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Yuanliang Liu, Zhan Liu, Jianjian Wei, Yuqi Lan, Shenyin Yang, Tao Jin. *Evaluation and prediction of the safe distance in liquid hydrogen spill accident*. Pages 1-8.

Safety is the primary concern during the processes of storage, transportation and application of liquid hydrogen. The flammable vapor cloud formed by liquid hydrogen spill poses serious threat to life and property, and it is vital to determine safe distance (the maximum downwind distance of flammable vapor cloud to the spill source) for risk assessment and safe protection. Three-dimensional CFD simulations predicting liquid hydrogen spill in open environment are performed, and variation characteristics of safe distance with different parameters are analyzed. The wind transporting, the atmospheric turbulence, and the shear force between cloud and air are all enhanced by increased wind speed, and consequently the safe distance increases in the first phase and then decreases with wind speed. Safe distance is positively related to liquid spill rate, while the increase rate slows down gradually. A correlation that relates safe distance with wind speed and spill rate is then established for the real-time guidance in a liquid hydrogen spill accident.

- **Keywords:** Safe distance; Liquid hydrogen spill; Wind speed; Spill rate

Jing Zhou, Feini Huang, Wenhao Shen, Zhang Liu, Jean-Pierre Corriou, Panagiotis Seferlis. *Sub-period division strategies combined with multiway principle component analysis for fault diagnosis on sequence batch reactor of wastewater treatment process in paper mill*. Pages 9-19.

Fault diagnosis of sequential batch reactor (SBR), a widely applied wastewater treatment technology in papermaking industry with huge discharge, has been a significant challenge due to the inherent multi-period characteristics of the process. In this paper, based on the conventional multi-way principal component analysis (MPCA) method (Scenario 0), two sub-period division strategies based on the processing phases of SBR process (Scenario 1) and the similarities of the loading matrices between the adjacent time slices (Scenario 2) are proposed for the detection of faults. Combined with Scenario 0, using the field data of blower current, level of SBR reactor, dissolved oxygen of wastewater and the blower valve opening in the SBR process of paper mill, two different fault diagnosis models with Scenarios 1 and 2 are developed and evaluated, respectively. The study results revealed that, both the calculated statistics of T2 and sum of prediction errors (SPE) of the fault diagnosis models with Scenarios 1 and 2 could detect the faults and

identify the fault locations and sources. Compared to Scenario 0 which neglects the correlations between the different stages of SBR process, the fault diagnosis model by Scenario 2 demonstrated a superiority ability in fault identification in terms of the fault's time onset and fault's sources with adequate accuracy. The results enable the feasible and reliable implementation of the developed sub-MPCA diagnosis model with Scenario 2 in the actual SBR plants.

- **Keywords:** Fault diagnosis; Paper mill; SBR; Sub-MPCA; Wastewater

S.O Sanni, E.L Viljoen, A.E Ofomaja. *Tailored synthesis of Ag/AgBr nanostructures coupled activated carbon with intimate interface interaction for enhanced photodegradation of tetracycline*. Pages 20-34.

Tailored synthesis of Ag/AgBr nanostructures (AABR) with intimate interface interaction for enhanced photocatalytic performance is a challenge for its extensive applications. Herein, tailored Ag/AgBr nanostructures promoted with char-microwave activated carbon (ACK) was synthesized through a modified deposition-precipitation method. The influence of four reaction parameters comprising of a mass of surfactant, temperature, ACK mass and ammonium hydroxide volume for the AABR-ACK composites were optimized using response surface methodology (RSM). Their simultaneous interactions on removal efficiency of tetracycline (TC) antibiotics under visible light were investigated under visible light. The high photocatalytic degradation of TC over AABR-ACK composites was governed by ammonium hydroxide volume and temperature. The SEM, XRD, FTIR, TEM, optical and electrochemical properties of the composites from these influential parameters, evidenced the formation of tailored AABR-ACK nanostructures with intimate interface interaction. The tailored near spheres nanostructures of AABR promoted with ACK boosted the visible light absorption, intimate interface contact, which promotes photo-induced charge pairs separation for the enhanced visible-light photocatalytic activity of AABR-ACK 7 composite TC (87 %). In addition, AABR-ACK 7 composite possessed significant recycle efficiency up to four consecutive cycles. The mineralization efficiency of AABR-ACK 7 on TC achieved 78.5 % and possible degradation pathways of TC were proposed. This work offers good insight into the tailored design of visible-light responsive heterojunction photocatalysts for sustainable environmental remediation.

- **Keywords:** Tailored synthesis; Intimate interface interaction; Ag/AgBr-coupled activated carbon; Deposition precipitation; Response surface methodology; Visible light

Shengchao Rui, Quan Li, Jin Guo, Xuxu Sun. *Experimental and numerical study on the effect of low vent burst pressure on vented methane-air deflagrations*. Pages 35-42.

This paper experimentally investigated the effect of low vent burst pressure on the overpressure buildup and flame evolution during the vented methane-air deflagrations in a 1m3 rectangular vessel. CFD software FLACS was assessed in simulation of vented methane-air explosions against the experiment. Experimental results demonstrate that four overpressure peaks of Popen, Pout, Pext and Pacc from the vent failure, flame venting, external explosion and acoustically enhanced combustion, respectively, were observed except for the free venting case, in which only two overpressure peaks of Pout and Pext were monitored. The flame behaviors corresponding to different overpressure peaks were monitored especially at Pacc, where an abrupt increase in flame luminosity was observed on the bottom of the vessel due to the combustion of pockets of flammable mixture. Popen and Pacc increase with the vent burst pressure while Pout and Pext are nearly independent of the vent burst pressure. Double flame accelerations were observed owing to the vent rupture and flame venting. The phenomena of Helmholtz oscillation and the bulk motion of flame bubble always appeared after the vent rupture. The predicted overpressure agrees reasonably well with the experimental data. The

discrepancy of the predicted and measured maximum peak overpressures reduces with increasing vent burst pressure. The predicted maximum peak overpressure and external flame length are slightly larger than those in experiment, which would facilitate the safe design in explosion venting and offer a better guidance in risk assessment. The simulation results also show that two overpressure peaks were recorded resulting from the pressure wave propagating above the vessel and the external explosion, respectively.

- **Keywords:** Vented explosion; Pressure oscillation; Methane-air mixtures; Safety

B. Gunes, J. Stokes, P. Davis, C. Connolly, J. Lawler. *Modelling and optimisation of the biogas yield after hybrid alkaline-ultrasonic pre-treatment in the early stages of anaerobic digestion of pot ale to shorten the processing time*. Pages 43-53.

Whiskey distillery wastewater (pot ale) is classified as a high organic content wastewater and its year-long large discharge volume makes it a suitable substrate for anaerobic digestion from environmental and economical perspectives. Prior to anaerobic digestion, a hybrid alkaline-ultrasonic pre-treatment was performed in order to alter the lignocellulosic structure of the pot ale. Effects of alkaline dose (0–3M NaOH), amplitude ratio (40–100%) and exposure time (1–3h) of ultrasonic pre-treatment on CH4, CO2 and H2S generation within the first 2 days of anaerobic digestion were investigated at a lab scale batch reactor. Response surface methodology (RSM) was adopted as a process modelling and optimisation tool. Significant enhancements in the hydrolysis rate constant and methane yield were achieved in the early stages of digestion. The highest methane yield of the first 2 days digestion was 333±5mL/g VS after implementation of ultrasonic pre-treatment at 70 % amplitude for 3h in isolation leading to 48±4.4 and 56±3.5 % reduction in chemical and biological oxygen demand respectively. The optimum pre-treatment conditions according to combined numerical and graphical optimisation, to maximise CH4 yield while minimising the H2S generation was identified as 40 % amplitude ratio, 1–2.5h exposure time and 0 – 0.6M NaOH.

- **Keywords:** Anaerobic digestion; Pot ale; Alkaline pre-treatment; Ultrasonic pre-treatment; Mathematical modelling; Response surface methodology

Peyvand Valeh-e-Sheyda, Javad Barati. *Mass transfer performance of carbon dioxide absorption in a packed column using monoethanoleamine-Glycerol as a hybrid solvent*. Pages 54-68.

Environmental concerns caused by chemical solvents need be managed through the advantages of hybrid bio-sourced solvents for CO2 capture. On the other side, to accurately predict the height of a CO2 absorption packed column, it is essential to estimate the mass transfer coefficients. This paper provides the experimental results of mass transfer performance of the aqueous mixture of MEA + Glycerol, as an industrially eco-friendly hybrid solvent, instead of a typical commercial alkanolamine solvent for CO2 capture in a laboratory-scale absorption packed column. For the first time, a predictive statistical model was built to investigate the influence of process variables, involving absorption temperature (30−45 °C), inlet gas flow rate (4−6 L/min), the initial solvent concentration of glycerol (5−15 wt %), and MEA (10−30 wt %) on the CO2 removal efficiency (ef), and the volumetric overall gas-phase mass transfer coefficient (KGaV) in the CO2+MEA + Glycerol system. The results of CO2-absorption showed that rising the glycerol concentration from 5 % to 15 % enhances the values of ef and KGaV by 4.5 % and 24.62 %, respectively, when the other three variables are considered fixed at their midpoints. Therefore, the presence of glycerol, as the promoter in a hybrid mixture of MEA-Gly, significantly gives rise to the mass transfer coefficient and CO2 removal efficiency.

- **Keywords:** Absorption; Carbon dioxide; Glycerol; Monoethanolamine; Overall gas-phase mass transfer coefficient; Packed bed column

Yamin Hu, Jiancheng Li, Shuang Wang, Lujiang Xu, Bahram Barati, Bin Cao, Haiwen Wang, Kaihan Xie, Qian Wang. *Catalytic fast hydropyrolysis of seaweed biomass with different zeolite catalysts to produce high-grade bio-oil*. Pages 69-76.

This paper studies the conversion of seaweed into liquid fuels through catalytic fast hydropyrolysis (CHP) with microporous ZSM-5, mesoporous MCM-41 and their mixtures for high-quality bio-oil production. Although the catalytic fast pyrolysis could increase bio-oil yield, the higher content of acids, furans and phenols in bio-oil were produced in the N2 atmosphere, which could aggravate the catalyst deactivation and increase thermal instability. The pyrolysis process in the presence of H2 with no catalyst showed a minor impact on the production yields. While the synergy of H2 with ZSM-5 and MCM-41 was found to substantially increase the bio-oil yield 36.22 % to 51.48 % and 41.84 %, respectively. Moreover, the CHP process not only increased the bio-oil yield but also enhanced its quality. Besides, entire aromatics content in the bio-oil from the CHP process increased, whereas the small molecule acids contents declined. Also, alcohol and ester content increased by 10.40 % and 3.58 %, respectively. Furthermore, furans and ketones were not detected, and the denitrification reactions were also improved with the co-catalyst. The present results suggest that CHP can be a viable way to convert seaweed biomass into liquid bio-fuel.

- **Keywords:** Seaweed biomass; Catalytic fast hydropyrolysis; ZSM-5; MCM-41; Co-catalyst

Nouha Bakaraki Turan, Hanife Sari Erkan, Guleda Onkal Engin. *Microplastics in wastewater treatment plants: Occurrence, fate and identification*. Pages 77-84.

This review highlights the methodologies for sampling, sample preparation, and identification of microplastics found in wastewater treatment plants. The presence and deposition of microplastics in the environment lead to serious environmental and ecological concerns. The role of wastewater treatment plants in spreading microplastics to the environment poses additional threats that need to be treated. Thus, the key challenges remain in understanding the fate and occurrence of microplastics in the wastewater treatment plant and the ability to detect them at each stage of the treatment. This review, therefore, helps to understand the fate and occurence of microplastics in the wastewater treatment plant. Besides, it is organized to present an overall discussion of the available microplastics detection techniques from sampling to identification.

- **Keywords:** Microplastics; Wastewater treatment plant; Detection; Identification

Bineeta Singh, Satyansh Singh, Pradeep Kumar. *In-depth analyses of kinetics, thermodynamics and solid reaction mechanism for pyrolysis of hazardous petroleum sludge based on isoconversional models for its energy potential*. Pages 85-94.

The pyrolysis of hazardous petroleum sludge (PS) has widely been used for its remediation and energy extraction. However, in view of process optimization, scale-up, design and simulation, the kinetic (activation energy and frequency factor) and thermodynamic parameters (change in enthalpy (Δ H), entropy (Δ S), and Gibb's free energy (Δ G)) along with reaction mechanism followed by pyrolysis has rarely been investigated. Therefore, pyrolysis of PS was investigated in thermogravimetric analyzer

(TGA) at three heating rates viz. 5, 10, 15 K min−1. The kinetic and thermodynamic parameters were estimated by iso-conversional methods such as Kissinger-Akahira-Sunose (KAS), Starink and Ozawa-Wall- Flynn (OWF) method. Further, solid reaction mechanism during pyrolysis was examined by employing Criado method (Z-master plot). The effect of heating rate on thermodynamic parameters and solid reaction mechanism was also examined. The average activation energy using Starink method was found to be 76.77 kJ mol−1. The frequency factor, Δ H, Δ S and Δ G at 5 K min−1, using activation energy from Starink method was found to be 3.23 × 107 sec-1, 70.78 kJ mol−1, -0.168 J mol-1 K-1, and 189.88 kJ mol−1, respectively. Z-master plot revealed that solid reaction mechanism depend on the degree of conversion and heating rate during pyrolysis of PS.

- **Keywords:** Pyrolysis; Petroleum sludge; Iso-conversional method; Kinetic parameters; Solid reaction mechanism

T. Nguyen, C. Strebinger, G.E. Bogin, J. Brune. *A 2D CFD model investigation of the impact of obstacles and turbulence model on methane flame propagation*. Pages 95-107.

The formation of explosive gas zones (EGZs) from flammable vapors, gases, or dust pose safety hazards to many industries. In many cases, explosions may occur in confined areas with obstacles in the path of flame expansion. By studying the effects of obstacle shape, turbulence model, and spark location on flame propagation and turbulence, a more complete understanding of the flame and fluid dynamics interaction has been achieved. Reynolds Averaged Navier-Stokes (RANS) models were tested to determine if these simplified turbulence models could capture the flame dynamics and propagation velocities using fewer computational resources compared to the higher fidelity Large Eddy Simulation (LES) turbulence model. Results showed that square obstacles caused faster flame propagation compared to hexagons and circles. The square had an average flame propagation velocity 26 % faster than the circle, and the hexagon was 16 % faster than the circle using a k-ω model. Modeling results indicate variation of spark location by as small as 10 % of the obstacle diameter can result in a difference of the flame propagation. Findings on turbulence model accuracy and computational time along with shape comparison can be applied in future modeling of large systems, providing crucial information for safety planning and explosion prevention.

