the range of ~ 79–149 g/g, with enhanced recyclability up to 20 numbers of cycles for various oils and organic solvents. Moreover, the sponge shows high separation efficiency of 99.9% for kerosene, diesel and petrol oil. For soybean oil and mustard oil, the separation efficiency is about ~97.0% and ~95.4% respectively. The use of very less expensive material with ease of fabrication technique will lead to the large scale production of the rGO-MS, which will help in the efficient oil/water separation process very economically.

- **Keywords:** Oil spill; Graphene; Graphene oxide; Hydrophobic; Melamine sponge

Xiaowei Zhai, Le Hao, Teng Ma, Bobo Song, Kai Wang, Jinlei Luo. *Non-linear soft sensing method for temperature of coal spontaneous combustion*. Pages 1023-1031.

The accurate measurement of the temperature of coal spontaneous combustion is a key technology for coal spontaneous combustion and fire prevention and is important to realising safe coal mining and reducing energy losses. A soft sensor model based on a hybrid-kernel-function support vector machine with an improved genetic algorithm is proposed for the nonlinear relationship between the concentration of a characteristic gas of coal spontaneous combustion and the temperature of the coal body. The natural oxidation process of the coal body is simulated using a coal-spontaneous-combustion oxidation warming experiment bench. The gas concentration and maximum temperature of the coal body at different moments in an oxidation warming experiment are taken as the model input data. Various soft sensor models are automatically optimised by a genetic algorithm in the training process, and the performances of the models are compared and evaluated in the field. The results show that the evaluation indexes of the hybrid-kernel-function model are better than those of the single-kernel function. In the training process, the evaluation indexes of the model with hyperparameters automatically optimised by the genetic algorithm are better than those other models, further verifying the nonlinear relationship between the gas concentration and coal temperature in the

process of coal spontaneous combustion and oxidation. The use of the improved support vector machine model basically results in no deviation between the soft sensor results and actual temperature data in the field test, indicating that the soft sensor model has high accuracy, generalisation ability and applicability. The improved support vector machine model has a mean absolute percentage error of ≤ 1.616%, mean absolute error of ≤ 0.533 ℃, and root-mean-square error of ≤ 0.608 ℃. These results indicate that the soft sensor problem of coal spontaneous combustion can be considered a typical small-sample regression method. The proposed method can be further applied to similar problems in the energy industry.

- **Keywords:** Coal spontaneous combustion; Secure mining; Genetic Algorithms (GA); Support vector machines (SVM); Soft sensors

Kiyotaka Tsunemi. *Risk assessment of nano-scale solid carbon sourced from a CO2-free hydrogen manufacturer used at a steel plant and disposed at a landfill site*. Pages 1032-1038.

A screening assessment of the human health risk from nanocarbon materials, which are solid carbon species produced in carbon-free hydrogen production by methane decomposition, was conducted during the life cycle stages of steel utilization and landfill disposal. First, the scenario was established for the use in the steel industry of a substantial amount of nano-scale solid carbon as an alternative to pulverized coal injected into the blast furnace. Additionally, the scenario was set for landfill disposal of solid carbon. For these scenarios, atmospheric emission quantities during loading and unloading and during storage of solid carbon were estimated using existing emission scenario documents. The atmospheric concentration of solid carbon was estimated using a low-rise industrial source dispersion model. Finally, human health risks were evaluated and compared with the general environmental threshold of carbon nanomaterials in the surrounding area. The results indicated that the atmospheric concentrations of solid carbon around the steel plant and the landfill site did not exceed the environmental threshold by implementing possible emission reduction measures.

- **Keywords:** Methane decomposition; Carbon nanomaterial; Atmospheric dispersion; Risk assessment; Steel industry; Landfill

Chao Chen, Jie Li, Yixin Zhao, Floris Goerlandt, Genserik Reniers, Liu Yiliu. *Resilience assessment and management*. Pages 1039-1051.

