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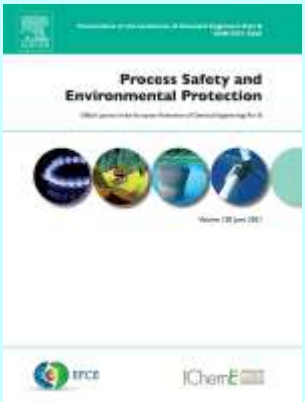

Shengyue Zhang, Yifei Yan, Lan Shi, Lifeng Li, Long Zhao, Rui Wang, Xiangzhen Yan. *A semi-empirical model for underground gas storage injection-production string time series remaining useful life analysis in process safety operation*. Pages 1-17.

Time series risk analysis in digitalized process operations offers a useful means to transform the unordered data information into actions and practices related to process safety. A method for easily implementing time series degradation state analysis is proposed and described in terms of the remaining useful life (RUL) counting process based on a digitization semi-empirical probabilistic model. The well logs are used to inform a case study describing underground gas storage (UGS) injection-production string degradation risk. The corrosive effect of carbon dioxide in a complex environment is also considered, which leads to the decrease of internal pressure strength (IPS) with wall thickness thinning as well as RUL. The relationship between the residual IPS and RUL of the injection-production string at different rates of wall-thinning is analyzed. Based on the Gamma process method, the key empirical parameter information with time series degradation process and the probability density functions of different degradation under corresponding conditions are obtained. Then based on the Sequential Monte Carlo algorithm, the degradation trajectory of time series with confidence belt is obtained, and the confidence interval quantization of the wall thinning rate of injection-production string under different working conditions is realized. The results show that a semi-empirical time series RUL analysis could be used to more realistically evaluate the degradation state of the injection-production string. The residual strength with the Klever-Stewart calculation model has high stability for the uncertainty characteristics of the stochastic process. The proposed model is expected to calculate and determine the RUL of string with different thinning rates of wall thickness, and then further determine the time series corrosion degradation state for risk early warning. It is thus concluded that the proposed digitization semi-empirical remaining useful life prediction model provides a highly intuitive and quantitative tool for assessing the risk of degradation at the RUL level in the injection-production string of UGS.

- **Keywords:** Underground gas storage; Injection-production string; Remaining useful life; Digitalized process safety operation; Time series degradation risk

Jianjun Cai, Rigang Zhong, Xiaojuan Liu, Qingcai Liu, Hao Wu, Feng Yan, Junbin Huang, Zuotai Zhang. *Effects of evaporation capacity on the formation and removal of PCDD/Fs in a full-scale municipal solid waste incinerator*. Pages 18-31.

Municipal solid waste (MSW) classification has become a hot topic with the requirement of "zero waste city"; however, incinerators are designed unclassified currently. Therefore, it is difficult to keep around the rated value of evaporation capacity. Herein, we investigated the effects of evaporation capacity on the formation and removal of PCDD/Fs in a full-scale incinerator firstly. The formation of PCDD/Fs at the 110 % evaporation was lower than that of 100 % from the primary superheater to economizer, as high oxygen concentration. After flue gas flowed through the position of activated carbon injection, PCDD/F emissions at the 100 % evaporation were lower than that at the 110 % as the primary air volume at 110 % was 1.21 times that of 100 %. It had no significant effects on the PCDD/F emissions of the stack gas for an increase approximate 10 % of the evaporation capacity. Although the removal efficiencies of PCDD/F congeners varied in the four parts of the air pollution control devices (APCDs), while it was similar for the effects of APCDs on the removal efficiencies of PCDD/Fs between the two operating conditions. For the two different operating conditions, the removal efficiencies of congeners were kept at high levels (96.32–99.81 %) after flue gas flowed through APCDs and the removal efficiencies of the less-chlorinated congeners general were higher than those in the more-chlorinated congeners. And the removal efficiencies of PCDFs were much higher than PCDDs. These findings provide some new option for controlling PCDD/F emissions in a full-scale incinerator under the MSW classification.

- **Keywords:** PCDD/Fs; Municipal solid waste incinerators; Evaporation capacity; Formation and removal mechanism

Bruno José Chiaramonte de Castro, Camila Raquel de Lacerda, Bruna Râmela de Melo, Rafael Sartim, Mônica Lopes Aguiar. *Performance assessment of a bench scale hybrid filter in the collection of nanoparticles*. Pages 32-42.

Hybrid filters are promising alternatives for particulate emission control. Although good results have been obtained in the application of hybrid filters for the collection of microparticles, there are still few studies for the collection of nanoparticles. This paper investigates the performance of a bench scale hybrid filter in the collection of nanoparticles of 10−300 nm. A factorial design was proposed to evaluate the influences of the electric field, the filtration velocity, and the filter medium on the nanoparticle collection of the hybrid filter (HF), which was composed by an electrostatic precipitator (ESP) followed by a fabric filter (FF). The electric field was varied from 0.0 to 4.0 kV cm−1, the filtration velocity, from 1.0 to 2.0 m min−1, and two filter media were tested: one of polyacrylonitrile (PAN) and the other of polyacrylonitrile with a polytetrafluorethylene membrane (PAN/PTFE). The electrostatic charging increased the collection efficiency not only in the ESP, but also in the PAN filter, indicating that the electrostatic attraction of the nanoparticles to the fibers was intensified, even without polarizing the filter medium with an external electric field. The particle penetration decreased by at least 19 % and the quality factor increased by at least 10 %.

- **Keywords:** Hybrid filter; Nanoparticles; Collection efficiency; Electrostatic attraction; Gas filtration

Rahim Şibil, Egemen Aras, Murat Kankal. *Comparison of various turbulence model performance in computational fluid dynamics analyses of the oxidation ditches with experimental validation*. Pages 43-59.

Experimental and numerical studies were carried out to determine the full-scale Oxidation Ditch (OD) hydrodynamics considering various turbulence models. Firstly, the experimental work was carried out in a full-scale plant by Acoustic Doppler Velocimeter (ADV) for field-measurements. Secondly, the experimental data was used to validate numerical models by using Computational Fluid Dynamics (CFD) software Ansys Fluent. Eight different turbulence models were compared in the numerical study to predict full-scale hydrodynamics. Results showed that standard k-ε, renormalization group k-ε, realizable k-ε turbulence models gave more accurate prediction results with relative errors of 13 %, 17 %, and 18 % respectively, whereas the standard k-ω turbulence model gave the worst prediction results with 39 % relative error. This study also shows that the velocities in the ODs are very low without external force such as air diffusers, rotors, and mixer and there is no homogeneous flow field distribution in the ODs. Moreover, the maximum wastewater velocities occurred at the inlet and outlet.

- **Keywords:** Turbulence modelling; CFD modeling; CFD validation; Acoustic doppler velocimeter

Lei Zhang, Haiyan Wang, Chen Chen, Peipei Wang, Liangwei Xu. *Experimental study to assess the explosion hazard of CH4/coal dust mixtures induced by high-temperature source surface*. Pages 60-71.

The explosion accident caused by the spontaneous combustion surface of coal after the coal dust is rolled up by the gas gushing from the goal seriously threatens the safety of coal coal mining. Based on this hazard, self-developed gas explosion equipment is used to detonate the CH4/coal dust mixture by high-temperature source. The process and mechanism of gas/coal dust explosion induced by coal spontaneous combustion in goaf were simulated, and its risk was evaluated. It is of great significance to understand the initiation mechanism of gas-solid mixture through coal spontaneous combustion in goaf. The results show that the explosion pressure (Pgd), explosion temperature (Tgd), rate of pressure rise ((dP/dt)gd), and explosion index (K) of CH4/coal dust mixtures are closely related to the temperature of high-temperature source and volatile content. The role of coal dust volatiles in homogeneous and nonhomogeneous reactions was revealed. Combined with three explosion parameters (Pgd, Tgd, K), the most dangerous explosion combination concentration of the selected CH4/coal dust mixture is (9.5 %, 500 g/m3), (9.5 %, 400 g/m3), and (8.5 %, 500 g/m3) at 1073 K ignition temperature. The involvement of coal dust leads to a lower explosion limit for CH4/air. The Jiang model has better applicability to the prediction of lower explosion limits for CH4/coal dust mixtures induced by the high-temperature source surface.