- **Keywords:** Obstacle; Methane-air explosion; Turbulence; Flame; CFD modeling

Dachao Ma, Liwu Liang, Erfeng Hu, Huaquan Chen, Dongbo Wang, Chao He, Qingge Feng. *Dechlorination of polyvinyl chloride by hydrothermal treatment with cupric ion*. Pages 108-117.

Hydrothermal treatment (HTT) is able to remove chlorine effectively from polyvinyl chloride (PVC), however, the reaction temperature is critical in practical application. Less energy-intensive hydrothermal dechlorination condition with cupric ion (Cu2+) has been proposed in this study. In particular, Cu2+ was applied in HTT of PVC at temperature ranging from 200 °C to 240 °C. It has been found that the introduction of Cu2+ distinctly accelerated PVC decomposition and dechlorination at 220 °C. When Cu2+ concentration was increased from 0.01 mol/L to 0.20 mol/L, the dechlorination efficiency was significantly improved from 15.46 %–67.89 %. Dramatic dechlorination occurred as residence time was longer than 15 min during HTT. Besides, both elimination and substitution dominated the HTT dechlorinaton. The facilitated dechlorination after the addition of Cu2+ was mainly due to the enhanced dispersion and formation of micropores in hydrochar. On the whole, HTT could be a promising pretreatment technology for copper-containing PVC in electronic wastes to prepared chlorine free hydrochar for combustion or pyrolysis applications, the optimal HTT condition would be 220 °C, 60 min with 0.1 mol/L Cu2+.

- **Keywords:** Hydrothermal treatment; Polyvinyl chloride; Dechlorination; Catalytic; Effect; Cupric ion

Augusto C.J. Santos, Cristiano A.V. Cavalcante, Lucas F.A. Ribeiro. *The use of second-hand items based on delay time modelling*. Pages 118-125.

In view of the increasing tendency to make use of second-hand items, we present a schematic framework that models the possible reuse of an item considering its defective condition, based on the delay time concept. A parallel between the traditional delay time model for single-component systems and the proposed model for the reuse of items is provided in order to emphasize our contribution. In general terms, our model may be applied to any component that wears out over time and that may be replaced by a new one or by a refurbished item. The results show reductions in the order of 36.7 % in the expected cost over an inspection cycle. Also, results indicate that the higher the level of reused items, the lower the expected cost, which suggests the reuse of items can serve not only to generate less severe environmental impacts but also to generate economic benefits. Finally, the main contribution of this paper is an inspection policy that encompasses the level of reused items, in a way that links the condition of the item with savings made by recycling it. The findings presented here reinforce the need to use recycled items, since apart from this leading to greater sustainability in the use of natural resources, some conditions may well result in cost savings.

- **Keywords:** Delay time; Single-component systems; Reuse of items; Second-hand items

Xuyan Liu, Hong Yang, Xiaoyue Fang, Xiaotong Wang, Yang Su. *Performance study and population structure analysis of hydrolytic acidification immobilized fillers using municipal wastewater*. Pages 126-135.

In municipal wastewater treatment, controlling the stability and efficiency of the anaerobic process is the premise and key to the high-standard discharge of organic matter and total nitrogen. In this study, two types of hydrolytic acidification, immobilized biological active fillers and traditional activated sludge, were used to treat municipal wastewater at different temperatures (13−24℃) and working conditions. The degradation of organic matter and the transformation of organic nitrogen in the anaerobic process were compared, and the internal flora of the immobilized fillers was systematically analyzed by high-throughput sequencing technology. The results show that the filler exhibited higher activity at low temperatures, and the residual organic nitrogen level in the effluent (0.3−0.5mgL−1) was significantly lower than that in the sludge reactor (0.8–1.2mgL−1). The performance of hydrolysis-acidification of skeleton-less fillers (EB3) was higher than that of skeletoned fillers (EB2) (the hydraulic retention time was 1h and fill rate was 8%). The organic nitrogen of fillers was completely converted, while the volatile fatty acid of EB3 effluent increased by 2–2.5mgL−1, greater than the increase in EB2 effluent (0.9–1.3mgL−1). Based on the results of high-throughput sequencing, the fillers contained the same functional species, albeit at different abundances. The immobilized fillers could improve the performance of traditional activated sludge to maintain biomass through reflux and achieved the dual advantages of fixing biomass and maintaining good anaerobic characteristics.

- **Keywords:** Microbial immobilization; Immobilized fillers; Hydrolysis-acidification; Ammoniation; Microbial community structure

Ansaf V Karim, Ambika Selvaraj. *Graphene composites in photocatalytic oxidation of aqueous organic contaminants: a state of art*. Pages 136-160.

Graphene is a single layer of graphite and highly promising allotrope of carbon that attracted significant research interest because of its unique structure and physicochemical properties. Graphene derivatives exhibit exceptional crystal and electronic properties and have already emerged as a photocatalytic material due to its higher surface area, charge transfer and adsorption capability. Graphene composites made up of graphene derivatives with conventional photocatalysts enhanced the performance of photocatalysis by extending the light absorption ability, photostability, pollutant adsorption, catalysis etc. and makes it a suitable material for water and wastewater treatment. In this review, the fundamental characteristics of graphene composites for photocatalytic enhancement, different preparation methods, its application in the treatment of recalcitrant organic compounds under UV and visible spectrum and the speculated mechanisms are discussed. A critical review on the reuse potential of graphene composites and its importance in practical application of photocatalysis are first of its kind. At every segment, the summary of significances, existing gaps, pathways and challenges and pathways to proceed forward are added. The current review helps in the cohesive understanding of the state of art in the research field of graphene-based photocatalysis.

- **Keywords:** Synthesis and characterization of graphene derivatives; Photocatalytic degradation of organic pollutants; Oxidative photocatalytic mechanisms; Visible light photocatalysis; Reuse of graphene composite photocatalysts

Shiva Ghiasvand, Alireza Rahmani, Mohammadtaghi Samadi, Ghorban Asgari, Saeid Azizian, Ali Poormohammadi. *Application of polystyrene nanofibers filled with sawdust as separator pads for separation of oil spills*. Pages 161-168.

In this work we report the use of separator pads made of polystyrene nanofibers filled with sawdust for the separation of oil spills. The polystyrene nanofiber membrane was first synthetized using two electrospinning and impregnation methods, and then the synthetized pads were filled with different types of sawdust including willows, poplars and chipboards. The proposed pads were utilized for the separation of oil spills from aqueous solutions. Pre-experiments showed that the poplar sawdust with particle size in the range 40–60 mesh had the highest sorption capacity for the separation of different oil spills. The adsorption capacity of the pads synthetized by the both electrospinning and impregnation methods for the separation of the all types of oil spills decreased with increasing reaction temperature. Moreover, their sorption capacity decreased with increasing pH up to natural pH, and then slightly increased by increasing the solution pH. The results showed that under optimum conditions (reaction temperature=25°C, pH=4, and contact time=1min), the adsorption capacities of the proposed pads by impregnation method for the separation of motor oil, diesel oil, furnace oil, and crude oil were 1, 0.63, 0.97 and 0.59g/g, respectively. Moreover, the adsorption capacities of the pads prepared by electrospinning method for the mentioned oils were 1.41, 1.4, 1.5 and 1.1g/g, respectively. The synthesized pads made of polystyrene nanofibers and sawdust offered a high efficiency for the removal of different types of oil spills, and therefore they can be used as cheap, available, reusable, eco-friendly and efficient technology for the separation of oil pollution in water aqueous.

- **Keywords:** Oil spills; Aqueous solution; Separator pads; Polystyrenene; Sawdust

Isaac Delove Tegladza, Qiuling Xu, Kai Xu, Guojun Lv, Jun Lu. *Electrocoagulation processes: A general review about role of electro-generated flocs in pollutant removal*. Pages 169-189.

Electrocoagulation (EC) is an acclaimed environmentally adequate approach to wastewater treatment. It is simple and economical by way of reducing the amount of chemical dosage, sludge generation and disposal, and the high costs involved in traditional chemical coagulation (CC). This paper discusses the mechanisms of pollutant removal by electro-generated hydroxide and oxyhydroxide flocs during EC process. The flocs' generation and formation with Fe, Al and other metal electrodes, and the influence of operating conditions (pH, current density, electrolyte composition, etc.) on floc structure are reviewed. Further, revisions were provided on recent studies about new areas in electro-generated (oxy)hydroxide flocs such as layered double hydroxides (LDHs) and green rusts (GR), common characterization techniques, and factors promoting EC floc production. Results clearly indicate that during EC, the most proposed removal mechanisms of (oxy)hydroxide flocs towards oxyanions, cationic heavy metals, and organic pollutants are adsorption and coprecipitation, charge neutralization and surface complexation, and direct/indirect radical oxidation respectively. EC process alone which has low radical generation is less efficient when treating organic pollutants. Consequently, coupling and combination of AOP-EC generates suitable amounts of radicals and flocs for organic pollutant removal.

- **Keywords:** Electrocoagulation; Surface hydroxyl; Hydroxide flocs; Adsorption; Electrochemical wastewater treatment

Minakshi Gohain, Maskura Hasin, Khalifa S.H. Eldiehy, Pritam Bardhan, Khairujjaman Laskar, Hridoyjit Phukon, Manabendra Mandal, Dipul Kalita, Dhanapati Deka. *Bio-ethanol production: A route to sustainability of fuels using bio-based heterogeneous catalyst derived from waste*. Pages 190-200.

Microalgae have been accepted as a potential feedstock for biofuel production due to their high oil content and rapid biomass production. In this study, deoiled Scenedesmus obliquus (SO) was used for evaluating whether deoiled algal biomass residue is potential as an alternative energy resource for bio-ethanol production with different heterogeneous catalysts. The SO biomass was examined for its physiochemical properties and also evaluated using FTIR, XRD, and TGA techniques. The successful hydrolysis of SO was performed employing different eco-friendly bio-based heterogeneous catalysts and hydrolysate thus obtained was then subjected to fermentation using Saccharomyces cerevisiaeand was analyzed through HPLC and GC which resulted in the production of bio-ethanol with the highest yield of 68.32 % at 8.24 g/L concentration.

- **Keywords:** Biomass; Scenedesmus obliquus; Heterogeneous catalysts; Saccharomyces cerevisiae; Bio-ethanol

Xiaotong Liu, Su He, Zhenan Han, Chunfei Wu. *Investigation of spherical alumina supported catalyst for carbon nanotubes production from waste polyethylene*. Pages 201-207.

Thermo-chemical conversion of plastics provides an economic flexible and environmentally friendly method to recycle waste plastics, and generates valuable materials, such as carbon nanotubes (CNTs) and syngas. The development of catalysts is a key challenge for improving the quantity and quality of CNTs. In this study, spherical catalysts loaded with Ni were studied to control CNTs growth using waste plastic as the feedstock. Three parameters were studied, including catalytic temperature, Ni content and plastics/catalysts ratio. A fixed two-stage reactor was used for thermal pyrolysis of

plastic waste and the materials were characterized with various methods including scanning electronic microscopy (SEM), temperature programme oxidation (TPO) and X-ray diffraction (XRD). The results showed that different contents of Ni loaded on sphere results in the formation of metal particles with various sizes, thus leading to CNTs production with different quantity and quality. In addition, an optimal catalytic temperature at 800 °C is suggested for CNTs formation with the Ni/sphere catalyst, as the catalyst might not be activated at 600 °C and 700 °C.

- **Keywords:** Plastics waste; Carbon nanotubessphere; Nickel; Catalyst

S. Bentancur, C.M. López-Vázquez, H.A. García, M. Duarte, D. Travers, D. Brdjanovic. *Modelling of a pulp mill wastewater treatment plant for improving its performance on phosphorus removal*. Pages 208-219.

The performance of a pulp mill wastewater treatment plant (WWTP) was assessed using the software BioWin aiming at providing alternatives for reducing even further the phosphorus (P) concentration in the treated effluent. The WWTP was designed without nutrient removal capacities, since pulp and paper wastewater is usually deficient in nutrients. However, the hard wood (Eucalyptus) which is processed in such plant has a higher P content compared to other types of woods, and part of that P ended up in the raw wastewater to be treated. The wastewater was characterized following the Dutch STOWA protocol. Once the model was calibrated, historical data from different periods of time was used to validate the model. The model was capable of describing the current plant operation, as well as its historical performance. Moreover, the model was used to evaluate different potential upgrading scenarios for the treatment plant aiming at increasing the plant performance on P removal. According to the model, the implementation of an anaerobic phase prior to the aerobic process showed to be a feasible scenario contributing to decrease the total phosphorus (TP) concentration in the treated effluent by approximately 58 %. In addition, applying chemical precipitation can further decrease the TP concentration below 0.1 mg/L. However, further research activities such as pilot-testing may be needed to validate the previous recommendations of applying enhance biological and chemical P removal at such pulp mill wastewater treatment plant.

- **Keywords:** Activated sludge; Modelling; Pulp mill; Wastewater; Phosphorus removal

Adewale Giwa, Ahmed Yusuf, Hammed Abiodun Balogun, Nonni Soraya Sambudi, Muhammad Roil Bilad, Idowu Adeyemi, Sudip Chakraborty, Stefano Curcio. *Recent advances in advanced oxidation processes for removal of contaminants from water: A comprehensive review*. Pages 220-256.

Water reuse for drinking, irrigation, district cooling, process heating/cooling, landscaping, etc. remains pivotal to water security and sustainability. Advanced oxidation processes (AOPs) are at the heart of the industrial wastewater treatment especially for the removal of contaminants of emerging concern. Recent studies conducted to advance AOP technologies for the degradation of industrial wastewater pollutants generally encompass seven areas, namely artificial neural networks (ANNs), sustainability, plasma activation, catalyst structures, AOP-Bioremediation, and membrane-based AOPs. This review presents the advancements in AOPs for oxidation and removal of a wide range of contaminants of emerging concern from water. Detailed discussions and a critical examination of recently published works are presented in this article. Many of the reports have recorded technical progress in the form of: improved energy efficiency through the use of low-energy and renewable energy sources, successful prediction of process performance and process control, improved light capturing capabilities through plasmonic

effect, successful integration with biological treatment methods and membrane filtration. In spite of this progress, a number of challenges still persist such as lack of appropriate ANN modeling structures, impractical spatial and temporal scales of investigation (i.e. scales that are too low for real operations), and membrane fouling in membrane-based AOPs. These challenges and the strategies for addressing them are discussed in this article.

- **Keywords:** Contaminants of emerging concern; Industrial wastewater; Advanced oxidation processes; Artificial neural networks; Sustainability; Integrated processes

Serdar Doğruel, Atalay Altun, Emine Ubay Çokgör, Güçlü Insel, Bülent Keskinler, Derin Orhon. *Anatomy of the organic carbon in an industrial wastewater: Implications of particle size distribution, respirometry and process modelling*. Pages 257-266.