Resilience assessment and management of technical systems have been increasingly important as the current applications in the process industries are becoming more complex. Several review papers on resilience management methods and applications have been published by researchers from different aspects. However, none of them put the focus on bibliometric analysis of the relevant research works especially those in the process industries. This study pays attention to system resilience assessment and management, by reviewing sources of relevant publications, collaboration of institutions and authors, and development trends. In addition, the development of resilience engineering and management is further investigated through analyzing the most influential and relevant journals of process safety and environmental protection. This review provides valuable information regarding knowledge structure, evolution and influential publications, and high-level insights for future research.

- **Keywords:** Resilience management; Resilience assessment; Bibliometric analysis; Data visualization; Process safety and environmental protection

Han Zheng, Jiangkun Du, Hua Zhong, Qian Yuan, Jiaquan Zhang, Wei Kang, Qingbin Sun, Min Tao, Wensheng Xiao, Dionysios D. Dionysiou, Ying Huang. *Enhanced persulfate activation by sulfur-modified Fe3O4 composites for atrazine degradation: Performance and mechanism*. Pages 1052-1065.

A novel sulfur-modified Fe3O4 composite (SF10) with excellent magnetic properties was prepared via a solvothermal method. Compared with unmodified Fe3O4, SF10 exhibited excellent performance on the activation of peroxydisulfate (PDS) for atrazine degradation and maintained good reusability. According to the quenching experiments and electron paramagnetic resonance (EPR) test, hydroxyl radical (•OH) and sulfate radical (SO4•−) were the main active species. Notably, comprehensive characterization of the morphology, crystal structure, electrochemical analysis, and surface chemical composite revealed that sulfur modification introduced pyrite and pyrrhotite phases into Fe3O4 structure to improve its catalytic activity and electron transfer capacity. Density functional theory calculations showed that sulfur modification enhanced the electron transfer from Fe3O4 to PDS and the adsorption of PDS on the catalyst surface, which was beneficial for the activation of PDS. Moreover, the surface reducing sulfur species (≡S2− and ≡S22−) acted as the electron donor for Fe(II) regeneration, driving a faster Fe(II)/Fe(III) redox cycle of SF10 for the activation of PDS. This study provides a further understanding of the synergism between sulfur and iron, and broadens the application of Fe3O4 in PDS-based advanced oxidation processes for wastewater treatment.

- **Keywords:** Atrazine; Peroxydisulfate; Sulfur-modified Fe3O4; Sulfate radicals; Water treatment

Laifeng Song, Zonghou Huang, Wenxin Mei, Zhuangzhuang Jia, Yin Yu, Qingsong Wang, Kaiqiang Jin. *Thermal runaway propagation behavior and energy flow distribution analysis of 280 Ah LiFePO4 battery*. Pages 1066-1078.

Thermal runaway propagation (TRP) of lithium iron phosphate batteries (LFP) has become a key technical problem due to its risk of causing large-scale fire accidents. This work systematically investigates the TRP behavior of 280 Ah LFP batteries with different SOCs through experiments. Three different SOCs including 40 %, 80 %, and 100 % are chosen. In addition to key TRP characteristic parameters such as temperature, TRP time and speed are analyzed, more importantly, the energy flow distribution during the TRP of large-size LFP module is also revealed. The results indicate that among the three groups of modules, TRP occurs only in the module with 100 % SOC, which is attributed to the higher internal energy (666.11 kJ) and heat transfer power (264.07 W). For the module with 100 % SOC, the TRP time interval fluctuates from 667 s to 1305 s, and the TRP speed is in the range of 0.05–0.12 mm/s. Furthermore, the energy flow distribution indicates that more than 75 % of the energy is used to heat battery itself, and approximately 20 % is carried out by ejecta. Less than 10 % can trigger neighboring batteries into thermal runaway. This work may provide important guidance for the process safety design of energy storage power stations.