- **Keywords:** CH4/coal dust mixture; High-temperature source; Goaf; Explosion characteristics; Gas

Meltem Ağtaş, Mehmet Dilaver, İsmail Koyuncu. *Halloysite nanoclay doped ceramic membrane fabrication and evaluation of textile wastewater treatment performance*. Pages 72-80.

In this study, halloysite nanoclay-doped ultrafiltration and tight-ultrafiltration ceramic membranes were fabricated by sequential layer deposition using relatively low temperatures. The produced membranes were structurally characterized by contact angle tests and a scanning electron microscope. The pure water flux and bovine serum albumin removal were also examined, in order to determine the performance of the membranes. Finally, 3 different real wastewater treatability tests were carried out and the change in membrane performance was observed by using hot textile wastewater. In the coated membranes, the pure water flux decreased from 2000 L/(m2.h) to 100 L/(m2.h) for the ultrafiltration membrane and from about 370 L/(m2.h) to 23 L/(m2.h) for the tight-ultrafiltration membrane. In the bovine serum albumin removal efficiency test, approximately 30 % removal was obtained for the ultrafiltration membrane and 100 %

for the tight-ultrafiltration membrane. In real wastewater filtration tests performed with the tight- ultrafiltration membrane, the average removal efficiency of approximately 40 % and above 44 % was obtained for chemical oxygen demand and total organic carbon and color removal, respectively. Finally, in the hot water test, it was observed that the permeate flux increased approximately 3 times, but there was no significant decrease in the treatment efficiency.

- **Keywords:** Ceramic membrane coating; Halloysite nanoclay; Textile wastewater treatment

Md. Shafiquzzaman, Husnain Haider, A. K. M. Ashadullah. *Optimization of algal-based membrane bioreactor for greywater treatment*. Pages 81-88.

For bioreactors, hydraulic retention time plays a very important role in biomass production. The effectiveness of Algal-based Membrane Bioreactor (AMBR) has not been adequately explored for domestic greywater treatment. The present study aims to assess AMBR's efficiency for treating domestic greywater operating at four hydraulic retention times (HRTs) of 1–7 d. Microalgal biomass production, removal efficiency, fouling characteristics, and net energy efficiency of the AMBR were optimized. The experimental study showed that algal biomass productivity increased with decreasing HRT, and the highest productivity (48 mg/L/d) was achieved at 2 d of HRT. Independent of HRT, 94 % BOD and 96 % anionic surfactant (AS) removals were achieved, while the highest TN and TP removals (59.5 % and 34.5 %) were achieved at HRT of 7 d. Effluent monitoring revealed that microalgae assimilation was the primary pathway of TN and TP removals. Membrane fouling frequency decreased with increasing HRT, and the lowest fouling was found at 7d of HRT. The highest methane yield (0.332 m3/d) and the net energy return NER (1.04) were estimated at HRT of 2 d. Overall, HRT of 2 d would be optimum for AMBR operation and can be modeled as a self-sustainable greywater treatment system with zero power requirements. The present study provides the basis for establishing the guidelines for AMBR design for the treatment and recycling of greywater.

- **Keywords:** Algal membrane bioreactor (AMBR); HRT; Greywater treatment; Biomass production; Removal efficiency

A. Leena Pauline, Kurian Joseph. *Hydrothermal carbonization of crude oil sludge – Characterization of hydrochar and hydrothermal liquor*. Pages 89-96.

Petroleum storage and refining leads to the generation of undesirable hazardous oily sludge waste stream in considerable quantities. Oily sludge was subjected to hydrothermal carbonization (HTC), in an effort to remediate hazardous waste and enhance resource recovery. Gas Chromatography-Mass Spectrometry and 13C Nuclear Magnetic Resonance were used to determine hydrocarbon fingerprints for degradation, reaction pathways and mechanism analysis. The accumulation and transformation of heavy metals from the mobile, unstable, acid extractable and reducible fractions to immobilized relatively stable fraction was analyzed by European Communities Bureau of Reference technique. Linear alkanes with methyl substitutions such as pentadecane and hexadecane increased to 70 % at 250 °C with increasing reaction severities due to condensation and polymerization reactions. 95 % of carbons in the final hydrochar fall in the C7-C20 size range. The bioavailability, ecological risk and toxicity of hydrochar decreased significantly due to heavy metal immobilization and reached low potential risk category. Hydrothermal liquor (HTL) was found to contain various valuable chemical species and degradation products including diethyl phthalate and benzene dicarboxylic acid. The results indicate the suitability of HTC for metals immobilization, resource optimization and hydrocarbon recovery.

- **Keywords:** Oily sludge; Hydrothermal carbonization; Hydrochar; Hydrocarbons recovery; Hydrothermal liquor

Wang Zhou, Xiangyu Zhao, Kuang Cheng, Yi Cao, Shuang-Hua Yang, Jianmeng Chen. *Source term estimation with deficient sensors: Error analysis and mobile station route design*. Pages 97-103.

Air pollution monitoring for chemical industrial parks suffers from sensor deficiency. To address this problem, this work focuses on mobile monitoring station solutions to complement the fixed measurement deficiency. Flexibility in measurement location makes the mobile solution advantageous over fixed stations not only in providing sufficient number of measurements to satisfy the traceability condition, but also in the possibility to design monitoring route optimally according to real-time wind directions. By taking these advantages, this work proposes a new method for optimal mobile route design so that the inference of uncertainties on the accuracy of source rate estimation is minimized. Based on the linear relationship between the concentration measurements and source emission rates, the effect of measurement noises on the estimation error is derived as an amplification factor through numerical analysis, then, the optimal monitoring route can be determined by minimizing the amplification. Numerical and real case studies are presented to test the performance of the method. The results suggest that the approach proposed can effectively improve the performance of source rate estimation by optimally choosing the monitoring route.

- **Keywords:** Source term estimation; UAV; Traceability; Air pollution; Optimization

Wenhe Wang, Tengfei He, Sen He, Tianyu You, Faisal Khan. *Modelling of thermal runaway propagation of NMC battery packs after fast charging operation*. Pages 104-117.

This study presents a mathematical model and experimental verification of factors influencing thermal runaway propagation of NCM811/C lithium-ion battery module after fast charging operation. The key factors considered for the thermal runaway propagation include charging C-rate, battery spacing, triggering temperature, speed, and interval of the thermal runaway propagation. The analysis of the 3D model shows that increasing the spacing and triggering temperature of the battery will reduce the risk of thermal runaway propagation of the battery module and change the order of thermal runaway propagation. Further, the thermal runaway propagation speed increases gradually with the propagation process; however, it is inhibited by increasing triggering temperature and battery spacing and the decrease of charging C-rate. These observations play a critical role in the lithium-ion battery pack design.

- **Keywords:** Lithium-ion battery; Thermal runaway propagation; Fast charging; Electrochemical-thermal coupled model

Alexandra Vasile, Adina Roxana Milăşan, Adina Elena Andrei, Ramona Nicoleta Turcu, Marius Florin Drăgoescu, Sorin Axinte, Maria Mihaly. *An integrated value chain to iron-containing mine tailings capitalization by a combined process of magnetic separation, microwave digestion and microemulsion – assisted extraction*. Pages 118-130.