This study evaluated the fate of chemical oxygen demand (COD) fractions of an organized industrial district effluent treated with pilot membrane bioreactor (MBR) system. A series of respirometric analyses were performed on raw wastewater together with 450 nm, 100 kDa and 1 kDa filtered samples obtained from particle size distribution (PSD) experiments. The PSD analysis revealed that more than 300 mg/L of the influent COD accumulated in the lowest size range (<2 nm), accounting for 49–52 % of the total COD. The bulk (64 %) of the influent COD consisted of soluble hydrolysable COD (SH1). The hydrolysis rates for SH1 (0.80–1.28 1/day) were slightly below the levels suggested for domestic wastewaters, indicating the presence of inhibitory compounds in industrial wastewaters. The COD removal efficiency of MBR pilot was found as 85 %; however, 43 % of effluent COD (106 mg/L) still included rapidly hydrolysable organics in the size bracket of 5–30 nm. In this respect, the COD fractions for activated sludge process models used for MBR applications require a new-insight to correctly reflect organic matter balances in the treatment system.

- **Keywords:** COD fractionation; Hydrolysable COD; Membrane bioreactor; Organized industrial district; Particle size distribution; Textile wastewater

Xiaohui Fan, Yuanjie Zhao, Zhiyun Ji, Haorui Li, Min Gan, Haoyu Zhou, Xuling Chen, Xiaoxian Huang. *New understanding about the relationship between surface ignition and low-carbon iron ore sintering performance*. Pages 267-275.

Surface ignition is the first and also the important step for iron ore sintering, which provides the initial source of energy to trigger the whole reactions. This investigation mainly focused on revealing the relationship between surface ignition and sintering performance, and elucidated the deep mechanism. Results indicate that the quality of sinter in the surface layer can be effectively improved by adjusting the ignition parameters. The preferred ignition parameters include ignition temperature of 1050 °C, ignition duration of 1 min and heat preservation of 1−2 min. The function mechanism of improved sinter quality is attributed to the increased high temperature duration for minerals melting, the enlarged melting zone, and the decreased cooling velocity. These changes facilitate the formation of enough adhesive phase of calcium ferrite, more of which generated in acicular morphology with high mechanical strength. Optimizing the ignition process reduced the solid fuel consumption due to the improved sintering performance, which then decreased the emission of NO and SO2. The research findings are of great significance for providing a guide for the design of desirable ignition system and making further contributions to energy conservation and emission reduction during sintering.

- **Keywords:** Iron ore sintering; Surface ignition; Energy preservation; Emission reduction

Mohamed E. Zayed, Jun Zhao, Ammar H. Elsheikh, Zhennan Zhao, Shengyuan Zhong, A.E. Kabeel. *Comprehensive parametric analysis, design and performance assessment of a solar dish/Stirling system*. Pages 276-291.

The development of solar dish/Stirling system as a promising green power generation technology, has received great attention from researches and governments. Nevertheless, the characterization and commercialization of SDS technologies need a deep understanding of the effect of different opt-geometrical and operational parameters on their performance. In this study, the modeling of a Solar Dish/Stirling System (SDSS) is presented to determine its power generation and overall efficiency. The opt-geometric sizing and thermal analysis of the SDSS have been mathematically modeled. Different parameters such as the concentrator diameter, the receiver temperature, the direct solar radiation, the wind speed, and the ambient temperature have been parametrically analyzed to determine their effect on the output power and total efficiency of the SDSS. Then, a commercial SDSS was designed based on the obtained parametric results and the thermal behavior of the system has been evaluated under meteorological conditions of Tianjin, China. Results showed that SDSS with concentrator diameters of (10–17.5 m) can produce great electrical capacities of (18.6–58.1 kW) with insignificant variation in the overall efficiency (23.7–24.25 %) compared to the SDSS with diameters of (2.5–8.5 m) that generates small capacities of (0.735–11.7 kW) with a remarkable variation of the overall efficiency (17.1–23.4 %) since the variation of the heat losses in the receiver are minimal for the SDSS with concentrator diameter larger than 10 m. Moreover, the results showed that the proposed SDSS could produce a power output of 23.11 kW with an efficiency of 23.05 %, under conditions of Tianjin during the summer solstice. Future investigations should be done on maximizing the optical and thermal performance of dish/Stirling components, accomplished by optimizing the industrialization process of concentrator segments and receiver, which considers an essential challenge for further SDSS development.

- **Keywords:** Solar dish; Stirling engine; Parametric analysis; Opt-geometric sizing; Performance assessment

Huaiwei Zhang, Liang Bao, Yifan Chen, Weidong Xuan, Yongjun Yuan. *Efficiency improvements of the CO-H2 mixed gas utilization related to the molten copper slag reducing modification*. Pages 292-299.

Molten reduction to release the value metals are the necessary step in the copper slag recovery process. How to effectively choose and utilize the reducing agents has an extremely important significance. In the research, molten reductions with the CO-H2-Ar mixed gases are investigated. De-oxidation amounts and de-oxidation rates maintain stability first and then decrease with the increase of CO/H2 ratios. They are all much higher than those of pure CO or H2 due to the water-gas shift reaction. The magnetite phase decreased gradually with the decrease of CO/H2 ratios, and some pure ferrous phase can generate in the slag as the ratios are less than 1:1. Otherwise, the apparent rate constants, the reaction orders and the activation energies for the various CO/H2 ratios are also measured. The results illustrate that the reaction process will vary with the variety of mixed gas compositions.

- **Keywords:** Smelting reduction; Molten modification; Waste recovery; Hydrogen energy

Thalyne de Almeida Ferreira Rocha, Maria do Carmo Ferreira, José Teixeira Freire. *Processing spent coffee ground powders for renewable energy generation: Mechanical dewatering and thermal drying*. Pages 300-311.

Mechanical dewatering and thermal techniques were evaluated as pre-treatment steps to reduce the water content of spent coffee ground (SCG) powders to thermal conversion. An exploratory evaluation of the fluid dynamic patterns in fluidization of wet SCG powders showed that stable fluidized regimes were achieved with powders of moisture levels under 50 %. Mechanical dewatering was effective to reduce the powder moisture content to 45 %. Adding vibration enhanced the powder feed rate in the drying bed, even for powders with moisture levels that lead to negligible cohesiveness. Using a dimensionless vibration number Γ = 4 with different vibration amplitudes (A = 0.015 and 0.003 m) resulted in different dynamic behaviors and influenced the solids feeding rate but did not affect the mean Sauter diameter of the elutriated powder. Thermal drying at Γ = 4 and A = 0.015 m allowed a steady and continuous operating regime for powder production. Under these vibration parameters, the optimum condition concerning moisture content (22 % w.b.) and mean particle size (0.37 mm) was predicted to occur at 70 °C, and U/Umf = 6. The dry powder was thermally characterized and confirmed the feasibility of using this residue in pyrolysis and combustion processes. The parameters of the reaction kinetic model and the apparent specific heat were obtained.

- **Keywords:** Energy generation; Vibrofluidized bed; Fluidization; Powder compression; Drying kinetic curves

Qishuai Yin, Jin Yang, Mayank Tyagi, Xu Zhou, Xinxin Hou, Bohan Cao. *Field data analysis and risk assessment of gas kick during industrial deepwater drilling process based on supervised learning algorithm*. Pages 312-328.

During industrial offshore deep-water drilling process, gas kick event occurs frequently due to extremely narrow Mud Weight (MW) window (minimum 0.01sg) and negligible safety margins for the well control purposes. Further, traditional gas kick detection methods in such environments have significant time-lag and can often lead to severe well control issues, and occasionally to well blowouts or borehole abandonment. In this study, firstly, the raw field data is processed through data collection, data cleaning, feature scaling, outlier detection, data labeling and dataset splitting. Additionally, a novel data labeling criterion for gas kick risks is proposed where five kick risks (Indicated by different colors in this study) are defined based on three key indicators: differential flow out (DFO), kick gain volume (Vol), and kick duration time (Time). Kick risk status represents one of the following cases: Case 0 - No indicators are activated (Green), Case 1 - Multi-drilling parameters deviation or DFO is activated (Orange), Case 2 - DFO and Vol are simultaneously activated (Light Red), Case 3 - DFO and Time are simultaneously activated (Light Red), Case 4 - DFO, Vol and Time alarms are simultaneously activated (Dark Red). Then, a novel data mining method using Long Short-Term Memory (LSTM) Recurrent Neural Network (RNN) is presented for early detection of gas kick events by analyzing time series data from field drilling process. The network parameters such as number of hidden layers and number of neurons are initialized to build the LSTM network. The learned LSTM model is evaluated using the testing set, and the best LSTM model (six (6)-layers eighty (80)-nodes (6 L*80 N)) is optimally selected and deployed. The accuracy of deployed LSTM model is 87 % in the testing dataset, which is reliable enough to identify the kick fault during the deep-water drilling field operation. Lastly, the LSTM model detected the gas kick events earlier than the "Tank Volume" detection method in several representative case studies to conclude that the application of LSTM model can potentially improve well control safety in the deep-water wells with narrow MW windows.

- **Keywords:** Industrial deep-water drilling; Gas kick; Field data analysis; Risk assessment; Early gas; Kick detection; Supervised learning

Mostafa Managheb, Soheil Zarghami, Toraj Mohammadi, Amir Atabak Asadi, Soleyman Sahebi. *Enhanced dynamic Cu(II) ion removal using hot-pressed chitosan / poly (vinyl alcohol) electrospun nanofibrous affinity membrane (ENAM)*. Pages 329-337.

Different Multilayer electrospun nanofibrous membranes were synthesized to study the effects of potentially important steps and parameters including hot-pressing and chitosan / poly (vinyl alcohol) (CTS/PVA) solutions on the membranes performance in Cu(II) ions removal. Due to the importance of continuous adsorption process, in this research, dynamic removal from synthetic wastewater of Cu(II) ions was discussed. Five ENAMs were prepared using different chitosan / poly (vinyl alcohol) (CTS/PVA) solutions. A bead free, smooth ENAM with uniform interconnected porous structure was obtained using 3 % wt./vol CTS solution with CTS/PVA weight ratio of 50/50. The average fiber diameter, porosity and average pore diameter of the as synthesized ENAM were 99.1 nm, 50.6 %, and 0.189 μm, respectively. Multilayer ENAMs were prepared with steady state pure water fluxes of 237–706 LMH/bar as well as time dependent rejections up to 98.6 %. Considering the slight (3 %) reduction of multilayer ENAMs rejection, as well as their high (80 %) flux recovery ratio (FRR) after two regeneration cycles, it can be concluded that the membranes are definitely reusable.

- **Keywords:** Chitosan / poly (vinyl alcohol) composite; Electrospun affinity fibrous membranes; Removal of Cu(II) ions; Environmental protection

Qi-yu Zhang, Lai-sheng Liu, Zeng-jin Liu. *Application of safety and reliability analysis in wastewater reclamation system*. Pages 338-349.

With the development of the world water resources situation, the reuse of wastewater will be one of the essential measures for solving water resources' problems and implementing practical and sustainable use of water resources. Wastewater reclamation risks have received considerable attention in all worlds, but research in this area is minimal, and a unified understanding and evaluation method has not yet been formed. Therefore, based on the system theory process analysis (STPA) method and hazard analysis and critical control point (HACCP) theory, this paper expounds on the concept of the safety and reliability of the wastewater reclamation system. Through the application of analysis methods, this paper proposes a verification method for the safety of the wastewater reclamation system and a reliability evaluation system for the wastewater reclamation system. Besides, the next research direction is further to improve the analysis model and evaluation index system to provide technical support for the construction of a safe, reliable, and economical wastewater recovery system.

- **Keywords:** Wastewater reclamation system; Safety; Reliability; STAMP; HACCP; Formal verification

Zijian Li, Peihong Zhang. *Fire behaviors of fuels with different sootiness levels in hot and humid conditions*. Pages 350-359.

The behaviors of fires fueled by materials that produce different levels of soot (diesel and alcohol) were studied under hot and humid conditions with natural ventilation. Experimental tests were performed under different initial ambient temperatures (20 °C and 30 °C) and relative humidity levels (50 % and 90 %), and flame temperature, thermal radiation and mass loss rate were measured. A theoretical flame radiation model was established and verified. The fire development index (FDI) was defined as the ratio of the peak flame temperature, Tp, to the duration, tp, during initial fire development

stage, and the fire severity index (FSI) was defined as the product of the flame thermal radiation, Rav, and the duration, td, during fully developed stage. The results validated the reasonableness of the established theoretical model. During initial fire development stage, increasing the initial ambient temperature increased the FDI, while increasing the relative humidity decreased it. During fully developed stage, increasing the initial ambient temperature or humidity resulted in a decrease in the FSI under limited-fuel conditions, and the ambient temperature more significantly affected the pool fires fueled by alcohol than those that consumed diesel. Additionally, under conditions of high temperature and high humidity, both the indices were reduced.

- **Keywords:** Fire behavior; Thermal radiation; Ambient temperature; Relative humidity; Sootiness

Zhenmin Luo, He Liang, Tao Wang, Fangming Cheng, Bin Su, Litao Liu, Bo Liu. *Evaluating the effect of multiple flammable gases on the flammability limit of CH4: Experimental study and theoretical calculation*. Pages 369-376.

As the main component of natural gas and an important chemical raw material, methane easily forms a mixture of flammable gases during production and processing. Therefore, understanding the flammability limit and limiting oxygen concentration of methane is very important in predicting the possibility of fire and explosion in industrial production and designing the corresponding monitoring parameters. To solve this problem, the effects of the addition of a C2H6/C2H4/CO/H2 mixture on the flammability limit of methane and the limiting oxygen concentration under N2 dilution were systematically studied. In addition, the flammability limit was evaluated using the limiting burning velocity theory and detailed reaction kinetic model, and a sensitivity analysis was conducted to study the chemical kinetics near the limit. The experimental results show that when the volume fraction of mixed gas gradually increases, the upper and lower flammability limit of methane both decrease, and the decrease in the lower flammability limit is larger than that of the upper flammability limit. Under the condition of nitrogen dilution, the limiting oxygen concentration gradually decreases with an increase in mixed gas concentration. The explosion triangle expands and moves to the lower-left corner, the flammability limit range increases, and a greater danger of explosion exists. The calculated results based on the limit laminar burning velocity are in good agreement with the experimental data. The sensitivity analysis shows that elementary reactions involving the active free radicals of OH, H and O have higher sensitivity. With the addition of mixed gas, the chain-branching reaction R31 is promoted, the chain termination reactions R12 and R41 are inhibited, the competition between the chain-branching reaction and chain termination reaction changes, and the flammability limit range of methane expands.

- **Keywords:** Flammability limit; Explosion risk: limiting oxygen concentration; Chemical kinetics

Ligong Wang, Hongyan Zhang, Zhuangqiang Dai, Yi Liu, Chang Chen, Guangqing Liu. *Effect of nicotine inhibition on anaerobic digestion and the co-digestion performance of tobacco stalks with different animal manures*. Pages 377-382.