- **Keywords:** Lithium-ion battery safety; Thermal runaway propagation; State of charge; Overheating; Heat transfer

Imane Haydari, Khalid Aziz, Savaş Kaya, Taner Daştan, Naaila Ouazzani, Laila Mandi, Faissal Aziz. *Green synthesis of reduced graphene oxide and their use on column adsorption of phenol from olive mill wastewater*. Pages 1079-1091.

A novel reduced graphene oxide (RGO) synthesis using Verbena officinalis as a green, reducing agent was out-reaching. RGO was encapsulated in sodium alginate (SA) by cross-linking (SA-RGO beads). SA-RGO beads have been used to treat olive mill wastewater (OMWW). This effluent is rich in phenolic compounds that inhibit biological degradation and are toxic at high concentrations. The newly prepared SA-RGO beads were characterized by scanning electron microscopy (SEM),energy-dispersive X-ray spectroscopy (EDS), X-ray diffractometer (XRD), BET surface area analyzer, and Fourier transforms infrared spectroscopy (FTIR). In addition, the organic compounds of Verbena officinalis were determined by HPLC to reveal the reduction mechanism of graphene oxide (GO). Finally, batch and fixed-bed column adsorption tests were performed to assess the performance of SA-RGO beads. The kinetics, isotherm models and adsorption thermodynamics show that the pseudo-second-order and Freundlich best present phenol adsorption and the endothermic reaction. Thomas and Yoon-Nelson's models satisfactorily described fixed-bed column adsorption. The optimized adsorption parameters were 3.68 g L−1 of adsorbent dosage, pH of 4.0, adsorption time of 135 min, and temperature of 25 °C. The reusability of SA-RGO beads and regeneration experiments with HCl (0.5 M) were performed in fixed-bed reactors. The results showed a phenol adsorption capacity of 994 mg g−1 for an initial concentration of 4000 mg L−1.

- **Keywords:** Adsorption; Green synthesis; Reduced graphene oxide; Phenol; Verbena officinalis

Natalie Schmidt, Jens Denecke, Juergen Schmidt, Michael Davies. *Numerical simulation of cooling a large-scale horizontal storage tank in a heavy rain event*. Pages 1092-1100.

A new CFD model has been developed for the accurate calculation of storage tank breathing during cooldown within a heavy rain event. All relevant phenomena occurring during the cooling of storage tanks in a heavy rain event were evaluated, namely temperature stratification and convection inside the tank, and heat transfer though the tank wall including a rain film on the outside. In this study, modeling for non-condensable media, such as dry air, is presented. Similar negative pressure scenarios occur during maintenance work when process plants are cleaned or when storage tanks are inertised. Here, the tank atmosphere was modeled with a Euler approach using a mixture multiphase model (MMP) to extend the functionality for condensable substances. The rain film on the outside of the tank was realized using a dispersed phase model (DMP) in combination with a thin film model in the cell closest to the wall. The model was developed using the software STARCCM+ (Siemens Industries Digital Software, 2022). The CFD model has been validated against experimental data available in the literature (Schmidt et al., 2022) for the cooling of a large scale horizontal storage tank of 191 m3. For the validation of the model, experimental thermographic data were evaluated and adapted for CFD.

- **Keywords:** Loss prevention; Vacuum damage; Tank breathing; Storage tank; Numerical simulation, CFD

Mohamed I. El-Hadary, S. Senthilraja, Mohamed E. Zayed *A hybrid system coupling spiral type solar photovoltaic thermal collector and electrocatalytic hydrogen production cell: Experimental investigation and numerical modeling*. Pages 1101-1120.