The recovery of metals from tailing ponds or dumps is a priority as they remained stored on large areas around the mining operations and represent an aggressive pollution source of natural water bodies. The paper objective is to develop a combined process for iron-containing mine tailings capitalization associates the benefits of magnetic separation to reduce the iron content, microwave digestion for metals forms solubilization from solid matrix and microemulsion for their extraction, concentration, and recycling from the

digested sample. The magnetic separation of ferromagnetic fraction, with over 50 % iron, leads to an improved extraction efficiency. The optimum digestion procedure uses aqua regia, hydrogen peroxide (30 % H2O2) and microwaves. The microemulsion extraction using Brij 30 (polyoxyethylene (4) lauryl ether) as surfactant, ethyl acetate:butyl acetate (1:1, v/v) as oil phase and acidic metal solutions as aqueous phase, and also NaSCN (0.1 M) as carrier agent, performed at room temperature and atmospheric pressure, reveals that excellent recovery performance for iron (98.3 %), lead (98.5 %), zinc (93.0 %) can be obtained. In addition, copper (63.0 %) is recovered quite efficiently. The maximum microemulsion loading capacity in terms of mass of total metal ions/L was 351 mg/L and was achieved by two successive extractions. It has been demonstrated that by two successive extractions, the loading capacity is mainly represented by iron content. The results obtained demonstrate that the three combined procedures involving magnetic separation, microwave digestion and microemulsion assisted extraction ccontributes to the reduction of mine waste deposits and, consequently, the environmental pollution with heavy metals.

- **Keywords:** Circular economy; Mines tailings; Heavy metals; Microemulsion; Waste minimization

Kazem Lakzian, Horng-Jang Liaw. *Flash point investigation of ternary mixtures of 1-butanol/2-pentanol + acetic acid + ethylbenzene*. Pages 131-141.

Flash point information is crucial for evaluating the fire and explosion (F&E) hazards of flammable liquids. Most flash point studies have investigated binary mixtures; thus, their results are inapplicable to commercial mixtures of several liquids. In this study, two ternary mixtures, namely 1-butanol − acetic acid − ethylbenzene and 2-pentanol − acetic acid − ethylbenzene, were investigated. These mixtures comprise two binary constituents with minimum flash point behavior (MinFPB) and one binary constituent with maximum flash point behavior (MaxFPB). The ternary constituents do not exhibit MinFPB or MaxFPB; therefore, the aforementioned ternary mixtures can be considered the first known members of the fp 3.3.0−1b class (Da Cunha et al., 2018). A model developed for ternary miscible mixtures was used to predict the flash point behaviors of the mixtures. The nonrandom two-liquid (NRTL), Wilson, original universal quasi-chemical functional-group activity coefficients (UNIFAC) and UNIFAC-Dortmund models were used to predict the activity coefficients of the binary and ternary constituents. The mixture of 1-butanol or 2-pentanol with acetic acid exhibited MaxFPB, indicating that acetic acid can substantially reduce the F&E risks of these alcohols. The findings can be applied in hazard identification, F&E hazard reduction, process safety design, fuel design, and the risk management of ignitable waste liquids.

- **Keywords:** Ternary mixture; Minimum flash point behaviour; Maximum flash point behaviour; Safety; Fuel; Risk management

Subbarama Kousik Suraparaju, Ragupathy Dhanusuraman, Sendhil Kumar Natarajan. *Performance evaluation of single slope solar still with novel pond fibres*. Pages 142-154.

The low efficiency of solar still is one of the most critical barriers to its effective utilization across the globe. The efficiency of solar still is being increased by using various energy storage materials, porous materials and other surface area enhancers. In this paper, an attempt has been made to enhance the freshwater productivity from the single slope solar still by using naturally available dried pond fibres. The dried pond fibres with better porosity have been floated over the seawater in the absorber bain for increasing the surface area of evaporation. The number of fibres to be floated is mainly chosen based on the percentage area of occupancy in the absorber bain. The effect of the number of pond fibres (3, 4, 5, 6, 10, 15, and 20 numbers) floated in the absorber basin on the

yield of solar still is investigated. The solar still with five number of dried pond fibres enhanced the freshwater productivity by 29.67 %. In contrast, the 3, 4, 6, 10, 15 and 20 number of dried pond fibres increases productivity by 10.57 %, 25.97 %, 26.81 %, 23.83 %, 4.43 % and 3.63 % respectively relative to the conventional solar still. The outcomes of the economic analysis reported that the cost per litre of freshwater produced under solar still with pond fibres is lower than the conventional solar still by 30.76 %. Also, the payback period of solar still with pond fibres and conventional solar are found to be 91 days and 115 days. However, the initial investment cost remains the same for both systems, as dried pond fibre is naturally available and the cost of fibre processing is minimal.

- **Keywords:** Solar still; Pond fibres; Productivity enhancement; Economic analysis; Augmenting evaporation; Optimization

Golnoosh Akhlamadi, Elaheh K. Goharshadi. *Sustainable and superhydrophobic cellulose nanocrystal-based aerogel derived from waste tissue paper as a sorbent for efficient oil/water separation*. Pages 155-167.

Extraction of cellulose nanocrystals (CNCs) from wastes is a valuable strategy from the environmental and economical points of view. Herein, a novel and cost-effective method for the preparation of superhydrophobic, environmentally friendly, and recyclable bio-aerogel by freeze-drying the aqueous suspension of CNCs extracted from waste tissue paper and polyvinyl alcohol (PVA) in the presence of hydrolyzed tetraethyl orthosilicate (TEOS) sol has been developed for the first time. The highly porous (98.42 %), ultralow density (0.017 g/cm3), and superhydrophobic (WCA of 154.93°±4.14) CNCs/PVA/TEOS aerogel can selectively remove oily contaminants from water (BET surface area of 76 m2/g). The aerogel showed a high sorption capacity in the range of 69−168 g/g for 6 oils and 8 organic solvents. The reusability experiments showed the aerogel could maintain more than 92 % of its sorption capacity even after 20 cycles of sorption-squeezing. The cyclic compressive stress-strain tests confirmed the good mechanical properties of the aerogel with 89 % of shape recovery after 50 cycles. The CNCs/PVA/TEOS aerogel can be used as a recyclable sorbent for removing oils/organic solvents from water.

- **Keywords:** Waste tissue paper; Cellulose nanocrystals; Aerogel; Oils/organic solvents separation; Stress-strain test

Lahouari Cheded, Rajamani Doraiswami. *A novel integrated framework for fault diagnosis with application to process safety*. Pages 168-188.

A novel integrated framework for Fault Detection and Isolation(FDI) is proposed, with applications to process safety, by sequentially integrating model-free(MFA) and model-based(MBA) approaches. The MFA includes Limit Checking/Visual and Plausibility analysis, Artificial Neural Network and Fuzzy Logic, Adaptive Neuro-Fuzzy Inference System. The MBA uses a Linear Parameter-Varying model to handle a wide class of generally-nonlinear physical systems. The adaptive Kalman filter(KF) residuals are used for FDI in the MBA. Novel emulators, cascaded with the system during off-line data acquisition, system identification and Bayes'measure of belief computation for each FDI scheme, have their parameters perturbed at each operating point, to mimic unforeseen operational scenarios, thus covering all operating regions. Critical information about the presence/absence of a fault is quickly gained via the faster FDI scheme. A more accurate subsystem's status is unfolded sequentially by the slower FDI scheme. The final decision on the fault status is obtained using a weighted Bayes classifier fusion scheme meeting the critical requirements of high(low) probability of correct decision (false alarm). Implications of FDI in process safety/environment protection are discussed. This framework is successfully evaluated on simulated and physical systems, including

benchmarked laboratory-scale two-tank system, by detecting and isolating sensor, actuator and leakage faults.