The disposal of large quantities of tobacco stalks and animal manures generated annually is among the serious challenges faced in China, especially the former, as its toxic composition (nicotine) can induce the risk of healthy impairment during tradition treatment process. Anaerobic digestion (AD) may be an efficient technique for tobacco stalks. Nevertheless, the impact of nicotine in tobacco stalks upon AD is still unclear so far. Thus, a simulated AD experiment using glucose with different nicotine concentrations was implemented, suggesting a nicotine concentration of more than 4% (w/w) could

inhibit AD. The nicotine component in tobacco stalks would not be an inhibitor on AD because its content was far below 4%. Meanwhile, in order to efficiently treat abundant tobacco stalks and manure wastes at the same time, untreated and alkaline hydrogen peroxide (AHP)-pretreated tobacco stalks were co-digested with three typical manures, including pig manure (PM), chicken manure (CM), and dairy manure (DM), to investigate their digestion performance. Co-digestion of pretreated tobacco stalks and PM at 1:4 ratio exhibited the highest methane production of 397.2 mL/g VS and had a synergistic effect. This study provides valuable guidance for simultaneously converting these two wastes in future AD applications.

- **Keywords:** Tobacco stalks; Nicotine; Anaerobic digestion; Co-digestion; Methane yield

P. Francis Prashanth, Burada Shravani, R. Vinu, Lavanya M., V. Ramesh Prabu. *Production of diesel range hydrocarbons from crude oil sludge via microwave-assisted pyrolysis and catalytic upgradation*. Pages 383-395.

Crude oil sludge is one of the key waste streams of the refinery, and it contains valuable hydrocarbons that can be potentially converted to fuels and petrochemicals. This study is unique in evaluating the effects of activated carbon susceptor (ACS) and catalysts to selectively recover hydrocarbons from crude sludge via microwave-assisted pyrolysis (MAP). Two different sludge samples received from the refinery, viz., sludge from storage tank bottoms (sludge 1) and mixed sludge (sludge 2), were characterized. Sludge 1 was rich in volatile matter and hydrocarbons, while sludge 2 contained a significant amount of ash, nitrogen, sulfur and iron. At 600 W microwave power with 10 % ACS loading, maximum oil yield of 87.3 wt.% was obtained from sludge 1, while it was 41.2 wt.% from sludge 2. An increase in yield of gaseous products with a concomitant decrease in oil yield was observed when the sample heating rates were increased by using high microwave power or high loading of ACS. MAP of crude sludge at 600 W with 10 % ACS produced char and oil with higher heating values (HHV) of 26 and 42.4 MJ kg−1, respectively. For the first time, ex situ catalytic upgradation with H-ZSM-5 and regenerated fluid catalytic cracking (FCC) catalyst was employed to produce refinery blendstocks from crude sludge through MAP. Catalytic upgradation resulted in significant deoxygenation of pyrolysates with low oxygen content (<5%), and high carbon (80−85 wt.%) and hydrogen (12−14 wt.%) content in the oil fraction. The HHV of the upgraded oil was 44−45 MJ kg−1. Importantly, the selectivity to hydrocarbons in the diesel range (C8 to C20) increased by more than 10 % in the oil fraction containing paraffins, iso-paraffins, and aromatic hydrocarbons. This study proves that a liquid fuel, resembling refinery blendstock, can be generated from crude oil sludge by adopting this process.

- **Keywords:** Crude oil sludge; Activated carbon; Susceptor; Microwave pyrolysis; Catalytic upgradation; H-ZSM-5; Hydrocarbons

Chuangang Fan, Rongwei Bu, Xiaoqing Xie, Yang Zhou. *Full-scale experimental study on water mist fire suppression in a railway tunnel rescue station: Temperature distribution characteristics*. Pages 396-411.

Rescue stations are essential for emergency evacuation in super-long railway tunnels. However, the deficiency of related studies aiming at improving the fire suppression performance of water mist system in fire scenarios limits its application significantly. In this work, 20 sets of full-scale water mist fire suppression experiments were conducted to examine the impacts of water mist system on smoke temperature characteristics, including water mist activation time (denoted by t), working pressure (P), k-factor (K) and longitudinal wind speed. Results show that when t = 3 min, P = 12 MPa, and K = 0.5, the best performance of temperature control could be achieved. Although there are violent temperature fluctuations in the train side, the smoke temperature could be easily restrained. Moreover, it is found that longitudinal ventilation is helpful to improve the

visibility at platform and reduce smoke temperature. When P = 12 MPa, the coupling effect of water mist and longitudinal ventilation on cooling smoke is better. In addition, the non-dimensional maximum temperature rise is found to show a great cubical dependency on vertical height, and decreases along with a larger longitudinal distance for all cases. Also, under longitudinal ventilation, the non-dimensional maximum temperature rises are lower than that without longitudinal ventilation in the coverage area of water mist. Results of this work can provide a significant reference for the design of water mist system in railway tunnel rescue stations.

- **Keywords:** Rescue station; Longitudinal ventilation; Water mist parameter; Temperature distribution

Bin Wang, Yan Huang, Wei Liu, Shu Chen, Jingping Zhu, Nelson Belzile, Yu-Wei Chen, Mengqin Liu, Chang Liu. *Returning excrement from livestock, poultry, and humans to farmland as nutrient resources for crop growth: Assessment of rural China*. Pages 412-423.

Traditionally, farmers in China have relied on excrement to supplement organic matter in soils, and to fertilize crops for human and animal consumption. Few studies have quantitatively analyzed the potential of returning livestock-poultry and human excrement in rural China to farmland as nutrient resources for crop growth. This study clarifies the temporal and spatial changes, distribution characteristics, nutrient contents, and econometric analysis of excrement in rural China from 1980 to 2019. Meanwhile, its potential as a nutrient resource for crop growth to substitute the utilization of chemical fertilizers was also assessed. Excrement production showed a large increase (138.49 %) in Northeast China, whereas the Northern, Northwest, Southwest and Southeast regions of China and the middle and lower reaches of the Yangtze River experienced an increase of 51.75, 33.63, 30.47, 24.24 and 24.10 %, respectively. The spatial distribution of both the rural excrement and its nutrients was concentrated in Southwest and Northern China and lower reaches of the Yangtze River, as the nutrients in these areas accounted for 69.67–86.76 % of the total. In this study, new evidence and more comprehensive fundamental data are provided for waste treatment and resource recycling in agriculture. Promoting the return of excrement to farmland has the potential to reduce the use of chemical fertilizers, lessen the emission of odorous gas, and remedy environmental stress, thereby assisting to the development of organic agriculture. Recommendations of sustainable development are made for the future development of returning excrement to farmland in this study. The introduction of practical policies on renewable resources is recommended to ensure the comprehensive utilization of excrement.

- **Keywords:** Distribution characteristics; Potential; Excrement; Nutrient resources; Rural China

Antonio David Moreno, José Antonio Magdalena, José Miguel Oliva, Silvia Greses, Caterina Coll Lozano, Marcos Latorre-Sánchez, María José Negro, Ana Susmozas, Raquel Iglesias, Mercedes Llamas, Elia Tomás-Pejó, Cristina González-Fernández. *Sequential bioethanol and methane production from municipal solid waste: An integrated biorefinery strategy towards cost-effectiveness*. Pages 424-431.

The organic fraction of municipal waste (OFMW), source-sorted (SS-OFMW) and non-sorted (NS-OFMW), was used as raw material for the sequential production of bioethanol and biogas. Non-isothermal and simultaneous saccharification and fermentation (NSSF) resulted in maximum ethanol concentrations of 51 g/L and 26 g/L for SS-OFMW and NS-OFMW samples, showing overall process yields of up to 80 % and 59 %, respectively, even without subjecting substrate to hydrothermal pretreatment. Subsequently, the solid residues resulting from the fermentation were further subjected to anaerobic digestion

(AD), showing a methanogenic potential of 384 ± 6 mL CH4/g of volatile solids (VSin) and 322 ± 3 mL CH4/g VSin, respectively. These methane yields were similar or even higher to those obtained when using non-fermented OFMW substrates (SS-OFMW: 380 ± 18 mL CH4/g VSin and NS-OFMW: 239 ± 4 mL CH4/g VSin), highlighting NSSF as a beneficial step to enhance methane yields during AD. Overall, bioconversion of OFMW would benefit from coupling bioethanol and biogas production since the biogas produced might be further employed as bioenergy source to compensate operational costs.

- **Keywords:** Anaerobic digestion; Bioethanol; Fermentation; Methane; Organic fraction of municipal waste

Guoyun Shi, Weichao Yu, Kun Wang, Fuhua Dang, Jing Gong, Yanan Lu. *Time-dependent economic risk analysis of the natural gas transmission pipeline system*. Pages 432-440.

A methodology to quantify the economic risk of a natural gas transmission pipeline system is developed in this study, and the effect of the line pack is considered. The methodology is based on the risk theory and hydraulic analysis of the transmission pipeline system. In the methodology, the failure probability of the key components in the transmission pipeline system are estimated firstly. Moreover, the transient compressible model for the pipeline system is employed to perform the consequence analysis, and the model is solved by the Semi-Implicit Method for Pressure-Linked Equation (SIMPLE) algorithm in the process of the consequence analysis. By combining the failure probability estimation with the consequence analysis, the economic risk when an accident happens can be evaluated. A detailed procedure for economic risk evaluation of a natural gas transmission pipeline system is presented, and its feasibility is confirmed with a real transmission pipeline system. Furthermore, impacts of the line pack on the economic risk are investigated, and suggestions to decrease the economy risk are proposed.

- **Keywords:** Economic risk; Line pack; Failure probability; Gas pipeline; Compressible fluid; SIMPLE algorithm

Zhaoyou Zhu, Huaqing Qi, Yuanyuan Shen, Xiaomin Qiu, Hongru Zhang, Jianguang Qi, Jingwei Yang, Lei Wang, Yinglong Wang, Yixin Ma, Jun Gao. *Energy-saving investigation of organic material recovery from wastewater via thermal coupling extractive distillation combined with heat pump based on thermoeconomic and environmental analysis*. Pages 441-450.

Cyclohexane and sec-butyl alcohol are widely used in the pharmaceutical and chemical industries. The separation of cyclohexane/sec-butyl alcohol/water azeotropic mixture is of great significance for mitigating environmental risk, recycling solvents, and maintaining developmental sustainability. Based on the COSMO-SAC model, the infinite dilution activity coefficients of the components were calculated, and the final solvent was further obtained by relative volatility and solvent power screening. Taking the total annual cost as the objective function, the extractive distillation process is optimized based on a sequential iterative optimization algorithm. To further reduce the process energy consumption, several energy-saving processes were explored. Energy-saving processes are compared in terms of total annual cost, CO2 emissions, and thermodynamic efficiency. It was found that the total annual cost and thermodynamic efficiency of the processes show an increasing trend, while CO2 emissions show a decreasing trend. The results of stage-exergy indicate that the processes with heat pump are relatively small. The heat pump combined with the thermal coupling extractive distillation process exhibits better thermoeconomic and environmental performance. It provides theoretical guidance for improving the separation and recovery of value organics and energy-saving

optimization of processes, which conforms to the theme of sustainable and environmental development.

- **Keywords:** Composite energy-saving process design; Organics recovery; Stage-Exergy efficiency; Environmental performance; Thermoeconomic analysis

Mohsen M.M. Ali, Zhigang Li, Hongtao Zhao, Abdullah Rawashdeh, Mohamadou Al Hassan, Mohammed Ado. *Characterization of the health and environmental radiological effects of TENORM and radiation hazard indicators in petroleum waste –Yemen*. Pages 451-463.

The technologically enhanced naturally occurring radioactive materials (TENORM), i.e., 40K, 232Th, and 226Ra in waste petroleum scale, sludge, and produced water in Ma'rib Refinery - Yemen - were measured using spectroscopy with HPGe detector. To determining the radiation hazard of TENORMs in waste petroleum, The radium equivalent activity (Raeq), gamma-ray index (Iγ), external radiation hazard index (Hex), internal radiation hazard index (Hin), absorbed dose rate (ADR), annual effective dose (AED), annual gonadal dose equivalent (AGDE), alpha index (Iα) excess lifetime cancer risk (ELCR), and activity utilization index (AUI) are calculated to determine the radiation hazard of TENORMs in waste petroleum. The radiological data were analyzed using multivariable statistical methods to determine the discrepancies and similarities between the various samples. Frequency distributions have been studied for all radionuclides. There were fourteen variables measured in the data studied. The results of the Pearson correlation coefficient showed a positive correlation between all concentrations of TENORMs and all radiation hazard indicators. Factor analysis results in a two-component representation of the data obtained from waste petroleum samples. The dendrogram resulting from the Hierarchical Cluster Analysis divided the twenty-eight waste petroleum samples into three main groups using fourteen variables.

- **Keywords:** Gamma-ray spectrometry; Scale; Sludge; Produced water; Natural radioactivity; Radiation hazards; Oil and gas industry; Health impact; Environmental impact

Mohammad Javad Bardi, Mohammad Amin Oliaee. *Impacts of different operational temperatures and organic loads in anaerobic co-digestion of food waste and sewage sludge on the fate of SARS-CoV-2*. Pages 464-472.

The impacts of different operational temperatures, and organic load (OL) on the fate of SARS-CoV-2 during the anaerobic co-digestion of food waste (FW) and sewage sludge (SS) was evaluated. The lab-scaled batch reactors (i.e. R1-R7) were performed under psychrophilic, mesophilic, and thermophilic conditions and the OL of systems was 1.5, 3.5, 6 gVS/L. The performance parameters showed that at higher OL the stability of systems failed and low biogas was produced. In contrast, increasing of operational temperature of systems induced more biogas generation due to the increment of metabolic activity of bacteria. Therefore, R1-R7 achieved biogas yield of 202.5, 249, 187, 260, 246, 163, and 300 mL/gVS respectively. Both SARS-CoV-2 genes i.e. ORF1ab, and N genes were detected in the effluent of psychrophilic reactors i.e. R1, and R2, with a total concentration of 46 × 103, and 11 × 103 copies/L respectively. In R3, no viral genes were observed, when the VFAs was accumulated up to 2000 mg/L and caused a pH drop to 5.6. At the mesophilic condition, the viral concentration was significantly declined, and no viral genes were observed at an OL of 3.5 gVS/L. Furthermore, the synergistic effect of temperature and accumulation of intermediate metabolites provided a sever condition for SARS-CoV-2 survival at an operational temperature and OL of 50 °C, and 1.5 gVS/L respectively.

- **Keywords:** Coronavirus; SARS-CoV-2; Anaerobic digestion; Operational temperatures and organic load effect; Food waste and sewage sludge

Lei Deng, Fei Tang, Xin Ma. *Experimental study on flame merging probability and pulsation frequency of annular hydrocarbon pool fires with various inner and outer diameters*. Pages 473-480.