The sustainable cogeneration of hydrogen and electricity is one of the promising strategies to boost the world’s energy demand. This work introduces a detailed numerical modeling and experimental study for a small-scale tri-production of heat, electricity, and hydrogen via an electrocatalytic hydrogen production cell (EHPC) powered by a solar photovoltaic thermal collector (SPVTC). A novel type of spiral fluid SPVTC integrated with

small-scale Hoffman's EHPC is designed and tested. The effect of type and flow rate of cooling fluid on the performance parameters of the hybrid SPVTC-EHPC; including PV electric power, surface cell temperature, cooling fluid exit temperature, electrical and thermal efficiency, and produced hydrogen yield is studied. The experimentations are carried out for the hybrid SPVTC-EHPC operating with two various cooling fluids, namely, water and air at various mass flow rates (20 and 40 L/h), and their results are compared with a standalone PV module without cooling. Moreover, CFD modeling of the water SPVTC, air SPVTC, and PV module designs is also conducted at different operating conditions. ANSYS software is applied to attain maximal efficiency from the collector by choosing the optimal spiral flow structure and determining the PV panel surface and coolant temperatures of the three proposed systems. The CFD simulation verification ensured a good fit between the computational and experimental results. The findings show that the reduction in the daily average PV surface temperature is obtained as 16.60% (54.46 °C) and 8.50% (59.75 °C) for the SPVTC-EHPC, compared to reference PV-EHPC system, when water and air are utilized as a coolant at flowrate of 40 L/h, respectively. Moreover, the daily hydrogen productivity is found as 4.41 kgH2/d for water-cooled SPVTC-EHPC (40 L/h), 4.03 kgH2/d for water SPVTC-EHPC (20 L/h), 3.60 kgH2/d for air-cooled SPVTC-EHPC (40 L/h), 3.24 kgH2/d for air SPVTC-EHPC (20 L/h), and 3.07 kgH2/d for the conventional PV module EHPC, respectively. This study offers an effective means to experimental and numerical aspects of both water and air-cooled SPVTC for the simultaneous production of electricity and hydrogen.

- **Keywords:** Solar photovoltaic/thermal collector; Electrocatalytic hydrogen production cell; Comparative energo-economic performance analysis; Hydrogen production rate; CFD

Safwat M. Safwat, Abdallah Khaled, Abdelsalam Elawwad, Minerva E. Matta. *Dual-chamber microbial fuel cells as biosensors for the toxicity detection of benzene, phenol, chromium, and copper in wastewater: Applicability investigation, effect of various catholyte solutions, and life cycle assessment*. Pages 1121-1136.

Microbial fuel cells (MFCs) were investigated as biosensors for the toxicity detection of benzene, phenol, chromium, and copper in wastewater as they can instantaneously indicate the presence of these contaminants. In this study, two rectangular MFCs, each composed of anodic and cathodic chambers separated by a proton exchange membrane, were operated in parallel. The anode comprised plain carbon cloth, and the cathode comprised plain carbon cloth covered by 0.5 mg/cm2 20% Pt. The anode chamber was filled with synthetic wastewater containing the designated chemical oxygen demand (COD) concentration, while the cathode chamber was filled with ferricyanide (MFC-F) or aerated tap water (MFC-T). The external resistances varied from 100 – 10,000 Ω, and organic load was assessed at COD values of 500, 750, and 1000 mg/L at a pH of 7. Toxic injections were performed at concentrations of 1, 5, 20, and 100 mg/L. Scanning electron microscope images revealed the formation of biofilm after the start-up period. The results indicate that the contaminants investigated caused an inhibitory effect when present at high concentrations. The inhibition ratios of benzene, phenol, chromium, and copper reached 2.9%, 5.1%, 41.8%, and 13.3%, respectively, for MFC-F. For MFC-T, the inhibition ratios of benzene, phenol, chromium, and copper were 14.3%, 10%, 10%, and 4.7%, respectively. MFC-T was more sensitive to the toxicity of organic compounds, while MFC-F was found to be more sensitive to heavy metal toxicity. A life cycle assessment was also conducted to determine the environmental impacts associated with the two biosensors.

- **Keywords:** Bio-electrochemical systems; Biosensors; Life cycle assessment; Toxicity; Wastewater

Duc-Anh Nguyen, Min-Su Roh, Sung Kim, Jin-Hyuk Kim. *Hydrodynamic and radial force characteristics with design of a single-channel pump for wastewater treatment based on the similarity law*. Pages 1137-1150.