- **Keywords:** Nonlinear system; Linear parameter-varying model fault detection and isolation; Sensor fault; Actuator fault; Leakage fault; Process safety; Environment protection; Kalman filter; Emulators; Model-based and model-free approaches; Bayes classifier fusion system identification; Sequential diagnosis approach; Artificial neural network; Adaptive neuro-fuzzy inference system

Egidijus Rytas Vaidogas. *Bayesian reasoning aimed at a prediction of failure patterns of fire induced pressure vessel explosions*. Pages 189-201.

The problem of assessing damage due to explosions of cylindrical pressure vessels is considered. The attention is focussed on a prediction of the arrangement of cracks in the vessel wall prior to its explosion. This arrangement of cracks is called the failure pattern. It is seen as essential information for forecasting ejection and projection of fragments generated by an explosion. Thermally induced explosions known as boiling liquid expanding vapour explosions are studied. The problem of prediction of failure patterns is formulated as a problem of estimating probabilities of these patterns. The scarcity of data on occurrences of failure patterns in the past explosion accidents was an incentive to estimate the failure pattern probabilities by means of Bayesian statistics. The main finding of the study is that the failure pattern probabilities can be handled within the Dirichlet-multinomial model and the epistemic uncertainty in these probabilities expressed by Dirichlet prior and posterior distributions. The Bayesian estimation of failure pattern probabilities is viewed as a way allowing to introduce the prediction of vessel fragmentation into the formal probabilistic risk analysis. The so-called minimally informative Dirichlet prior distribution is suggested for the probability estimation as a prior suitable to Bayesian updating with scarce data. It is stated that currently the probabilistic prediction of failure patterns on the basis of past accident data is the only practicable way to assess the potential type of vessel fragmentation. A conventional (deterministic) mechanical and/or metallurgical analysis does not provide reliable models for failure pattern prediction in case of explosions under study.

- **Keywords:** Pressure vessel; Explosion; BLEVE; Fragment; Failure pattern; Bayesian estimation

Zhicheng Wu, Hao Zhang, Lingyu Shao, Yifan Wang, Wenchao Gao, Dingzhen Wang, Weihong Wu, Chenghang Zheng, Xiang Gao. *Nonferrous metal flue gas purification based on high-temperature electrostatic precipitation*. Pages 202-210.

The removal of fly ash from nonferrous metals industry at high temperatures in electrostatic precipitators (ESPs) has attracted wide attention in reducing the industrial pollution. In this study, the removal characteristics of copper smelting (ash A) and nickel smelting fly ash (ash B) under regular and circulating flue gas conditions were investigated through a high-temperature wire-plate ESP. The two kinds of ash have various resistivity ranges at different temperatures, resulting in better removal of ash B than ash A at relatively low temperatures, whereas the opposite result was obtained at 573 K and 673 K. Besides, under the circulating flue gas condition, the number percentage of large particles was decreased while small particles ascended as the increase of the residence time. After sufficient residence time, the particle mass concentration would reach a stable value under 10 mg/m3. Furthermore, the removal characteristics of the two ash under the barbed electrode (DE2) compared with the round rod electrode (DE1) was also conducted. Results indicated DE2 owned a higher removal efficiency for both ash at high temperature no matter under which condition. Combining

the electrode optimization by DE2 and the action of circulating flue gas, the ultimate collection efficiency of ash A and ash B could reach 95.65 % and 95.12 % at 673 K.

- **Keywords:** Nonferrous metal fly ash; High-temperature electrostatic precipitator; Removal characteristics; Circulating flue gas; Electrode optimization

Zhijun Li, Shilong Li, Zhiyang Li, Yan Wang, Zhenguo Li, Mengliang Li, Penghao Jiao, Dong Cai. *Simulation study of NO2-Assisted regeneration performance of variable cell geometry catalyzed diesel particulate filter*. Pages 211-222.

With the increasingly strict emission regulations of countries around the world, reducing the particulate emissions of diesel engines is the focus of research. In this paper, the optimal asymmetry ratio was researched by comparing pressure drop under different operation conditions through the validated model. When soot loading is 0 g/L, the optimal asymmetric ratio is 1.1. When soot loading is 4 g/L, the optimal asymmetric ratio is 1.2. And performances of passive regeneration of catalyzed diesel particulate filters with different channel shapes were also studied. Based on the remaining soot loading, regeneration efficiency and pressure drop, the hexagonal channel has obvious advantages in NO2 assisted passive regeneration, followed by the asymmetrical square channel, and the octagonal channel is the worst.

- **Keywords:** Catalytic diesel particulate filter; NO2-assisted regeneration; Soot loading; Asymmetric square; Hexagonal; Octagonal

Shenshi Huang, Ruichao Wei, Tian Xie, Jian Wang. *Evaluation of fire hazards in typical vegetable oil residues*. Pages 223-235.

Vegetable oil residues, which are often used for biogas production, are prone to fires. The decomposition and fire behaviors of four vegetable oil residues, namely rapeseed oil residue (ROR), peanut oil residue (POR), gingili oil residue (GOR), and soybean oil residue (SOR), were investigated using elemental analysis, thermogravimetry-differential scanning calorimetry-derivative thermogravimetry (TG-DSC-DTG), Fourier transform infrared (FTIR) spectrometry, and a cone calorimeter. Based on the TG-DSC-DTG results, ROR is the residue most susceptible to spontaneous ignition and complete decomposition. Further, although the FTIR results showed that the functional group compositions of the four residues are similar, according to cone colorimetry experiments, SOR has the lowest critical heat flux and the lowest peak value of heat release rate under an external heat flux.

- **Keywords:** Vegetable oil residues; Fire risk assessment; Cone calorimeter; Combustion products; Decomposition characteristics

Shinjini Paul Choudhury, Bandita Dalasingh, Izharul Haq, Ajay S. Kalamdhad. *Methane production and toxicity evaluation of petroleum refinery biosludge through optimization of different modes of heat*. Pages 236-248.

The colossal amount of hydrocarbon-rich sludge generated from effluent treatment plants of petroleum refineries has enormous potential for methane-rich biogas production. The biodegradation of petroleum refinery biosludge (PRB) was compared between undigested residue (UR) and anaerobically acclimated or digested sludge (DS) from an anaerobic reactor at five different inoculum:sludge ratios (0.3, 0.4, 0.5, 0.7, 1.0 based on volatile solids content). Upon performing batch anaerobic degradation assay tests, methanogen-rich DS provided a better seeding environment with maximum methane yield being attained at ratio DS:PRB = 0.5. The long hydrolysis phase of the complex hydrocarbon

substrate was intended to be improved through the optimization of different modes of heat application (dry heat, pressurized moist heat, agitated open moist heat and microwave irradiation). The best mode was dry heat which when applied at 140 °C for 60 min improved soluble chemical oxygen demand and fatty acids concentration of untreated sludge by 2.28 and 1.3 folds respectively. Dry heat application enhanced methane production by 24.8 % with 48.7 % organic matter removal in presence of DS as inoculum. Morphological and chemical characterization corroborated the fragmentation of aliphatic hydrocarbon bonds through dry heat application. Positive energy recovery (21,826 kJ) from PRB upon dry heat pretreatment evinces its feasibility at a larger scale. The presence of toxic organic pollutants was confirmed by Gas Chromatography–Mass Spectroscopy (GC–MS) analysis and the phytotoxicity assay using V. radiata showed concentration-dependent decrease in seed germination, shoot length, root length and biomass after the digestion process in comparison to control thereby, suggesting a sustainable and promising method to petrochemical industries for utilization and transformation of such toxic hydrocarbon-rich sludge into a renewable energy source.