Hydrocarbon pool fires can cause serious fire accidents. This study focused on the flame-merging behavior and pulsation frequency of annular hydrocarbon pool fires with various inner and outer diameters. Experiments were performed with annular pool fires having outer diameters (D) in the range of 0.15–0.55 m and inner diameters (d) in the range of 0.05–0.45 m. The fuel used was n-heptane. The flame-merging probability and pulsation frequency of annular pool fires with various inner and outer diameters were examined. With the development of the pool fire, the initially produced "annular flame" finally merged. According to the dimensional analysis, a fitted correlation of the piece function with different heat-release rates and annular-pool sizes was proposed for describing the flame merging and pulsation frequency, and the proposed correlation in this work is suitable for no wind conditions.

- **Keywords:** Annular pool fire; Flame merging; Mass loss rate; Pulsation frequency

Jun Qiu, Daishe Wu, Da-Ren Chen, Jianlong Li. *Reverse pulsed-flow cleaning of pleated filter cartridges having an inner pleated filter cone*. Pages 481-489.

Different from conventional pleated filter cartridges, which apply pleated filter media as the cartridge sidewall, seal one end as the base and open the other end as the entrance for cleaning flow, ones with inner pleated filter cones, called as cone pleated filter cartridges, have been recently proposed to increase the filtration area and to improve the efficiency of the reverse pulsed-flow cleaning. This work investigated the cleaning performance of cone pleated filter cartridges via the numerical modeling. Our modeling shows that, for a cone pleated filter cartridge cleaned by a reverse pulsed-flow, a high- and low- pressure zones were developed in the inside spaces close to the open and sealed ends of filter cartridges, respectively, and the variation of static pressure was observed in the radial cross section of filter cartridges was negligible. For cone pleated filter cartridges with a low cone height HC (i.e., < 660 mm, the cartridge height), a negative pressure zone was found in the inside region near the open end of cartridges. Two events of pressure waves were experienced during the cleaning of cone pleated filter cartridges. Between both wave events, the first one was significantly affected by HC. As the HC was increased, the overall cleaning intensity developed inside the cartridges was topped for filters with HC = 760 mm and then decreased. In addition, the cleaning uniformity of cone pleated filter cartridges was generally improved compared to to that for ones without pleated filter cones.

- **Keywords:** Pleated filter cartridges; Inner filter cones; Reverse pulsed-flow cleaning; Pressure evolution; Dust collector

Liang Sun, Han Jiang, Yuxuan Zhao, Xiaoyan Deng, Shen Ke, Yan Li, Minge Tian. *Implementation of fluidized-bed Fenton as tertiary treatment of nitro-aromatic industrial wastewater*. Pages 490-498.

In this study, the fluidized-bed Fenton (FBF) process was evaluated as a tertiary treatment of the second effluent from a nitro-aromatic industrial wastewater treatment plant. The soluble iron removal performances of four carriers, including quartz sand, construction sand, activated carbon, and zeolite, were examined. For the carriers, the results showed that a large surface area was available for the iron removal due to the

heterogeneous nucleation, while a smooth surface contained less mesoporous seemed favorable for the consecutive iron removal because of the brittle iron oxide thickness and wash off effect. The essential variables for analysis include the initial pH and the molar ratio of [Fe2+]/[H2O2]. The results showed that the COD and SUVA254 removal efficiencies, including the utilization ratio of H2O2 on COD removal, had little difference with the increase of initial pH, suggesting that the adaptive pH range of FBF can extend from 2.5 to 7.4. However, high pH caused iron removal via homogeneous nucleation not by heterogeneous nucleation, resulting in the reduction. Under the sufficient H2O2 addition, the removal performances improved when the molar ratio of [Fe2+]/[H2O2] increased to 0.625, but a high iron addition led to a negative effect on iron removal due to the resolvable phenomenon by excess H2O2. An actual engineering project illustrated that FBF progress was a useful and cost-effective method for tertiary treatment.

- **Keywords:** Fluidized-bed Fenton; Tertiary treatment; Nitro-aromatic industrial wastewater; Iron removal

Shuai Yuan, Chenxi Ji, Haitian Han, Yue Sun, Chad V. Mashuga. *A review of aerosol flammability and explosion related incidents, standards, studies, and risk analysis*. Pages 499-514.

In the process industries, the flammable and explosive hazards of aerosols receive less attention and have less understanding as compared to gases and dust clouds. Numerous incidents in various industries have revealed the distinct differences between the hazards of a bulk liquid compared to those of aerosols. Flash point, the criterion for liquid flammability becomes insignificant when the liquid is present in aerosol form. A practical discussion of the criteria for aerosol flammability hazard assessment is needed. Unlike standard measurements for gas and dust clouds, an aerosol flammability standard test method, such as ASTM D3065−01, has not been widely adopted owing to the lack of quantification. Therefore, it is important to establish quantitative aerosol flammability and aerosol explosion testing procedures. This paper comprehensively reviews the methodologies to generate aerosols, both lab and large-scale aerosol combustion and explosion experiments, and liquid flammability risk assessments. Additionally, this paper reviews important but sparsely studied areas such as aerosol deflagration to detonation transition (DDT) and proposes a systematic strategy to investigate the complicated mechanism and consequences of aerosol combustion and explosions.

- **Keywords:** Aerosol review; Flammability; Aerosol explosion; Aerosol generation; Aerosol risk analysis

Guobao Zhang, Biao Sun, Shuzheng Song, Hao Wang, Gang Zhou. *CFD comparative analysis on the pollution characteristics of coal dust under turbulent airflow from coal cutting in the fully mechanized mining face*. Pages 515-530.

In order to investigate the effects of turbulent airflow from coal cutting (TACC) on the pollution characteristics of coal dust, the pollution behaviors of coal dust under the action of system ventilation airflow (SVA) only (Condition 1) and the addition of TACC disturbance (Condition 2) were respectively simulated and verified through a comparison with the field measurement data. The results show that the effects of TACC on the pollution characteristics of coal dust cannot be ignored on the operation site. TACC could not only enhance the turbulent intensity in the flow field, but also induce the positive deviation of airflow. The airflow with a velocity of about 1.0~1.75 m/s in the footway space moved from the region X=0.3~36.8 m, Y=4.1~4.5 m under Condition 1 to the region X=-5.1~26.5 m, Y=3.8~4.5 m under Condition 2. After the addition of TACC disturbance, the absolute value of positively-deviated airflow velocity component in the operational range of rear drum driver rose from 0~0.8 m/s to 0.2~1.8 m/s. Meanwhile,

the flow field under Condition 2 could effectively cause lateral dispersion of coal dust to the footway space, which led to an increase in the lateral dispersion scale of coal dust. Under Condition 2, the region polluted by cutting-induced coal dust moved forward by 11.3 m along the negative direction of X-axis, and the peak coal dust concentration along the footway space was approximately doubled.

- **Keywords:** Coal dust; Turbulent airflow from coal cutting; System ventilation airflow; Migration and pollution characteristics; Fully mechanized mining face; Numerical simulation

Bing Mei, Yahong Qin, Mohammad Taghavi. *Thermodynamic performance of a new hybrid system based on concentrating solar system, molten carbonate fuel cell and organic Rankine cycle with CO2 capturing analysis*. Pages 531-551.

This paper presents the performance analysis of the process consisting of the molten carbonate fuel cell (MCFC), parabolic dish collector (PDC), linear Fresnel reflector (LFR), Organic Rankine Cycle (ORC) and the gas turbine, with the carbon dioxide separation process. In proposed novel process, the MCFC waste heat is used to generate additional electricity in the ORC. In addition, a gas turbine embedded in the process also generates electricity. This hybrid system also uses two concentrating solar collectors, i.e. LFR and PDC. The former raises the water temperature b7efore mixing with fuel and the latter raises the temperature of the mixture (water and fuel) before entering the reformer. Furthermore, in present study the performance of parabolic trough collector is investigated, assuming it provides the required duty of evaporator of ORC. Finally, the present study examines the process of carbon dioxide separation. The results revealed that, overall, electrical and exergy efficiency of the hybrid cycle is 58.02 %, 44.2 % and 74.9 %, respectively. Furthermore, the total exergy destruction rate and removal efficiency of the system are 13.67 MW and 78.9 %, respectively. In addition, about 35 collectors of LFR and 55 collectors of PDC are needed to supply the required duty of solar thermal collectors.

- **Keywords:** Molten carbonate fuel cell; Parabolic dish collector; Linear fresnel reflector; Organic rankine cycle; Hybrid system; Performance analysis

Cuiwei Liu, Yihan Liao, Jie Liang, Zhaoxue Cui, Yuxing Li. *Quantifying methane release and dispersion estimations for buried natural gas pipeline leakages*. Pages 552-563.

The methane into the soil from buried natural gas pipelines due to small leakages, changes the soil properties, posing potential risks to humans and the environment. It is essential to estimate the leakage rate and monitor the methane diffusion range outside the pipeline, which is challengeable due to the presence of soil. The main contribution of this work is to bridge the gap between estimating the leakage rate of underground pipelines and predicting the diffusion behaviors through calculating the gas concentration in the soil. The quantified leakage rate estimation model for air was firstly established by experimental results and validated by the numerical results, which was further modified by the methane with the numerical simulations. The methane diffusion model in the soil was then performed, through which, the influencing factors were explained and validated. In addition, the methane release and dispersion results in the soil could be used as the boundary conditions of gas diffusion model in the air. The results show that the quantifying estimation correlations can predict the leakage rate and dispersion range in the soil accurately, with errors less than 7.2 % and 15 %, respectively. Moreover, the quantified relations have been validated by the full-field experiments. And, the dispersion behaviors in the air could be portrayed instead of being regarded as a jet flow.

- **Keywords:** Natural gas pipelines; Quantifying estimation; Leakage rate; Diffusion range; Soil

Steffi Talwar, Anoop Kumar Verma, Vikas Kumar Sangal. *Synergistic degradation employing photocatalysis and photo-Fenton process of real industrial pharmaceutical effluent utilizing the Iron-Titanium dioxide composite*. Pages 564-576.

The present work focuses on the treatment of real industrial pharmaceutical effluent, utilizing novel composite beads made up of waste foundry sand (FS) and fuller's earth (FE), both being good source of iron. These composite beads serves as a surface for the coating of TiO2 along withfacilitating the iron leaching, thus leading to the in-situ dual effect of photocatalysis and photo-Fenton. Optimization of various parameters like a number of beads, treatment time, the dosage of H2O2 using batch and the continuous re-circulation mode reactor has been studied in the sunlight. For the batch scale study, the treatment time of 3.65 h, the number of beads as 98 (98 % surface area covered), and H2O2 dose as 800 mg L−1 were came out to be optimized conditions with maximum % COD reduction. The dual effect was effective in eliminating the complex compounds present in the effluent as confirmed through GC–MS analysis along with the significant reduction in (COD) (71 %) for batch reactor. The treatment time for the real wastewater was reduced by 60−70 min as compared to the exclusive processes of photo-Fenton and TiO2 photocatalysis. In the continuous recirculation mode, 75 % reduction in COD was obtained in 5 h. Further, the bacterial assays proved the disposability of the treated wastewater as per the government regulations. Cost analysis of the overall treatment was also evaluated of the prototype for the complete revelation of the dual process for commercial-scale applications and it was found to be <0.1$ L-1. The composite was successfully recycled for more than 150 cycles without loss in activity of catalyst. The intactness of dual activity during recycles was confirmed through various characterization techniques like XRD, SEM-EDS, FTIR and UV-DRS.

- **Keywords:** Real pharmaceutical wastewater; In-situ dual effect; Durability; Synergistic effect; Composite beads

Lixin Qian, Yifan Wang, Mingliang Liu, Yulin Hu, Tiejun Chun, Qingmin Meng, Hongming Long, Ya Wang. *Performance evaluation of urea injection on the emission reduction of dioxins and furans in a commercial municipal solid waste incinerator*. Pages 577-585.

Polychlorinated dibenzo-p-furans and dioxins (PCDD/Fs) that pose a great threat to human health are commonly found during the incineration of municipal solid waste. In this study, industrial urea was injected into a commercial MSW incinerator flue gas to evaluate the suppression performances of PCDD/Fs, and the possible inhibition mechanisms were proposed. The results show that the use of urea dramatically reduced the PCDD/Fs emission concentration from 8.87 to 0.63ng/Nm3, along with a significant decrease in the I-TEQ value (0.26 → 0.047ng I-TEQ/Nm3), below the Chinese national standard of 0.1ng I-TEQ/Nm3. The emission reduction cost of the industrial urea was over 41 % lower than that of using activated carbon. Urea molecule poisoned the metal ions, thus seriously inhibiting the de novo synthesis of PCDD/Fs. Furthermore, the decomposition products of urea reduced the concentration of HCl in the flue gas, thereby reducing the formation of Cl2 and hindering the chlorination reaction, which was identified from the reduction of chlorination degree and lower distribution of high-chlorinated PCDD/Fs. This research provided some practice basis and experience to reduce the emission of PCDD/Fs from municipal solid waste incineration for future commercial promotion and application.

- **Keywords:** Urea; PCDD/Fs; Municipal solid waste; Inhibitor; Emission reduction

Ishaka Muhammad, George Manos. *Intensification of co-pyrolysis of plastic with biomass via pretreatment*. Pages 586-598.

Biomass pyrolysis performance is improved through co-pyrolysis with hydrogen rich plastic producing more liquid fuel products of higher quality. Furthermore, beyond the synergetic effect, in catalytic pyrolysis the presence of plastic may facilitate the contact between catalyst and biomass. In this study, the effect of pretreatment of plastic/biomass was investigated, in order to further improve the above aims. The first pretreatment method was pre-degradation treatment at relatively low temperatures where solid state reactions alter the structure of plastic/biomass but no volatile products are formed. In addition, a second pretreatment method was used for the catalytic pyrolysis of cellulose, namely co-pressing of cellulose and catalyst particles into mixed pellets. Thermogravimetric results confirmed that pre-degradation treatment reduced the decomposition temperature of cellulose. Pre-degradation diminished the hindering effect of the cellulose-derived char/ catalyst-coke demonstrating significant interaction between cellulose and lldPE (linear low density polyethylene) before the charring/coking stage of cellulose. While in the absence of catalyst, there is a minimal interaction between lldPE and cellulose, as the molten lldPE layers around cellulose particles inhibited the escape of the biomass-derived volatile products, the use of catalyst along with pre-degradation provided maximum interaction between lldPE and cellulose pyrolysates which proceeded at lower reaction temperature without any hindrance from char/coke formation. Furthermore, pre-degradation treatment increased the liquid yield with associated increase in char/coke yield. The presence of lldPE during the cellulose pyrolysis decreased the concentration of char/coke on the catalyst while higher amounts of hard coke/char had accumulated on the pre-treated samples. Liquid product characterisation indicated that co-pressing of cellulose with catalyst is more effective in converting cellulose-derived products into aromatics. The results suggest that pre-treatment processes have increased the synergy between lldPE and cellulose, thereby enhancing the quantity and quality of the desired liquid product.