Single-channel pumps are widely employed for wastewater treatment in Korea. To render possible the application of this type of pump in other countries using different power frequencies, the present study applies the similarity law to redesign the impeller geometry of the single-channel pump optimized in a previous study. To this end, the numerical simulations are conducted using steady and unsteady Reynolds-averaged Navier–Stokes equations and a shear stress transport reattachment modification turbulence model. Numerical simulations are confirmed by an experiment based on the 11th API610 standard. At design flow rate condition, the novel pump model meets the design requirement with the minimum total head coefficient of 3.078. The distance between the center of the radial force and the origin of the new model is notably decreased in comparison with the reference model, especially at the design point with a reduction of 3.418 times. Moreover, the results of the unsteady radial force are consistent with those of the steady radial force. The pressure oscillations in the new model are likewise reduced compared to the reference model, particularly at several measuring points under design flow rate with pressure oscillations dropping from 8.5% and 10.1–5.3% and 1.2%, respectively. The non-uniform high-pressure region caused by the rotor-stator interaction at the outlet of the impeller is evidently suppressed in the new model. The new single-channel pump is feasible for new power frequency and performs better with low vibration and noise levels during the operation.

- **Keywords:** Wastewater treatment; Single-channel pump; Efficiency; Radial force; Pressure fluctuation; Impeller-volute interaction

Rongkun Du, Fengguang Chai, Rencheng Zhu, Yuxi Yan, Shunyi Li, Yongxiang Niu. *Achieving efficient biodegradation of hydrophobic toluene via the enhancement of β-cyclodextrin and atomization*. Pages 1151-1160.

Industrial production processes produce large amounts of toluene, endangering human health and air quality. The hydrophobicity of toluene limits the removal performance in biotrickling filters (BTFs). To improve the removal efficiency of toluene in BTFs, β-cyclodextrin (β-CD) coupled with atomization was employed in this study. The results showed that β-CD and atomization significantly enhanced the biodegradation of toluene and the maximum elimination capacity reached 90.9 g/(m3·h). At the optimized conditions that β-CD additional of 12.5 g/L and an atomizer with power of 19.8 W, the removal efficiency of toluene was up to 92.6 % (inlet concentration, 0.7 g/m3), which was 17 % higher than that of the control. The use of β-CD combined with atomization increased the extracellular protein and polysaccharide contents. The biofilm surface hydrophobicity of the experimental group reached 79 % which was 1.34 times that of the control. The abundance of toluene degrading bacteria, Pseudomonas sp. and Mycobacterium sp., significantly increased under β-CD with atomization. The addition of β-CD with atomization increased mass transfer, the relative hydrophobicity of biofilm, and the functional microbes so as to enhance treatment of toluene. This study may provide guidelines for the design and technological development of hydrophobic toluene control in industrial waste gas.

- **Keywords:** Toluene; Biotrickling filters; β-Cyclodextrin; Atomization; Microbial community; Biofilm surface hydrophobicity

Pengqian Liu, Changhang Xu, Jing Xie, Mingfu Fu, Yifei Chen, Zichen Liu, Zhiyuan Zhang. *A CNN-based transfer learning method for leakage detection of pipeline under multiple working conditions with AE signals*. Pages 1161-1172.