- **Keywords:** Petroleum refinery biosludge; Methane production; Inoculation; Thermal pretreatment; Phytotoxicity assessment

Xingxian Bao, Tongxuan Fan, Chen Shi, Guanlan Yang. *Deep learning methods for damage detection of jacket-type offshore platforms*. Pages 249-261.

Recently, big data and machine learning based damage detection methods to support risk management of offshore facilities have received great attention, compared to traditional modal parameters-based methods. This paper illustrates the application of deep learning methods in damage detection of offshore platforms using measured vibration response of the structures subjected to random excitations. The numerical example of a jacket-type offshore platform under random wave excitation is applied to verify the applicability of convolutional neural network (CNN), long short-term memory (LSTM) networks, and CNN-LSTM method. The comparison of the three approaches are conducted in terms of accuracy and efficiency of damage localization and severity estimation for the simulated damage cases. In addition, the random decrement technique (RDT) for data preprocessing is used to improve the capability of damage detection of the three deep learning methods in noisy conditions. Moreover, the proposed RDT combined with the deep learning methods are applied to laboratory tests of a jacket platform model under random loading produced by a shaking table. Minor and major damages at different locations are discussed. Results show that the proposed combination method has an outstanding performance in structural damage detection even in noisy conditions, and also has great potential application in industrial process safety and operational risk management.

- **Keywords:** Damage detection; Deep learning; Random decrement technique; Offshore platforms

Kobra Pourabdollah. *Agglomeration of coke particles by aliphatic binders: A hidden pollutant in effluent of steam crackers*. Pages 262-277.

This work is aiming at exploration of agglomeration process leading to the increasing pollution potential of pyrolytic coke particles in effluent of steam crackers before entering the water resources. The submicron particles of pyrolytic coke are formed in steam crackers in diameter range of 0.2–5.0μm and enter the oceans as industrial effluent while the COD, TDS, TSS, odor and turbidity values are in acceptable range. The agglomeration tendency of submicron pyrolytic coke fines was attributed to selective adsorption of self–assembled monolayers (long–chain normal aliphatic alkanes, C14–C24) on the surfaces of pyrolytic coke particles. The monolayer scaffold forms a thermal

sensitive adhesive coating for agglomeration of suspended particles. The results of liquid chromatography–mass spectrometry (LC–MS) revealed no polymeric or oligomeric substrates in the monolayer scaffolds since the maximum molecular weight of adsorbed solutes was determined to be below 500 Da. The outcomes showed that the amount of submicron particles of pyrolytic coke in the industrial effluents can be reduced by removing long–chain normal aliphatic alkanes (C14–C24) as the source of self–assembled monolayers. Finally, the mechanism of temperature dependent vertical/horizontal adsorption modes was examined.

- **Keywords:** Submicron particles; Agglomeration; Pyrolytic coke; Steam cracker

I.S. Voytkov, R.S. Volkov, N.P. Kopylov, E.Yu. Syshkina, A.V. Tomilin, P.A. Strizhak. *Impact of scattered radiation on thermal radiation shielding by water curtains*. Pages 278-290.

Water curtains are used for shielding thermal radiation from combustion sources. Unlike fire-protection structures, they provide fire containment without blocking the movement of people and they allow firefighters and trucks to approach the combustion source. Water curtains can be produced by fixed-site automatic systems to prevent fire from spreading to the neighboring fire compartment or by nozzles attached to a fire-fighting truck or pipeline. Here we studied the shielding of thermal radiation from a typical compartment fire with a view to developing a prediction model. To record the water curtain characteristics, we used the experimental methods of Particle Image Velocimetry and Shadow Photography. The heat fluxes were recorded at different distances from the radiation source ranging from 300 to 1000 mm. We have established how the coefficient of heat flux absorption by the water curtain depends on the characteristics of the latter: thickness (100–400 mm), droplet size (10–120 μm), and volume concentration (0.005–0.04 L/m3). The greatest influence on the absorption intensity comes from the total droplet evaporation area. Based on the experimental data, we have developed a physical and mathematical model estimating the impact of scattered radiation on thermal transmittance from the combustion source. Using this model, we have determined the necessary parameters of water curtains, such as length, width, thickness, and droplet size, for the effective shielding of thermal radiation from combustion sources with different heat fluxes.

- **Keywords:** Fire; Heat flux; Water curtain; Heat radiation shielding; Sprayed water; Transmittance

Qizhong Li, Shennan Zhou, Zhongqi Wang. *Quantitative risk assessment of explosion rescue by integrating CFD modeling with GRNN*. Pages 291-305.

Gas explosions remain a significant industrial hazard, characterized by sudden outbreak, rapid development, and huge destruction. Quantitative risk assessment (QRA) has played an effective role in safety management and emergency preparedness for such incidents. Although a lot of attempts have been done to analyze the explosion risks, few works have been conducted on the risk for responding rescuers during these missions. This paper presents an explosion rescue risk assessment methodology for emergency decision support by integrating with a general regression neural network (GRNN) with computational fluid dynamics (CFD) modeling. Underground coal mine gas explosions are taken as an example. The likelihood exposure consequence (LEC) method is combined with a fault tree to establish a rescue risk assessment model that consists of 5 levels. The CFD modeling for possible explosion scenarios is continuously performed by automatically varying the predefined parameters. The generated data is used for the development and improvement of the GRNN model. Provided with real-time data, the GRNN model can predict the effects of a blast within few seconds, which are then used to calculate the occurrence probability of secondary explosions. As a result, the rescuers'

level exposure to explosion risk can be estimated. This will allow a better-informed rescue decision making. The proposed integrated method is applied to the Laoyingyan coal mine to demonstrate its applicability and effectiveness.

- **Keywords:** Quantitative risk assessment; CFD modeling; GRNN; Secondary explosion; Rescue risk

Jianfeng Zhou, Genserik Reniers, Valerio Cozzani. *Improved probit models to assess equipment failure caused by domino effect accounting for dynamic and synergistic effects of multiple fires*. Pages 306-314.

Accidents resulting in industrial fires in chemical and process installations and in industrial parks where relevant quantities of hazardous substances are stored or processed may cause domino effects. Probit models developed and used in a multitude of studies can provide the probability of equipment failure, but they do not consider the effect of multiple radiation sources, and thus fail to capture the effects of severe scenarios as those where multiple fires start at different times in different units. In the present study, a critical thermal dose for equipment failure is defined. A direct procedure for the calculation of ttf based on the critical thermal dose is then introduced, which is able to account for the time at which the different secondary fires start or are extinguished. This allows considering the effects of the primary and of several secondary fire scenarios in causing a domino effect, updating the time to failure on the basis of the dynamic evolution of multiple fire scenarios. The proposed approach is demonstrated through case-studies addressing fire-induced domino effects in an oil storage tank farm.

- **Keywords:** Chemical fires; Domino effects; Probit models; Time to failure

Lin Teng, Xigui Li, Shijian Lu, Bin Liu, Yuxing Li, Weidong Li. *Computational fluid dynamics study of CO2 dispersion with phase change of water following the release of supercritical CO2 pipeline*. Pages 315-328.

Accidental release of pressurized CO2 pipeline in carbon capture and storage involves the interaction of phase change and heavy-gas dispersion. However, the effect of the phase change of water vapor in air on the performance of cold CO2 dispersion is usually neglected. In this study, a three-dimensional two-phase computational fluid dynamics (CFD) model is developed to evaluate the cold CO2 dispersion by considering the phase change of water. A phase-change model based on the homogeneous relaxation model is used to describe the evaporation and condensation of water. The effects of terrain roughness, atmospheric stability, and turbulence models on the dispersion are also considered. The numerical results show that the model that uses the k–ω turbulent equations is superior to the other models. The results in which the phase change of water is considered exhibit a better agreement with the data from the experiments than those that do not consider it. The model is subsequently used in urban areas, which results in over-predicted CO2 concentration in the near field and under-predicted CO2 concentration in the far field when the phase change of water vapor is considered than that when it is neglected. Therefore, we proposed that the phase change of water vapor in the atmosphere should not be overlooked in the more accurate modeling of cold CO2 dispersion.