- **Keywords:** Pre-treatment process; Co-pyrolysis; Liquid characterisation; Coke characterisation

Dan Wang, Ping Huang, Xinming Qian, Ziqian Wu, Qi Jing. *Study on the natural gas diffusion behavior in sewage pipeline by a new outdoor full-scale water cycling experimental pipeline system*. Pages 599-609.

To initiate the experimental study of natural gas diffusion in sewage pipeline and evaluate the sewage pipeline risk, a new outdoor full-scale water cycling experimental pipeline system was built. The concentration distributions and characteristic time were measured in a comprehensive monitoring system. As the rate of the gas leakage flow decreases, the alarm time increases significantly. It is found that the influence of water flow direction on methane gas diffusion is different under varying gas flow rates. Furthermore, the methane diffusion rate in sewage pipeline is also a function of water flow rate and water level height. Based on the experimental results, the corresponding suggestions for prevention and control of gas leakage accidents in sewage pipelines were put forward to improve the urban public security management system and the security capacity of urban public security.

- **Keywords:** Natural gas; Sewage pipeline; Diffusion behavior; Concentration monitoring; Alarm time

Long Ding, Faisal Khan, Xiaoxue Guo, Jie Ji. *A novel approach to reduce fire-induced domino effect risk by leveraging loading/unloading demands in chemical industrial parks*. Pages 610-619.

Due to complexities and uncertainties, risk management of domino effects in chemical plants in operation is challenging. A global optimal risk management scheme can hardly be obtained, therefore, finding a targeted local optimal risk management scheme can be prudent. In the present study, a novel risk management approach is proposed to reduce fire-induced domino effect risk by leveraging loading/unloading demands based on risk aggregation and inventory management. The proposed approach uses the aggregation of three risk indicators as part of the risk management strategy. The first risk indicator is the loss of containment (LOC) risk of chemical installations, which indicates how likely a storage tank may cause a primary fire accident. The second risk indicator is the secondary fire accident inducing ability of chemical installations, which indicates how likely a primary tank may cause secondary fire accidents only. The third risk indicator is the inter-unit closeness degree of chemical installations, which indicates how severe the overall consequence a primary tank may cause. Combining the aggregate risk with the inventory availability of storage tanks, candidate risk management schemes are proposed based on inventory management on chemical loading/unloading demands. The optimal risk management scheme is determined based on the potential losses of fire-induced domino effects. A case study demonstrates the effectiveness of the proposed methodology and risk management strategy for fire-induced domino effects.

- **Keywords:** Risk management; Risk indicators; Loading/unloading demands; Multi-objective decision-making; Candidate scheme planning criteria

Bruno de Oliveira Freitas, Luan de Souza Leite, Luiz Antonio Daniel. *Chlorine and peracetic acid in decentralized wastewater treatment: Disinfection, oxidation and odor control*. Pages 620-628.

Decentralized wastewater treatment is a viable and sustainable alternative to having universal access to sanitation, especially for developing countries and small communities. Chlorine and peracetic acid (PAA) have been studied widely to promote wastewater disinfection, however there are few comparative studies applied to decentralized wastewater treatments. This paper investigated the application of chlorine and PAA in two biological reactor effluents regarding disinfection, organic matter oxidation, and odor control. Full factorial design was used to quantify the effect of the Chlorine and PAA dose (5, 10, and 15 mg L−1) and contact time (5, 10, and 15 min) in the batch experiments. Chlorine and PAA were inefficient in reducing the organic matter showing an increment in the chemical oxygen demand (COD) concentration in most of the tests. Sulfide was oxidized by chlorine (0.0–39.9 %) and PAA (3.5–73.5 %) for both reactor effluents. Inactivation results from E. coli and total coliform by chlorine and PAA showed that the effluent quality has a stronger influence than the disinfectant type. The best operational condition (15 mg L−1, 15 min) were also tested in the continuous mode flow, whose results are in agreement with those found in the batch tests. These results provide valuable support in terms of establishing practical guidelines for chlorine and PAA applications in decentralized wastewater treatment in Brazil.

- **Keywords:** Chlorine; Peracetic acid; Sulfide removal; Biological reactor

Katherine Hyde. *Turbidity measurement: Its application for water resource recycling in buildings*. Pages 629-638.

Supplying treated greywater within buildings delivers continuous additional resilience and improvements in water efficiency. This includes the making available (by substitution) of greywater resources suitable for non-potable purposes such as flushing toilets. Thereby, the overall daily consumption of pristine potable water for flushing and other lower quality uses is reduced. The empirical measurement of turbidity was confirmed as an accurate and resilient indicator of greywater quality, greywater treatment process efficiency and of well-functioning greywater reuse systems in the short-, medium- and long-term. The methodology applies turbidity monitoring for evidential management and

control of treated greywater quality, essential for greywater recycling in the building stock. The results demonstrated evidence of co-variation between turbidity and biochemical oxygen demand in a lightly-loaded greywater treatment process. Real-time monitoring of turbidity delivers responsive, reliable, in-situ and remote measurements for informing building management systems (BMS), comprising an essential part of routine monitoring of greywater treatment plant. The analytical evidence confirms the importance of turbidity measurement and control in both current and future UK and international greywater standards. By undertaking turbidity measurements in compliance with BS 8525−2:2011, greater assurance in the use and compliance of greywater supplies in the built environment is achieved. Consequently, the rationale for including the empirical measurement of turbidity to demonstrate satisfactory management of the greywater quality, treatment system operation, monitoring and compliance in buildings has been confirmed.

- **Keywords:** Process performance and turbidity measurement; Turbidity monitoring and building management systems (BMS); Quality criteria in treated

Boxian Chen, Suping Yu, Xuan Zhao. *The separation of radionuclides and silicon from boron-containing radioactive wastewater with modified reverse osmosis membranes*. Pages 639-646.

The ability to reuse boron and minimize the volume of radioactive waste could be accomplished with modified reverse osmosis (RO) membranes. RO membranes were fabricated via polyethylenimine (PEI) grafting to separate silicon and radionuclides from boron-containing radioactive wastewater. The positively charged RO membrane promoted more efficient removal of nuclides and silicon while the rejection of boron declined from 55.88 % to 41.71 % after modification. Compared with virgin RO membrane, the SFB-Si, SFB-Cs, and SFB-Co of the modified RO membranes increased from 6.02, 5.16, and 12.62–29.52, 61.91, and 547.15, respectively. SFB-Si, SFB-Cs, and SFB-Co of the simulated RO system with modified RO membranes further increased to 156.96, 1068.12, and 83617.88, respectively. As a result, permeate water with 433.92mgL−1 boron, 0.04mgL−1 silicon, 1.62μg·L−1 Cs(I), and 0.02μg·L−1 Co(II) was obtained, which could satisfy radionuclide treatment requirements and allow for the reuse of boron. Overall, modified RO membranes would be able to reuse boron and minimize the volume of discharge of radioactive wastewater.

- **Keywords:** Wastewater treatment; Radioactive wastewater; Reverse osmosis; Modification; Boron

Rongxing Bian, Jihong Chen, Weihua Li, Yingjie Sun, Xiaoli Chai, Huawei Wang, Yanan Wang, Jianwei Zhao. *Numerical modeling of methane oxidation and emission from landfill cover soil coupling water-heat-gas transfer: Effects of meteorological factors*. Pages 647-655.

CH4 emissions from landfills present temporal and spatial variation due to the changing meteorological conditions. The combined effect of meteorological parameter on CH4 transport, oxidation and emission are not fully understood. In this study a water-heat-gas transfer model embedding a meteorological module and CH4 oxidation was built to elucidate the CH4 transport, oxidation and emissions in landfill cover soils. A series of parametric studies are carried out to investigate the influence of barometric pressure, air temperature and rainfall on CH4 transport, oxidation and emissions in landfill cover soil. Finally, a real-time climatic condition was conducted to predict the daily CH4 oxidation and emissions from different climatic zones. The simulated results indicated that a low atmospheric pressure would convert the dominant gas transport mechanism from diffusion to advection and therefore result in a lower CH4 oxidation efficiency. In a landfill, the cover soil would also have a higher CH4 oxidation capacity because of the

heat conduction from the waste layer under cold conditions. A significant decrease of CH4 emission flux was observed during the rainfall. After rainfall event, the CH4 emission flux was significantly positively correlated with rain intensity. This study proved that building a real-time landfill CH4 emission model considering varying climatic conditions is necessary to improve the accuracy of model predicting.

- **Keywords:** Methane oxidation; Landfill cover soil; Meteorological factors; Gas advection; Water-heat-gas transfer

Argyris Panagopoulos. *Techno-economic assessment of minimal liquid discharge (MLD) treatment systems for saline wastewater (brine) management and treatment*. Pages 656-669.

The management and treatment of brine (saline wastewater) are of great importance, as its discharge to the environment poses a significant threat. A new strategy called minimal liquid discharge (MLD) appears to be a promising and more cost-effective option than zero liquid discharge (ZLD) as it uses only membrane-based technologies, leading to up to 95 % freshwater recovery. This research study introduces and presents for the first time a techno-economic assessment of five MLD treatment schemes that can be implemented in the brine treatment. The technologies included are reverse osmosis (RO), high-pressure RO, forward osmosis (FO), osmotically assisted RO (OARO), and membrane distillation (MD). Results showed that the MLD schemes costs ranged from US$0.79/m3 to US$1.36/m3, while the freshwater recovery ranged from 78 % to 89 %. In schemes 2 and 5, the implementation of MD substantially increased the energy consumption (>20 kW h/m3), however, these schemes were more economical (<US$1/m3) than the other 3 schemes. If the produced freshwater is sold, then the profit from the MLD treatment can reach up to US$2.21/m3. Furthermore, the costs of MLD schemes are at the same level as the subsurface water supplies, so MLD schemes can be valuable in countries relying on subsurface water sources.

- **Keywords:** Minimal liquid discharge (MLD); Zero liquid discharge (ZLD); Brine management; High-Salinity wastewater treatment; Industrial wastewater treatment; Techno-economic analysis

Junyuan Guo, Qifan Gao, Shuqing Yang, Fei Zheng, Bingxue Du, Shilin Wen, Dayin Wang. *Degradation of pyrene in contaminated water and soil by Fe2+-activated persulfate oxidation: Performance, kinetics, and background electrolytes (Cl-, HCO3- and humic acid) effects.* Pages 686-693.

SO4−-based oxidation technologies have been considered as key solution in polycyclic aromatic hydrocarbons (PAHs) degradation. This study constructed Fe2+-activated persulfate oxidation to degrade pyrene in water and soil by using batch and column experiments. Pyrene degradation kinetic in polluted water and effects of soil background electrolytes (Cl−, HCO3− and humic acid) on pyrene degradation were both investigated. The variation of soil properties during pyrene degradation in soil was evaluated. Polluted water remediation results showed that approximately 93.2 % of pyrene was degraded by 65 mM of persulfate with Fe2+/persulfate molar ratio of 0.25. In soil, 88.5 % of pyrene was degraded under the same persulfate concentration and Fe2+/persulfate molar ratio, and there was a slight decrease of soil pH (from 6.7 to 5.4). Cl−, HCO3− and humic acid in soil brought an adverse effect to pyrene degradation through scavenging SO4−. Column study of soil remediation proved the superiority of Fe2+ in activating persulfate, whose application in soil remediation can finally reduce soil pollution and simultaneously avoid the excessive soil acidification in in-situ remediation. In addition, by evaluating the soil organic matter and total organic carbon during the remediation process, it was found

that the soil properties have been improved. Therefore, Fe2+-activated persulfate oxidation would be a feasible way to remediate pyrene polluted water/soil.

- **Keywords:** Soil; Water; Pyrene; Fe2+; Persulfate oxidation; Soil properties

Xiao-xuan Wei, Chun-chen Nie, Yue-xian Yu, Jun-xiang Wang, Xian-jun Lyu, Peng Wu, Xiang-nan Zhu. *Environment-friendly recycling of resin in waste printed circuit boards*. Pages 694-701.

Waste printed circuit boards (WPCBs) are considered as an attractive secondary resource and potential environmental pollutant due to the coexistence of valuable components and hazardous substances. The pre-concentration and utilization of resins in non-metallic components are concerned in this study. Mechanical grinding and physical separation were used for the dissociation and recovery of resin. Grinding results show that the R-R model can accurately describe the size composition of grinding products. The dissociation degree of resins increases with the grinding fineness, and the release rate of organics reach 78.79 % with 5 min grinding. Utilizing the natural floatability of dissociated organics, resin can be recovered effectively, which is mainly due to the increase of yield rather than the increase of grade. The resin grade can be enhanced by the difference of its density with that of glass fiber, and the resin content can reach 83.39 % with the sorting density of 1.6 g/cm3. Based on the pyrolysis characteristics of organics determined by TGA, the organics concentrate is utilized by pyrolysis in the form of pyrolysis oil with main components of phenols. This study provides a sustainable and environmentally friendly technology for the reuse of low-value but environmentally threatening non-metallic components in WPCBs.

- **Keywords:** WPCBs; Resin; Flotation; Heavy liquid separation; Thermal decomposition

Mohamed Elhelw, Adel El-Shobaky, Abdelhamid Attia, Wael M. El-Maghlany. *Advanced dynamic modeling study of fire and smoke of crude oil storage tanks*. Pages 670-685.

The combustion properties of large-scale crude oil pool fire have great significance for security design and firefighting of current crude oil reserves. Burning rate, flame shape and radiation intensity are the most important parameters for fire properties. The novelty of this study is that the Fire Dynamics Simulator (FDS) is adopted to simulate pool fires in a tank farm. It does not only investigate and analyze heat radiation flux, but also the temperature difference rise and flame/smoke temperature contours behavior. This simulation is performed in order to predict the potentials of a large crude oil storage tank fire outbreak and the smoke temperature distribution that counters in and around the tank. These data are used in designing tank farms and applying the firefighting strategy. A super CPU with large RAM is used to operate the simulation program, to simulate one of the largest crude oil farms in the world. The model will be investigated for identifying the worst-case scenarios that might occur in a large crude oil tank. One of these scenarios might be fire outbreak in rim seal in one of the four storage tanks, where the fire is transferred to full surface fire. The model predicts the potential of tank fire outbreak, smoke tracing and both smoke/flame temperature that spreads at wind speed of 3 m/s, 9 m/s, 18 m/s in south-west direction. FDS model provides qualitative data that increase the level of safety, such as the minimum safe separation distances and the location of firefighters during the firefighting process. It also determines the most critical area, which is needed for water-cooling system. This study also tackles the duration after which human beings feel pain after being exposed to heat radiation.