Pipeline leakage detection is a crucial part of pipeline integrity management. Acoustic emission (AE) based leakage detection is widely used in this field. The latest detection methods are combined AE with convolutional neural networks. However, these methods are often confined to the complex signal processing and computing power and only target specific working conditions. To address these issues, this study proposes a convolutional neural network-based transfer learning (CNN-TL) method for pipeline leakage detection under multiple working conditions. Seven AE datasets are collected from pipeline leakage experiments under different work environments, transporting medium, and fluid pressure. The proposed method converted raw AE signals into three-channel images by a novel conversion method, which avoids reliance on expert knowledge and complex signal processing. CNN-TL is investigated by two different approaches, feature-based CNN-TL and parameter-based CNN-TL. The following nine pre-trained CNN models are used to select the optimal CNN-TL model: Alexnet, Squeezenet, Vgg19, Googlenet, Inceptionv3, Mobilenetv2, Xception, Resnet101, and Densenet201. Results show that the proposed feature-based CNN-TL method significantly outperformed parameter-based CNN-TL and traditional CNN methods, especially on two-phase flow datasets. The highest accuracy of seven AE datasets obtained by the feature-based CNN-TL methods are 100.00%, 100.00%, 100.00%, 99.33%, 85.67%, 87.67%, 74.33%, 83.33% respectively. Moreover, the computation time of proposed method is 16.78 s on average by using the best layers in feature-based CNN-TL. It can be concluded that the proposed method does not rely on signal processing, requires less computational power, and can accomplish accurate detection of pipeline leaks under multiple working conditions.

- **Keywords:** Acoustic emission; Pipeline leakage detection; Convolutional neural network; Transfer learning

Poku Gyasi, Jiandong Wang. *Design of alarm thresholds and delay timers for non-IID process variables based on alarm durations*. Pages 1173-1187.

Many alarm systems suffer from false and missed alarms that are detrimental to the safety and efficiency of industrial process operations. This paper proposes a method to jointly design alarm thresholds and delay timers to achieve desired ratio values of false and missed alarms to be reduced. The proposed method is essentially based on cumulative probabilities of alarm durations of false and missed alarms. Most existing methods separately design alarm thresholds or delay timers, or jointly design them based on probability distributions of process variables that are strictly assumed to be independent and identically distributed (IID). On the contrary, the exploitation of cumulative probabilities of alarm durations makes the proposed method be applicable to non-IID process variables. A technical challenge of how to credibly estimate cumulative probabilities of alarm durations is solved by Bayesian estimation rule. The proposed method is illustrated by numerical and industrial examples, with a comparison with existing methods.

- **Keywords:** Industrial alarm systems; Alarm thresholds; Delay timers; False alarms; Missed alarms; Alarm durations

Chelliah Koventhan, Rajaram Pandiyan, Shen-Ming Chen. *Rational design of dysprosium cobalt oxide decorated on flower-like molybdenum disulfide: Development of an electrochemical sensor for antipsychotic drug promazine*. Pages 1188-1199.

The construction of perovskite oxides and metal chalcogenide nanocomposites has been employed to develop electrochemical sensors with outstanding sensitivity and low detection limit. In this work, we have successfully synthesized dysprosium cobalt oxide (DCO) encapsulated with molybdenum disulfide (MS) via ultrasonication way, which is employed for the electrochemical determination of antipsychotic drug promazine (PMZ). The as-prepared DCO/MS nanocomposite was scrutinized by different techniques such as X-ray diffractometer (XRD), Fourier transform infrared spectroscopy (FT-IR), X-ray photoelectron spectroscopy (XPS) analysis, field emission scanning electron microscope (FE-SEM), and high-resolution transmission electron microscope (HR-TEM). Further, the prepared nanocomposites were modified on a glassy carbon electrode (GCE) surface and electrochemical activity was inspected through cyclic voltammetry (CV) and differential pulse voltammetry (DPV) in 0.1 M phosphate buffer solution (PB) with a potential window of 0.0–0.9 V. As a result, DCO/MS promotes superior electrochemical performance because of high electrochemical active surface area (0.396 cm2), good conductivity, and synergetic effect. The developed electrochemical sensor exhibits a broad linear range (0.002 – 695.6 μM) and the lowest detection limit of 0.005 μM, excellent sensitivity, repeatability, and reproducibility. Finally, the fabricated sensor was successively used for the real-time detection of PMZ in environmental and biological samples with feasible recoveries.