- **Keywords:** Computational fluid dynamics; Release of CO2 pipeline; Phase change; Dispersion of heavy gas; Carbon capture and storage

Wei Wang, Hanpeng Wang, Bing Zhang, Su Wang, Wenbin Xing. *Coal and gas outburst prediction model based on extension theory and its application*. Pages 329-337.

To accurately predict the risk of coal and gas outbursts under different conditions, an outburst risk prediction system and risk level indices value system were constructed based on extension theory. The prediction system includes 6 indices and 4 risk levels. The subjective and objective weights of the prediction indices were determined according to a fuzzy analytic hierarchy process and simple correlation function, respectively. Finally, a prediction model for the quantitative characterization of the outburst risk through the degree of correlation of the risk level was established. The outburst risk of 12 high-gas mines was predicted by using the prediction model. The prediction result of the outburst risk level was consistent with actual outburst disaster occurrences, and the variation of the actual outburst coal and rock mass quality was consistent with the degree of correlation of the maximum risk level. Based on typical outbursts of coal seam, the values of gas pressure and coal seam gas content were reduced step by step, and then the adjusted values were substituted into the prediction model. When the coal seam gas pressure was reduced to 0.75 MPa, the outburst risk level was reduced to low risk. This value is consistent with the empirical value (0.74 MPa) that is used to define an outburst of coal seam at a coal mine site. The prediction model has practical significance to prevent coal and gas outbursts, optimize gas drainage outburst prevention technology, and improve process safety risk control in coal mine.

- **Keywords:** Coal and gas outburst; Extension theory; Fuzzy analytic hierarchy process; Risk prediction

Rita de Cássia F. Soares da Silva, Juliana M. Luna, Raquel D. Rufino, Leonie A. Sarubbo. *Ecotoxicity of the formulated biosurfactant from Pseudomonas cepacia CCT 6659 and application in the bioremediation of terrestrial and aquatic environments impacted by oil spills*. Pages 338-347.

Dispersants with a low environmental impact are necessary for oil spill remediation. Thus, the biosurfactant produced by the bacterium Pseudomonas cepacia CCT6659 using industrial waste and formulated using a method of adding food preservative was evaluated for its toxicity against the vegetable Allium cepa and aquatic species such as the freshwater fish Poecilia vivipara and the bivalve Anomalocardia brasiliana. The biosurfactant was also applied in the removal of hydrophobic contaminant in sand and soils, in sea stones, in the dispersion and in the bioremediation of oil in seawater. The surfactant was considered to be of low toxicity for the bioindicators evaluated. As a petroderivative removal agent, the formulated tensoactive reached 76.55 % removal in soil and 84.50 % in sea stones. The biosurfactant was able to disperse 96.00 % of oil in seawater and promoted an increase in the biodegradation of oil by 70.00 % during a bioremediation process carried out in seawater. Therefore, the formulated biosurfactant presents suitable conditions for application as a dispersing agent in the decontamination of terrestrial and aquatic environments impacted by oil spills in substitution of chemical and toxic compounds.

- **Keywords:** Formulation; Bioremediation; Petroleum; Acute toxicity; Biosurfactant

Po-Hsuan Yen, Wei-Hsiang Chen, Chung- Shin Yuan, Yu-Lun Tseng, Jiann-Shen Lee, Chih- Cheng Wu. *Exploratory investigation on the suppression efficiency of fugitive dust emitted from coal stockpile: Comparison of innovative atomizing and traditional spraying technologies*. Pages 348-359.

This research applied two suppression technologies of atomizing dust suppression (ADS) and spraying dust suppression (SDS) to eliminate fugitive dust emitted from coal stockpiles and further investigated their optimal operating parameters. In field tests, the mass concentrations of TSP, PM10, and PM2.5 were simultaneously measured at both

upwind and downwind sites of a simulated coal stockpile to determine the suppression efficiency of fugitive dust. High concentrations of fugitive dust were observed under a strong wind speed of 10 m/s, particularly for particle sizes larger than 7 μm. Overall, the suppression efficiencies of fugitive dust by ADS (75.50–88.17 %) were always higher than those by SDS (70.70–84.50 %). Fine mist atomized by ADS covered a wider surface area of the coal stockpiles and captured more dust in the air than SDS. The suppression efficiencies of fugitive dust for intermittent watering (82.81 %) were higher than those for continuous watering (77.75 %). Intermittent watering could maintain a protective moisture layer over the entire surface of coal stockpiles, thus extending the drying time of moisture from the coal stockpiles. The optimal operating parameter for ADS was intermittent atomizing at an angle of 30°, while that for SDS was intermittent spraying at an angle of 45°.

- **Keywords:** Coal stockpiles; Fugitive dust emissions; Water spraying technologies; Optimal operating parameters; Suppression efficiencies

Vikranth Pridhvi Yandrapu, Nagamalleswara Rao Kanidarapu. *Process design for energy efficient, economically feasible, environmentally safe methyl chloride production process plant: Chlorination of methane route*. Pages 360-371.

Methyl chloride is the starting raw material for chloromethanes and the demand for chloromethane is increasing steadily in the world market. Continuous improvement in product quality, reducing the product cost, improving the operation efficiency, minimizing the environmental emissions, and enhancing the process plant safety are some of the challenges or constraints facing by the chloromethane industry. In this research work, an attempt has been made to address these challenges using process systems engineering. As a first step, a process simulation model is designed conceptually using the Aspen HYSYS V11 for the production of 99.9 % pure methyl chloride from the methane chlorination route. Energy analysis is performed for the effective utilization of the utilities by adding one new heat exchanger. This modification reduced the utility cost by 31.17 % and recovered the 13028 kW of energy from the process with a payback period of 0.8759 years. Energy savings reduced the product cost by 3.26 %. Heat integration reduced greenhouse gas emissions by 16.5 %. Process plant safety is improved by using depressurization studies. Safety calculations are performed for the storage tank protection and the tank is used for the storage of methyl chloride product. Sizing calculations are performed for safety valves to vent off excess vapor through pressure safety valves to protect the equipment against overpressure scenarios. Process design engineers and process safety engineers can use the methodology developed in this study to design energy-efficient, economically feasible, and environmentally safe chemical process plants.

- **Keywords:** Conceptual design; Energy analysis; Greenhouse gas; Heat integration; Process design; Plant safety

Dexiao Ma, Guozhao Ji, Dong Wang, Aimin Li. *Reinforced contact between sludge and hot wall for enhancing conductive drying by applying external load: Heat and mass transfer analysis*. Pages 372-383.

Conductive drying is widely used in sludge management for emission reduction and energy recovery. However, interfacial vapor film between sludge and hot wall inhibits drying efficiency. This study employed external load to reinforce the contact of sludge with hot wall for facilitating interfacial heat transfer. Subsequently, a drying model was developed for heat and mass transfer mechanism analysis. The influence of external loads was explored on conductive drying behavior at 180 °C and 0, 25, 100 kPa. The drying rates were increased with external load. The drying process consisted of the

warm-up, constant rate, and two falling rate periods. Without external load, moisture migration was dominated by liquid water diffusion induced by capillary force in the first falling rate period. However, at 100 kPa, the convective flow of water and vapor dominated the moisture migration in the first falling rate period due to increased interfacial heat transfer, evaporation rate, and gas pressure. Then vapor diffusion was predominant owing to enhanced gas diffusivity. Besides, this study provided essential information on design optimization of industrial applications, such as moisture content prediction for searching for equilibrium points between energy consumption and resource recovery and the critical factors for enhancing moisture migration.