- **Keywords:** Crude oil tank fire; Large-scale CFD model; Numerical simulation; Flame shape; Thermal radiation intensity

Ishaka Muhammad, George Manos. *Simultaneous pretreatment and catalytic conversion of polyolefins into hydrocarbon fuels over acidic zeolite catalysts*. Pages 702-717.

The effect of pre-degradation treatment in catalytic pyrolysis of polymer was assessed using thermogravimetric analysis (TGA) and pyrolysis reactor experiments of different polymers on various catalysts. Intimate contact between the polymer and catalyst was achieved using physical, mechanical and thermal treatments. The results from the TGA analysis show that pre-degradation treatment has greatly improved the performance of the catalyst attaining maximum degradation at lower temperature. Pre-degradation treatment had increased the liquid yield and lowered the coke yield at various extents depending on the catalyst structure and acidity. The ZSM-5 catalyst with high Si/Al ratio showed maximum amount of (C5–C9) and ZSM-5 with lower Si/Al ratio has maximum percentage of (C14–C20). Based on the performance of the pre-degradation treatment methods, normal mixing produced the maximum amount of lighter fractions and therefore pre-degradation treatment can serve to enhance the gasoline fraction while the diesel fraction can be optimised using the co-pressing method, where polymer and catalyst particles were thoroughly mixed and co-pressed together into mixed particles. Coke characterisation showed coke formed by linear low density polyethylene contained more volatile coke components while polypropylene coke had higher percentage of hard coke. ZSM-5 had lower retention of coke components with volatile coke precursors. The volatility of the coke increases while coke concentration and decreases as the catalyst amount decreases. Pre-degradation treatment facilitated the formation of soft coke components that are easy to remove in inert atmosphere.

- **Keywords:** Pre-degradation treatment; Polyolefins; Zeolite catalysts; Liquid characterisation; Coke characterisation

Xing Zhong, Rong Li, Zehong Wang, Yanping Wang, Wei Wang, Dan Yu. *Highly flexible, transparent film prepared by upcycle of wasted jute fabrics with functional properties*. Pages 718-725.

and provide a prospect to waste management. In this work, a multiple recyclable transparent functional film was fabricated through ionic liquid (IL) assisted regeneration process with a higher yield of 90.40 %, compared with other polymer regeneration process using IL. Fourier Transfer Infrared Spectroscopy (FTIR), X-ray diffraction (XRD), UV–vis Spectrophotometer, as well as tensile strength test were carried out to explore the performance of the regenerated jute film. This transparent renewable jute film can be made into many functional materials, like packaging materials, electrically conductive films or information storage devices. Furthermore, it can be dissolved in IL and regenerate new films for multiple cycles, which can still maintain a relatively high transparency and a considerable mechanical property. Compared to other fabric recycle process, the solvent and production both can be effectively recycled, which can be considered as a green and sustainable tool to manage waste fabrics.

- **Keywords:** Jute; Multiple recycle; Ionic liquid; Transparent conductive film; Information storage device

Fangli Ning, Zhanghong Cheng, Di Meng, Shuang Duan, Juan Wei. *Enhanced spectrum convolutional neural architecture: An intelligent leak detection method for gas pipeline*. Pages 726-735.

In this work, a novel convolutional neural architecture (SE-CNN), which combines spectrum enhancement (SE) and convolutional neural network (CNN), is proposed to detect the leak of gas pipeline. The SE has the effect of enhancing the leak signals and reducing background noise. CNN can automatically extract leak features and realize leak

diagnosis. The experimental results show that the SE-CNN can achieve an average accuracy of 94.3% for 6 categories and only requires 1.04s of detection time. In this experiment, the diameters of the main pipeline and the branch pipeline are 125mm and 25mm. Due to its excellent accuracy and efficiency, the proposed enhanced spectrum convolutional neural architecture paves the way for real-time leak detection in industrial environments, which can ensure the process safety of gas pipeline transportation. Under strong background noise, the average accuracy of the SE-CNN can reach 94.3%, which is 33%, 3.7% higher than that of SVM and CNN. In particular, the SE can be regarded as a data compression method, which can significantly reduce the original data size. The training time of the SE-CNN is 539s, reducing 90.6% compared with CNN.

- **Keywords:** Spectrum enhancement; Convolutional neural network; Leak detection

Yanjue Song, Suzhen Li. *Gas leak detection in galvanised steel pipe with internal flow noise using convolutional neural network*. Pages 736-744.

Galvanised Steel Pipe (GSP) is the most common gas pipeline in populated areas. Existing leak detection research aimed at welded steel pipe is not suitable for GSP system due to their differences in line pressure, connection method, and leak path. This paper presents a gas leak detection method for galvanised steel pipe based on acoustic emission. An experimental setup composed of eight segments is designed to quantitatively simulate gas leak in GSP network considering flow-induced noise. The experiments verify that internal flow noise demonstrates similarity to leak-induced signals and thus interferes with leak detection based on shallow machine learning approaches. Convolutional Neural Network (CNN) is therefore introduced to solve the problem. Different network architectures are investigated and evaluated. Two types of inputs are discussed, namely time-domain signal and time-frequency distribution. Leak detection result show that the proposed method is robust to internal flow noise. When leak rate is greater than 0.03 L/s, the best model achieves overall accuracy more than 93 % in both the test set and the cross-validation set. The model performances indicate that traditional frequency analysis is ineffective to improve the flow-noise robustness of the CNN-based leak detector.

- **Keywords:** Leak detection; Acoustic emission; Galvanised steel pipe; Convolutional neural network; Internal flow noise

Hadi Rostamzadeh, Towhid Gholizadeh, Sajjad Rostamzadeh, Shahram Vosoughi, Ali Asghar Farshad. *Role of ejector expander in optimal inherently safety design of cascade NH3/Propane/CO2 vapor compression refrigeration systems*. Pages 745-762.

Due to significant energy/exergy losses in expansion part of the cascade vapor compression cooling (C-VCC) systems in process engineering, the use of ejector expanders has been widely recommended. Although such an idea improves the energy and exergy performance indicators along with the unit cost of the process, safety aspect of the plant degrades considerably. In order to quantitatively investigate the role of ejector expander in safety of the C-VCC systems, quantitative risk assessment (QRA) along with 4E (energy, exergy, economic, and environment) analysis of the basic C-VCC (BC-VCC) system and ejector expander C-VCC (EEC-VCC) system are carried out and the results are compared with each other around the optimal and base points. In the base mode, the contribution of the expansion process to the overall risk of the BC-VCC system increases from 4.33 $/year to 50.56 $/year (for NH3) and from 116 $/year to 1393 $/year (for Propane) due to the employment of ejector expander instead of the expansion valve. Also, that means using NH3 instead of Propane in the EEC-VCC system substantially improves safety aspect of the whole unit. Although the maximum number of death is obtained due to release of Propane from the condenser of the system during the

Flash Fire accident, the compressor of the high-temperature circuit (HTC) highly contributes to the overall risk due to its high release frequency. The results of multi-objective optimization for the NH3/CO2–based BC-VCC system showed that the COP (coefficient of performance), exergy efficiency, total cost, and risk can be improved by 56.66 %, 24.6 %, 26.14 %, and 1.78 %, respectively. Considering Propane/CO2 as a refrigerant pair used in the BC-VCC system, the COP, exergy efficiency, total cost, and risk were improved by 59.47 %, 26.77 %, 19.94 %, and 16.22 %, respectively. As an important conclusion, although employing ejector expander in the NH3/CO2 or Propane/CO2 BC-VCC system improves thermodynamic and cost metrics, such consideration significantly degrades the risk of the plant.

- **Keywords:** Inherently safer design (ISD); Quantitative risk assessment (QRA); Ejector expander; Cascade vapor compression cooling (C-VCC) cycle; 4E analysis; Optimization

Yifan Wang, Wenchao Gao, Xuefeng Zhang, Hao Zhang, Wenju Liu, Yaoji Chen, Lingyu Shao, Zhicheng Wu, Haobo Dai, Chenghang Zheng, Xiang Gao. *Exploring the role of sulfuric acid aerosol in corona discharge through a honeycomb wet electrostatic precipitator*. Pages 763-769.

The high emission of SO3 or sulfuric acid aerosol became a new environmental issue and has attracted international concerns. The sulfuric acid aerosol could be removed through droplet charging and transportation in the electric field. However, the charged droplets also have a converse effect on the electrostatic field. In this study, a novel-designed current measurement system contained 171 probes was designed to automatically scan and record the current density distribution along the airflow direction. Results show that the average current density was reduced by 31.3 % when SO3 concentration was increased from 0 to 53.6 mg/m3, and the current density of the first electrode was only accounted for 11.3 % of the original current. A higher corona onset voltage was required to ionize the flue gas because of a reverse electric field formed by the charged droplets. The current density was also decreased with the flue gas velocity under the SO3 presence condition. When the flue gas velocity reached 4 m/s, the corona suppression was severe and the inflection point was no longer obvious. The region that the relative current density below 0.6 was comprised 70 %. The current density could be enhanced by increasing the spike length and decreasing the spike spacing. The larger the corona current of the discharge electrode, the less the effect of the particle space-charge. Meanwhile, some suggestions for relieving corona suppression by enhancing the corona discharge at the inlet and promoting the droplet growth were proposed.

- **Keywords:** Wet electrostatic precipitator; Corona discharge; Sulfuric acid aerosol; Corona suppression; Current density distribution

Kaiqiang Jin, Qingsong Wang, Qiangling Duan, Jiayan Chen, Jinhua Sun. *Effect of metal wire mesh on premixed H2/air flame quenching behaviors in a closed tube*. Pages 770-778.

For the purpose of solving the safety problems of fire and explosion which may occur during hydrogen pipeline transportations, this paper experimentally investigates premixed hydrogen-air flame quenching behaviors under action of metal wire mesh in a closed tube. High-speed schlieren photography system is employed to reveal flame quenching results. Pressure transducer is adopted to test pressure changes. View from schlieren images, it is found that the wire mesh significantly enhances wrinkles of inverted flame front in lean-fuel combustion case (Φ = 0.42), but weakens the flame inversion extent for Φ = 1.00, 1.59, and 2.38 conditions. In addition, the results indicate that the flame quenching performance is improved pretty as the volume of metal wire mesh (VM) increases. Besides, compared with lean-fuel combustion cases, the wire mesh

presents a more effective suppression effect on rich-fuel cases due to the coupling suppression effects on pressure waves and combustion process together. Moreover, it is found that the critical quenching speed increases linearly as VM increases, but the maximum critical quenching pressure is always kept at a constant value of approximately 0.115 MPa. The results may provide a significant reference for designing hydrogen flame arrestors to improve the safety of hydrogen pipeline transportations and engineering applications.

- **Keywords:** Premixed; Hydrogen; Metal wire mesh; Quenching behaviors

Lang Xing, Jia Wen, Caiya Yan, Qian Wang, Xiaohong Hu, Zhuangzhuang Xue. *Improving the microenvironment of Cd-contaminated river sediments through humic substances washing and zeolite immobilization*. Pages 779-788.

A combined remediation through washing using humic substances (HS) followed by fixation using zeolite was employed to remediate Cd-contaminated sediment. Cadmium speciation and a series of microbial endpoints were discussed to evaluate the effectiveness of remediation. The combined treatment slightly reduced soil pH and increased soil electrical conductivity and organic matter. The Cd removal efficiency ranged from 11.4 %–26.0 % by HS washing. Zeolite immobilization further increased the residual Cd by 9.0 %–16.4 %, compared with the corresponding HS washing alone. The acid-soluble Cd decreased from the original 1.266 to the lowest 0.466 mg kg−1, while the residual Cd increased from 1.397 to a maximum of 1.595 mg kg−1 in the combined treatments. The change of dehydrogenase was the most sensitive (the maximum increase was 220 times). The increased microbial biomass implied that sediment microenvironment was optimized. In vitro digestion results showed that Cd accessibility decreased by 3.9%–67.9%. Principal component analysis suggested that treatments related to the high-concentration HS washing, especially 2000 mg L−1 HS washing +100 g kg−1 zeolite stabilization, had the best biological performance and it is a feasible technique to restore microenvironment of Cd-contaminated sediments.

- **Keywords:** Sediment washing; Combined remediation; Enzyme activity; Microbial biomass; Cadmium bioavailability

Fazeleh Khazaie, Soheila Shokrollahzadeh, Yasamin Bide, Shabnam Sheshmani, Ashraf S. Shahvelayati. *Forward osmosis using highly water dispersible sodium alginate sulfate coated-Fe3O4 nanoparticles as innovative draw solution for water desalination*. Pages 789-799

The remarkable advancement of forward osmosis (FO) as a promising technology for water treatment encounter difficulties due to the synthesis and recovery of a suitable draw solution (DS). The easy recyclability of the draw solution and energy consumption are the critical issues in FO processes. In this work, we have introduced the magnetic core-hydrophilic shell nanoparticles as an efficient draw solute for FO processes. The surface of nanoparticles was modified with sodium alginate sulfate (SAS) as a biocompatible, low toxic and relatively low-cost hydrophilic material. In this regard, the dispersibility and stability of Fe3O4 nanoparticles in aqueous solution was enhanced. The average water flux of 0.06 g mL–1 Fe3O4@SiO2-SAS was determined as 12.8 and 8.5 L m–2 h–1 with a reverse solute flux of 1.48 and 0.23 g m–2 h–1 in PRO and FO modes, respectively. Concentrations of 0.05, 0.1 and 0.2 M NaCl have been used as feed solution to study the performance of the DS for desalination process. Moreover, the optimum DS was successfully used for treatment of a real wastewater. Eventually, the synthesized draw solution was recovered by a magnetic field and its reusability was tested. High stability and simple regeneration of DS decreases the cost of water production.

- **Keywords:** Fe3O4 magnetic nanoparticles; Sodium alginate; Sulfonation; Forward osmosis; Draw solution

Xiaoxiao Li, Kexi Liao, Guoxi He, Jianhua Zhao. *Influence of blunt-nose and conical fragment on domino accident probability in spherical-tank area*. Pages 800-810.

Considering wind-speed influence, a new acceleration model is established, and a trajectory equation is obtained. The impact-depth models of a cone and end-cover debris are also established based on the cavity expansion theory. Combined with the residual strength theory, a new spherical-tank failure-probability model is established, and the probability model of a domino accident caused by the debris is obtained. Additionally, the influence of different fragment shapes on the domino accident probability in spherical tanks is analysed, and minimum penetration rate of the spherical-tank failure caused by different fragment masses is calculated. Subsequently, using statistics, the correlation between failure-probability and distance between spherical tanks and shape parameters was determined. The results indicate that the debris shape significantly influences the impact-depth of the spherical-tank wall, and impact-depth of the conical-nose geometry is significantly greater than that of the blunt-nose geometry. Moreover, the minimum velocity of the conical-nose geometry penetrating the target is significantly less than that of the blunt-nose geometry. The shape change of the conical-nose geometry has almost no influence on the probability of the domino accident, whereas, that of the blunt-nose geometry significantly influences the domino accident probability.