- **Keywords:** Dysprosium cobalt oxide; Molybdenum disulfide; Electrochemical detection; Promazine; Environmental and biological samples

Figen Gündüz, Mikail Olam, Hüseyin Karaca. *Direct liquefaction of low rank lignite with peach seed kernel and waste polypropylene for alternative fuel production*. Pages 1208-1216.

In this study, alternative fuel potentials to petroleum were investigated by direct liquefaction of peach seed kernel (PSK), Muğla-Yatağan lignite (MYL) and waste polypropylene (wPP) separately and together. The effects of PSK and wPP on the yield and selectivity of oil products obtained by direct liquefaction of MYL were also examined. Direct liquefaction experiments were performed in a batch reactor at 1/3 solid/solvent, reaction temperature of 400 °C and reaction time of 60 min. The highest total conversion and oil + gas yield were 95% and 85% direct liquefaction of wPP, respectively. According to the calorific value analysis of the chars, the highest gross calorific value of chars was 7709 cal/g in the liquefaction of PSK, and the lowest net calorific value was 2783 cal/g in the liquefaction of MYL. PSK and wPP increased oil yield of MLY from 28% to 60% and 68%, respectively. According to the GC-MS analysis of oils (light liquid products), alternative fuels to gasoline can be produced by direct liquefaction of PSK, wPP and wPP/MYL. Alternative fuels to diesel can be produced by direct liquefaction of MYL and PSK/MYL. The co-liquefaction of MYL with wPP and PSK improved the yield and product components of the oils. The oil + gas yield of MYL was approximately increased PSK by 12% and wPP by 6%.

- **Keywords:** Lignite; Peach seed kernel; Waste polypropylene; Co-liquefaction; Total conversion; Oil; Characterization

Hessam Shabanizadeh, Mohsen Taghavijeloudar. *Potential of pomegranate seed powder as a novel natural flocculant for pulp and paper wastewater treatment: Characterization, comparison and combination with alum*. Pages 1217-1227.

Using natural flocculants for water and wastewater treatment through coagulation-flocculation process has received growing attention due to its simplicity and safety process. In this research, the performance of pomegranate seed powder as a novel natural flocculant in treating pulp and paper wastewater (PPWW) was evaluated. Chemical oxygen demand (COD) reduction and turbidity removal from PPWW were monitored using different dosages of pomegranate seeds and alum salt. In addition, the synergistic effect of dual flocculation between pomegranate seeds and alum on PPWW treatment was investigated and optimized. Zeta potential (ZP), Fourier transform infrared (FTIR) and scanning electron microscopy (SEM) analyses were conducted to elucidate the flocculation mechanism. The results revealed that pomegranate seeds composed of active substances such as protein, polysaccharides and fiber contents that contribute to its coagulating ability. The highest removal efficiencies of 60% and 87% were achieved for COD and turbidity, respectively when using pomegranate seeds at the optimal dosage of 600 mg/L after 30 min treatment. Dual flocculation of pomegranate seeds and alum showed a synergistic effect, resulting in a maximum removal of 81% of COD and 98% of turbidity under optimal condition: Alum = 400 mg/L and pomegranate seeds = 800 mg/L at much shorter treatment time (2 min). The ZP and FTIR test results and SEM images revealed that charge neutralization and sweeping mechanism induced by alum combined with bridging mechanism by pomegranate seeds led to the synergy.

- **Keywords:** Pomegranate seeds; Natural flocculants; Wastewater treatment; Alum; Synergistic flocculation; PH adjustment

Pranjal Tripathi, Sonam Tiwari, Ravi Kumar Sonwani, Ram Sharan Singh. *A step towards enhancing the efficiency of biofilm mediated degradation of brilliant green dye in packed bed bioreactor: Statistical and toxicity analysis*. Pages 1228-1239.