- **Keywords:** Conductive drying; External load; Moisture migration; Multiphase model; Sewage sludge

Aihua Liu, Jieyun Chen, Xiner Lu, Didi Li, Wenbin Xu. *Influence of components interaction on pyrolysis and explosion of biomass dust*. Pages 384-392.

The understanding of the influence of the interactions among lignocellulosic biomass components on pyrolysis and explosion can aid in preventing and controlling dust explosions. This study aimed to examine the pyrolysis behavior and explosion parameters of cellulose, hemicellulose, and lignin, the components of biomass dust, and their mixtures to expound the influence of their interaction through a comparative analysis of the experimental results and predicted values, using a thermogravimetric analyzer and 20 L spherical explosion vessel. The results show that a higher fraction of cellulose enhances the mixture's weight loss peak intensity and explosion pressure. The increase in hemicellulose improves the shoulder peak intensity and the explosion rate of pressure rise. An increase of lignin leads to an increase in solid residue and a decrease in explosion pressure. The interaction among the components leads to the experimental thermogravimetric curve lagging the predicted curve obtained by the weighted average of the individual components. The explosion pressure of the mixture is mainly determined by the promotion and inhibition effect of cellulose and lignin, respectively, and the rate of pressure rise is mainly affected by hemicellulose content.

- **Keywords:** Lignocellulosic biomass; Biomass components; Dust explosions; Explosion severity; Promotion and inhibition

Mohammad Ebadollahi, Hadi Rostamzadeh, Omid Pourali, Hadi Ghaebi, Majid Amidpour. *Inherently safety design of a dual-loop bi-evaporator combined cooling and power system: 4E and safety based optimization approach*. Pages 393-409.

In this article, a dual-loop bi-evaporator CCP (combined cooling and power) system is presented to simultaneously supply electricity, air-conditioning, and freezing demands. The system consists of two organic Rankine cycles (ORCs) for power generation and two ejector cooling cycles (ECCs) for cooling production which is adjusted at two different cooling temperature levels, using waste heat from the exhaust gases of a biogas plant as prime mover. The system is investigated from energy, exergy, exergoeconomic, exergoenvironmental, and safety standpoints. Later, the performance of the devised unit is optimized by simultaneously accounting the central metrics obtained from 4E + safety analysis. Four benchmarks with the same applications (i.e., cogeneration of power and cooling at two different temperature levels) are selected and the superiorities of the present CCP system over these previously available systems are investigated. At optimal point, the net power, air-conditioning, and freezing products are computed 96.59 kW, 302.4 kW, and 23.01 kW, respectively. Furthermore, the optimal energy efficiency, exergy efficiency, unit cost of product, environmental impact of product, and total risk are calculated 56.09 %, 25.45 %, 37.54 $/GJ, 4026 mPts/GJ, and 1716 $/Year,

respectively. Moreover, the generator is recognized as the main source of irreversibility, while the pump used in the high-temperature circuit has the highest amount of risk level between all components. By rising the heat source temperature, the energy efficiency, unit cost of product, environmental impact of product, and total risk level are increased, while the exergy efficiency is reduced.

- **Keywords:** Bi-evaporator; Dual-loop cogeneration; 4E+safety optimization; Inherently safety design (ISD); Quantitative risk assessment (QRA)

Shugang Li, Bo Zhao, Haifei Lin, Haiqing Shuang, Xiangguo Kong, Erhao Yang. *Review and prospects of surfactant-enhanced spray dust suppression: Mechanisms and effectiveness*. Pages 410-424.

Surfactant-enhanced water spray technology, one of the most economical and efficient dust suppression technologies, is widely used for dust control in mining. Unfortunately, current research on this technology appears to be scattered, and the results do not provide an effective approach for coal dust control. Aimed at addressing this problem by critically reviewing coal dust agglomeration mechanisms and dust suppression effectiveness, this review summarized four steps for droplets capturing coal dust, and two agglomeration mechanisms(immersion and distribution mechanisms) are illustrated based on them. In addition, the dust suppression effect is categorized as either indirect dust suppression or direct dust suppression, depending on the coal dust removal effect. The suppression results show that surfactants can significantly improve the indirect dust suppression, the direct dust suppression efficiency of surfactant-enhanced water spray technology is generally between 80 % and 95 % and can be increased by approximately 40 % compared to the conventional spray dust reduction efficiency, and the suppression efficiency for respirable coal dust (below PM10) is approximately 1 % lower than that of total dust. In the discussion on the challenges and further research directions, relative motion and capture of fine particles, effect evaluation methods and standard, relationship between direct and indirect dust suppression effects, as well as field application technology, are suggested as the main challenges and directions for improving the efficiency of this technology.

- **Keywords:** Respirable coal dust; Surfactant; Spraying; Wettability; Dust agglomeration mechanism; Dust suppression effect

Jiwoo Lee, Daeeun Kwon, Jeonghwan Kim. *Long-term performance evaluation of granular activated carbon fluidization and biogas sparging in anaerobic fluidized bed membrane bioreactor: Membrane fouling and micropollutant removal.* Pages 425-432.

In this study, fluidization of granular activated carbon (GAC) by the recirculation of a bulk suspension through an anaerobic fluidized bed membrane bioreactor (AFMBR) and biogas sparging from the bottom of an anaerobic membrane bioreactor (G-AnMBR) for treating low-strength wastewater were compared to investigate organic removal and fouling rate. The chemical oxygen demand (COD) removal efficiency obtained by both the AFMBR and G-AnMBR exceeded 90 %, and the proportion of methane in the biogas produced was 60 % at the same hydraulic retention time (HRT). In the AFMBR, the transmembrane pressure (TMP) gradually increased, but a rapid TMP jump was not observed during operational period. In the G-AnMBR, the TMP increased rapidly as the biogas flowrate was 2 and 3 L/min (LPM) at 8 h of HRT while the TMP below 0.1 bar was maintained over 90 d at 4 LPM. Our results also indicated that organic micropollutants, such as Bisphenol A (BPA), Sulfamethoxazole (SMX), and Methylparaben (MeP), were removed by AFMBR almost completely. However, the G-AnMBR showed relatively low SMX and MeP removal efficiencies of 47.6 % and 74.9 %, respectively. The estimated energy required to operate the G-AnMBR was 1.37 kW h/m3, while it was only 0.06 kW h/m3 for AFMBR.

- **Keywords:** Anaerobic membrane bioreactor; Membrane fouling; Granular activated carbon; Biogas-sparging; Micropollutants

Zhikang Yu, Cheng Sun, Jiamei Fang, Lin Zhang, Yiyang Hu, Bingguo Bao, Shi Bu, Weigang Xu, Yixiang Ji. *Water recovery efficiency improvement using the enhanced structure of the mist eliminator*. Pages 433-446.

Thermal power plants are users of high water consumption, and the water consumption of cooling towers accounts for more than half of the total water consumption of the whole plant. Therefore, water saving of cooling towers is the key to water saving in thermal power plants. Wave-plate demister as a component of cooling tower influences the performance of entire system. Demister realizes the collection of liquid droplets with the penalty of extra pressure loss. Curved bends and drainage hooks are proposed as enhancing structures of demister to increase separation efficiency and reducing pressure loss simultaneously. Computational result shows that interaction between curved bend and hooks improves the overall performance of demister. Moreover, effect of enhancing parameters on the performance is presented, specifically, Euler number and separation efficiency are correlated as functions of curved bend radius and hook length. Most importantly, an experiment is conducted on a real cooling tower. It shows that the overall thermal capacity is lowered with the presence of demister. Pressure drop, separation efficiency and heat transfer of the entire system are tested with and without demisters, based on which a new criterion is proposed to evaluate the influence of demister on the overall performance of cooling tower in terms of thermal efficiency and droplets collection. Performance indexes as functions of enhancing parameters and droplets dynamic are plotted. Therefore, a quick design of demister can be realized in achieving an optimal performance of cooling tower.