This study aims to investigate the biodegradation of brilliant green (BG) dye in a packed bed bioreactor (PBBR) using Bacillus lichenifomis immobilized polyurethane (PU) foam as support material. The operating process parameters (e.g., pH, dye concentration, and inoculum dose) were optimized using response surface methodology (RSM) and artificial neural network (ANN). A sensitivity analysis reveals that pH has comparatively more significance (46 %) than the other parameters. Further, PBBR was continuously operated at various inlet feed flow rates (10–50 mL/h) under optimum conditions for 60 days. Maximum removal efficiency (RE) and elimination capacity (EC) were found to be 91.2 % and 88.0 mg/L.d, respectively. Monod and Andrews-Haldane models were applied for kinetic study and kinetics parameters μmax and Ks was found to be 0.125 per day and 38.9 mg/L for Monod and 0.175 per day and 45.1 mg/L for Andrew – Haldane model respectively. UV–vis and FTIR analysis confirmed the successful biodegradation of BG dye. Stress caused by BG dye was assessed by chlorophyll (a and b) and carotenoid content. Superoxide dismutase (SOD) activity was analyzed for biologically treated samples. Bacterial toxicity study reveals that biologically treated samples showed significantly less bioluminescence inhibition.

- **Keywords:** Biodegradation; Artificial neural network; Kinetic parameter; Photosynthetic pigment; Bioluminescence assay

Yanan Jiao, Chunhui Zhang, Peidong Su, Yuanhui Tang, Zhipeng Huang, Tao Ma. *A review of acid mine drainage: Formation mechanism, treatment technology, typical engineering cases and resource utilization*. Pages 1240-1260.

Acid mine drainage (AMD) contains high concentrations of heavy metals and sulfates with strong acidity. AMD exists in several major coal-producing countries such as China, the United States, Canada, etc., and it poses significant threaten to the environment and human health owing to it exists in nature for a long time and continues to cause harm after mining. In China, about 3.5 billion tons of AMD was produced annually and their negative effects on the ecological environment and human health in mining area cannot be ignored. Herein, the formation mechanism and environmental impact of AMD are discussed thoroughly. Additionally, the principles and applications of several AMD treatment technologies are discussed in detail and the limitations of the practical application of AMD in China are summarized. On this basis, the current status and importance of the resource utilization of AMD are further discussed. Finally, the future direction of AMD treatment is proposed. In principle, this review will provide useful implications in guiding the treatment and resource utilization of AMD.

- **Keywords:** Acid mine drainage; Heave metals; Coal mining; Resource utilization

Shu-Hui Liu, Yen-Ni Tsai, Chiaying Chen, Chi-Wen Lin, Ting-Jun Zhu. *Enhanced sulfolane-contaminated groundwater degradation and power generation by a mini tubular microbial fuel cell/electro-Fenton combined system*. Pages 1261-1268.

A tubular microbial fuel cell/electro-Fenton (MFC/EF) combined system was developed for field-scale applications. This tubular MFC/EF combined system treats groundwater containing sulfolane by driving the Fenton reaction at the cathode using bioelectricity that is generated at the anode. Proper aeration and an adequate supply of carbon were found to improve significantly the performance of a tubular MFC/EF combined system. The tubular MFC/EF combined system exhibited high voltage output (525 mV) and high power density (691 mW/m3). The generation of H2O2 from the cathode at 1 L/min aeration was 20 times that at 0.1 L/min, and achieved 100% removal efficiency of sulfolane (50 mg/L). The bicinchoninic acid assay detected an increase in the amount of bacteria by a factor of 2.2 as a result of electrical stimulation following tubular MFC/EF operation. The biotoxicity of sulfolane after tubular MFC/EF treatment revealed that the light inhibition of Vibrio fischeri was only 4% at 1 L/min aeration, owing to the by-product (SO42-). The results demonstrated that the tubular MFC/EF combined system was effective in removing sulfolane and reducing the toxicity of by-products in the purification of water.

- **Keywords:** Sulfolane removal; Microbial fuel cell; Aeration rate; Iron releasing efficiency; Bioelectricity; Biotoxicity