- **Keywords:** Cooling tower; Mist eliminator; Pressure loss; Separation efficiency; CFD

Kai Wang, Yingfeng Yuan, Mengmeng Chen, Dezheng Wang. *A POIs based method for determining spatial distribution of urban fire risk*. Pages 447-457.

Rapid development of the city makes it faces increasing challenges in controlling fire accidents. In order to improve the effectiveness in urban fire control, the distribution of urban fire risk should be identified accurately. Accordingly, a new method for urban fire risk assessment is proposed in this study. The method is based on the points of interest (POIs) data. The original POIs need to be sorted and reclassified because they are commonly repeatable and unreasonably classified. After reclassification, the weight of each category of the POIs in terms of fire risk is determined based on the historical fire accident data and experts' judgment. Then, the kernel density analysis (KDA) is conducted on all categories of the POIs by using ArcGIS software. After that, the distribution of the fire risk can be obtained and visualized based on the weights and KDA results of all categories of the POIs. Moreover, Zhongyuan District of Zhengzhou city is taken as an example to verify the effectiveness of the proposed method. The results indicate that the high fire risk areas are mainly located in southwest of the target district. Accordingly, specific measures are proposed to mitigate fire risks in the referred region.

- **Keywords:** Urban fire risk; POIs; Historical fire accidents; KDA

Rajeevan Arunthavanathan, Faisal Khan, Salim Ahmed, Syed Imtiaz. *A deep learning model for process fault prognosis*. Pages 467-479.

Early fault detection and fault prognosis are crucial functions to ensure safe process operations. Fault prognosis can detect and isolate early developing faults as well as

predict fault propagation. To promptly detect potential faults in process systems, it is important to examine the fault symptoms as early as possible. In recent years, fault prognosis approaches have led to the remaining useful life prediction. Therefore, in a process system, advancing prognosis approaches will be beneficial for early fault detection in terms of process safety, and to predict the remaining useful life, targeting the system's reliability. In data-driven models, early fault detection is regarded as a time-dependent sequence learning problem; the future data sequence is predicted using the previous data pattern. Studying recent years' research shows that a recurrent neural network (RNN) can solve the sequence learning problem. This paper proposes an early potential fault detection approach by examining the fault symptoms in multivariate complex process systems. The proposed model has been developed using the Convolutional Neural Network (CNN)- Long Short-Term Memory (LSTM) approach to forecast the system parameters for future sampling windows' recognition and an unsupervised One-class-SVM used for fault symptoms' detection using forecasted data window. The performance of the proposed method is assessed using Tennessee Eastman process time-series data. The results confirm that the proposed method effectively detects potential fault conditions in multivariate dynamic systems by detecting the fault symptoms early as possible.

- **Keywords:** Process safety; Data-driven model; LSTM model; Fault prognosis; Fault diagnosis

Faramarz Bagherzadeh, Amirreza Shojaei Nouri, Mohamad-Javad Mehrani, Suresh Thennadil. *Prediction of energy consumption and evaluation of affecting factors in a full-scale WWTP using a machine learning approach*. Pages 458-466.

Treatment of municipal wastewater to meet the stringent effluent quality standards is an energy-intensive process and the main contributor to the costs of wastewater treatment plants (WWTPs). Analysis and prediction of energy consumption (EC) are essential in designing and operating sustainable energy-saving WWTPs. In this study, the effect of wastewater, hydraulic, and climate-based parameters on the daily consumption of EC by East Melbourne WWTP was investigated based on the data collected over six years (2014−2019). Data engineering methods were applied to combine features from different resources. To this end, four various feature selection (FS) algorithms were used to reveal the relations among those variables and to select the most relevant variables for training the machine learning (ML) models. Further, the application of artificial neural networks (ANN) and two decision tree algorithms of Gradient Boosting Machine (GBM), and Random Forest (RF) were studied to predict EC records followed by a 95 % confidence interval assessment. Results of FS algorithms revealed that total nitrogen, chemical oxygen demand (COD), and inflow-flow had the highest impact on WWTP energy consumption. Moreover, GBM had the best performance prediction among all other regression algorithms. 95 % of confidence interval showed a reasonable prediction error band (±68 MWh/Day).

- **Keywords:** Machine learning; Energy consumption; Power-grid prediction; WWTP; Feature selection; Wastewater characteristics

Douglas Thiago S. Alves, Gilson Brito Alves Lima. *Establishing an onshore pipeline incident database to support operational risk management in Brazil - part 1: Defining architecture*. Pages 480-504.

This work aims to propose an interdisciplinary research for establishing a national onshore pipeline incident database. The creation of a failure database has the potential to allow effective demonstration to control authorities and the society of safety improvements implemented by operators over time, support the development of dynamic

risk assessment and management models and comparison with international benchmarks metrics, among other benefits. Therefore, in this part 1 a robust approach is proposed in order to previously define an appropriate data collection architecture that reflects the current context of this activity in Brazil. Defining architecture properly is a key issue to ensure that future data collection would be able to generate relevant information (and them knowledge) to support and strengthen operational risk management. Through a systematic literature review, the state of art regarding several international benchmarks was established for mapping the parameters that typically compose pipeline incident databases taxonomies. Categories regarding events of failure, pipeline network and database management were identified. In sequence, an anonymous survey was carried out considering this information, involving 180 pipeline specialists of different profiles/backgrounds. Statistical tests were proposed for assessing consistency of its results and selecting the parameters that would finally compose Brazilian pipeline database architecture according to expert elicitation. Based on it, in part 2 a bowtie diagram is elaborated, depicting causes, consequences, prevention and mitigation controls associated with pipeline failure events. In addition, the calculation of failure statistics from historical data obtained from a Brazilian pipeline operator demonstrates that the architecture proposed in part 1 has practical applicability and can be used for the purposes of this work.

- **Keywords:** Pipeline incident database; Database architecture; Major accident hazards; Fire and explosion; Environmental impacts

Vahid Ghamari, Hassan Hajabdollahi, Mohammad Shafiey Dehaj. *Comparison of gas turbine and diesel engine in optimal design of CCHP plant integrated with multi-effect and reverse osmosis desalinations*. Pages 505-518.

The combined heating, cooling, power (CCHP) and freshwater system are designed separately with two types of desalination plants including multi-effect desalination with thermal vapor compression (MED-TVC) and reverse osmosis (RO). This combined system meets the heating, cooling, power and fresh water needs of a hotel in Iran. Gas turbines and diesel engines are considered as prime movers (PM) for conversion of fuel to power and heat. The integration of the CCHP system with RO desalination was investigated in two modes of RO without colloidal fouling (first day of operation) and with colloidal fouling formation rate in a period of 90 days. The genetic algorithm (GA) was implemented to find the optimal values of 21 design parameters in the case of CCHP system with RO desalination and 22 design parameters in the case of CCHP system with MED-TVC desalination to minimize the annual cost. Optimization results showed that the diesel engine prime mover has a greater advantage over the gas turbine in the all studied modes. In addition, combination of CCHP + RO without colloidal fouling and with colloidal fouling and combination of CCHP + MED-TVC with diesel engine as PM showed 9.66 %, 1.80 % and 11.68 % reduction in annual cost compared with gas turbine as PM, respectively.

- **Keywords:** Trigeneration plant; Desalination; Prime mover; Optimization