- **Keywords:** Spherical-tank; Monte Carlo methods; Impact-depth; Domino accident; Failure-probability

Mostafa Pouyakian, Mohammad Javad Jafari, Fereydoon Laal, Farshad Nourai, Esmaeil Zarei. *A comprehensive approach to analyze the risk of floating roof storage tanks*. Pages 811-836.

In this study, a comprehensive approach based on the Fuzzy Bayesian Network (FBN) was presented to reduce completeness, modeling, and parameter uncertainties and to analyze the risk of hazardous material release in floating roof storage tanks accurately. In this method, managerial, organizational, human and process factors, were investigated using human and process HAZOP technique before the occurrence of accident scenarios. These factors were examined after the intended scenario in a sequential modeling approach based on SHIPP methodology as a barrier model. Moreover, according to the initial probabilities and interference of barriers, the relevant conditional probability tables (CPTs) were modified by utilizing l-NOR gates, and the accident scenario model was developed using the Bow-tie (BT) model. Triangular fuzzy numbers and expert opinion incorporated into the Bayesian network to deal with the uncertainty in the occurrence probability of basic events and safety barriers. The methanol storage tank was selected to present the applicability potential of the proposed model. The results showed that the validation of the position and conditional probabilities (CPs) of barriers in the BT structure will reduce the uncertainties, and the combination of FBN and lNOR gate is an appropriate way to evaluate the risk of tanks accurately.

- **Keywords:** Uncertainty; Fuzzy Bayesian network; Organizational and human factors; Storage tanks

K. Kumari, Prasanjit Dey, Chandan Kumar, Dewangshu Pandit, S.S. Mishra, Vikash Kisku, S.K. Chaulya, S.K. Ray, G.M. Prasad. *UMAP and LSTM based fire status and explosibility prediction for sealed-off area in underground coal mine*. Pages 837-852.

A uniform manifold approximation and projection (UMAP) and long short-term memory (LSTM) deep learning model have been proposed to forecast a sealed-off area's fire status in underground coal mines. It protects miners' life by providing early warning to the miners regarding the impending mine hazards. The proposed forecasting model graphically displays fire status in the form of Ellicott's extension graph. An experiment has been conducted to measure the proposed forecasting model's efficiency and two existing machine learning models, namely support vector regression (SVR) and auto-regressive integrated moving average (ARIMA) models. It has been found that gas concentration prediction of the proposed UMAP-LSTM model has the lowest root mean square error of 0.288, 0.006, 0.0995, 0.902, 0.238, 0.452, and 0.006 for O2, CO, CH4, CO2, H2, N2, and C2H4 gases respectively than the existing SVR and ARIMA models, which indicates higher efficiency of the proposed prediction model.

- **Keywords:** UMAP; LSTM; Sealed-off area; Underground coal mine; Explosibility prediction

Shuzheng Song, Gang Zhou, Jinjie Duan, Lichao Zhang, Danhong Gao, Biao Sun. *Numerical simulation investigation on optimal dust-exhausting airflow volume in fully mechanized caving face of high-gas coal mine*. Pages 853-866.

To obtain the optimal dust-exhausting airflow volume on the premise that the gas concentration in the fully mechanized caving face of high-gas coal mine can be fully diluted to the safe range, gas-respirable dust (RD) coupling dispersion under various inlet airflow volumes (Q) were simulated numerically. The results show that when Q≥2100 m3/min, the gas concentration in the mining face is fully diluted. RD is distributed in basically the same way under various airflow volumes. When Q is raised from 2100 m3/min to 2500 m3/min, the RD concentration falls continuously. However, Q continues to increase, RD concentrations no longer decrease significantly. when Q is promoted to 2700 m3/min, the phenomenon of dust reentrainment occurs. Therefore, 2500 m3/min can be regarded as the optimal dust-exhausting airflow volume. Field measurement and verification shows hat the average relative errors between the simulated results and measured results of airflow velocity, gas concentration and RD concentration are 5.8 %, 4.13 % and 5.18 % respectively, which means that the numerical simulation results boast high reliability.

- **Keywords:** High-gas coal mine; Fully mechanized caving face; Gas dilution; Respirable dust dispersion; Optimal dust-exhausting airflow volume

Xingyuan Li, Yongzhang Zhou, Jingru Zhang. *Status and associated human health risk of zinc accumulation in agricultural soils across China*. Pages 867-876.

Zinc (Zn) is not only an essential element for organisms, but it might also be an environmental pollutant. However, to date, there have not been any studies on Zn accumulation in Chinese agricultural soils at the national scale. In this study, soil Zn concentrations were obtained for soils from 277 sites with potential pollution (the "PP group") and 1186 normal agricultural sites in China through a comprehensive literature search. Compared with the reported Zn contents of soils of other countries and regions in the world, the average concentration of Zn in soils in China (86.14 mg·kg−1) is relatively high. The total inventory of Zn in China's agricultural soils was calculated to be 3.08 × 1010 tonnes. Zn contamination was serious in the PP group (e.g. 7076 mg·kg−1 in Yunnan province), and was primarily derived from anthropogenic activities including mining, smelting, and sewage irrigation. The accumulation of Zn in soils was influenced by different factors in different regions of China and varied with land-use pattern, with Zn concentrations in soils of different agriculture types decreasing in the following order:

orchard > paddy field > vegetable land > wheat land. Zn pollution and associated risks in soils of regions in the PP group were more severe than those in normal agricultural soils. The hazard index (HI) values (for the PP group) for different human population groups varied as follows: children (2.40) > adult females (1.39) > adult males (1.23). The highest HI value obtained of 26.77 pertained to children. Overall, this study provides a comprehensive assessment of Zn accumulation in agricultural soils, and the results provide valuable information for the management and risk prevention of Zn contamination in China's soils.

- **Keywords:** Zinc reserves; Influencing factors; Spatial distribution; Noncarcinogenic risks

Lu Feng, Alastair James Ward, Morten Ambye-Jensen, Henrik Bjarne Møller. *Pilot-scale anaerobic digestion of by-product liquid (brown juice) from grass protein extraction using an un-heated anaerobic filter*. Pages 886-892.

The present study investigated the feasibility of using pilot-scale anaerobic filter to treat by-product liquid (brown juice, BJ) from grass protein extraction in a green biorefinery, and produce biogas via anaerobic digestion without co-digestion substrate. Prior to feed into the un-heated anaerobic filter reactor, the BJ was warmed up to 55−60 °C in order to maintain the digestion temperature. The influence of retention time and feeding frequencies were tested in order to optimize the overall performance. The study demonstrated that anaerobic filter is feasible for converting BJ to biogas. The specific CH production reached 230 mL gCOD−1 d −1 while up to 80 % of influent COD was removed within a hydraulic retention time of 5.5 days. In addition, higher feeding frequencies enhanced the process stability as it narrowed the temperature variation and decreased the instant impact on buffer capacity.

- **Keywords:** Biogas; Feeding regime; Green biorefinery; Hydraulic retention time; Mesophilic

Y. Javid. *A bi-objective mathematical model to determine risk-based inspection programs*. Pages 893-904.

The present study aims to develop a bi-objective mathematical model to determine risk-based inspection programs for reducing the total costs as well as the risk arisen. The main objective of this paper is to determine the number and type of inspection techniques to be done in each time period. The NSGA II and MOPSO meta-heuristic algorithms both have been applied to solve the problem. To compare the results of these two algorithms and to select the most efficient algorithm, 7 indices in two categories are implemented. In the first category, the means of the first and second objective functions and in the second category, the indices of comparison of multi objective algorithms have been evaluated. The results of the comparisons of these indices using TOPSIS method show the high efficiency of MOPSO algorithm in solving the presented problem.

- **Keywords:** Risk based inspection programs; Cost reduction; Risk mitigation; Meta-heuristic algorithms

Pezhman Kazemi, Christophe Bengoa, Jean-Philippe Steyer, Jaume Giralt *Data-driven techniques for fault detection in anaerobic digestion process*. Pages 905-915.

Anaerobic digestion (AD) is an appropriate process for bio-energy (biogas) production from waste and wastewater receiving a high level of attention at both academic and industrial scale due to increasing public awareness regarding environmental protection

and energy security. Monitoring such processes is an imperative task to ensure optimized operation and prevent failures and serious consequences during the operation of the plant. To fulfill this task, a practical data-driven framework for fault detection in AD is proposed and validated on a simulated data set obtained using the benchmark simulation model No.2 (BSM2) from the International Water Association (IWA). The proposed framework is based on data-driven soft-sensors predicting total volatile fatty acids (VFA), mainly consisting of acetate, propionate, valerate and butyrate concentrations inside the digester. The VFA concentration is considered because it does not only reflect the current process health, but it is also sensitive to the incoming feeding imbalances. VFA soft-sensors using different advanced techniques such as support vector machine (SVM), extreme learning machine (ELM) and ensemble of neural network (ENN) are tested and compared in terms of accuracy and fault detection (FD) robustness. A principal component analysis (PCA) model was also developed to compare the proposed approaches with the traditional FD method. By applying soft-sensors, the residual signal, i.e., the difference between estimated and measured VFA values can be generated. This residual signal can then be used in combination with univariate statistical control charts to detect the faults. A comparison of the proposed FD framework with PCA method clearly demonstrates the over performance and feasibility of the proposed monitoring framework.

- **Keywords:** BSM2; Bootstrapping; Anaerobic digestion; Soft-sensor; Neural network; CUSUM chart

Jianfeng Zhou, Genserik Reniers. *Petri net simulation of multi-department emergency response to avert domino effects in chemical industry accidents*. Pages 916-926.

Emergency response plays an important role in preventing or delaying the domino effect of chemical accidents. Requirements for emergency response to a major accident may exceed the capacity of the emergency department within the region of responsibility for the accident, in which case multi-department emergency response is necessary. In this work, modeling problems related to the arrival of emergency teams at different times in multi-department emergency response are discussed. These problems will dynamically influence the time to failure of adjacent facilities in the event of a fire. A timed colored hybrid Petri-net (TCHPN) approach is proposed to solve these problems and analyze multi-department emergency response processes. An example of responding to a tank fire illustrates the proposed approach. An emergency response process is simulated, and probabilities of fire escalation prevention under different fire levels are analyzed.

- **Keywords:** Chemical accidents; Emergency response; Domino effects; Petri-net

Jingyu Zhu, Guoming Chen, Faisal Khan, Ming Yang, Xinhong Li, Xiangkun Meng, Rui He. *A sequence-based method for dynamic reliability assessment of MPD systems*. Pages 927-942.

Managed Pressure Drilling (MPD) system is widely used in the deepwater drilling operation. Reliability assessment plays a critical role in the MPD system in the management of drilling operation risk and the prevention of blowouts. However, the reliability assessment of the MPD system is challenged due to its sequential operations and multiple processes. Consequently, the present work proposes a sequence-based dynamic reliability assessment method, which focuses on the dynamic modeling of sequential operations for the MPD system by integrating GO-FLOW and dynamic Bayesian Network (DBN). GO-FLOW models are firstly used to define the time interaction between multiple phases for complex systems. A sequence-based mapping method is also proposed for the DBN to construct the reliability model of the MPD system throughout the entire drilling cycle. In the end, the case study analyzed by the proposed framework indicates that the reliability of the MPD system decreases with increasing drilling depth,

and the reliability of "tripping in" is highest among four different phases, while the "drilling process" is the lowest. The method provides an important technique that can be implemented with online condition monitoring tools to assess and monitor the reliability of the MPD operation in real-time.

- **Keywords:** Reliability assessment; MPD system; GO-FLOW method; Dynamic bayesian network; Deepwater drilling

Monika Niemczyk, Parvin Berenjkar, Nicole Wilkinson, Stan Lozecznik, Richard Sparling, Qiuyan Yuan. *Enhancement of CH4 oxidation potential in bio-based landfill cover materials*. Pages 943-951.

This study evaluated the efficacy of two compost materials, yard waste and leaf compost (YWLC) and biosolids compost (BSC), as bio-based landfill cover materials for oxidizing methane (CH4). A series of laboratory batch incubations were conducted to assess the CH4 oxidation potential of the composts and potential enhancement of CH4 oxidation under different conditions. Higher initial rates of CH4 oxidation were yielded in a sample of YWLC cured beyond the maturity standard at the compost site due to a reduction in raBOD and subsequent reduction in heterotrophic competition for oxygen. Results showed that the YWLC already had methanotrophic bacteria within the compost community with an initial CH4 oxidation rate of up to 95.9 μmol g(d.w.)−1 d−1. An optimum moisture content (MC) of 65 % and 50 % ww was obtained for YWLC with CH4 oxidation rates of up to 175−180 μmol g(d.w.)-1 d-1. In an assessment of long-term CH4 oxidation rates, a sample of BSC showed a long lag (60 days) to start consuming CH4; however, after this lag, it reached a CH4 oxidation rate of 160−170 μmol g(d.w.)-1 d-1, which was similar to that of the YWLC (130−140 μmol g(d.w.)-1 d-1) at the end of the 100 day experiment. While very little initial CH4 removal was detected in the BSC, different blends of BSC with YWLC were found to enhance CH4 oxidation indicating that there was a benefit to mixing the two composts. The highest long-term CH4 oxidation rates were observed in 1:1 and 1:4 (YWLC:BSC) mixing ratios (360−380 μmol g(d.w.)-1 d−1). Neither the in-situ MC, heavy metals concentrations, nutrient content, nor the in-situ population of methanotrophs were determined to be limiting variables for CH4 oxidation start-up in the BSC.

- **Keywords:** Methanotrophs; Landfill biocover; CH4oxidation rate; Batch incubation; Compost

Maria Cristina Collivignarelli, Claudio De Rose, Alessandro Abbà, Marco Baldi, Giorgio Bertanza, Roberta Pedrazzani, Sabrina Sorlini, Marco Carnevale Miino. *Analysis of lockdown for CoViD-19 impact on NO2 in London, Milan and Paris: What lesson can be learnt?* *fast* Pages 952-960.

Nitrogen dioxide (NO2) can have harmful effects on human health and can act as a precursor for the formation of other air pollutants in urban environment such as secondary PM2.5 and ozone. The lockdown measures for CoViD-19 allowed to simulate on a large scale the massive and prolonged reduction of road traffic (the main source for NO2 in urban environment). This work aims to selectively assess the maximum impact that total traffic blocking measures can have on NO2. For this reason, three megacities (London, Milan and Paris) were chosen which had similar characteristics in terms of climatic conditions, population, policies of urban traffic management and lockdown measures. 52 air quality control units have been used to compare data measured in lockdown and in the same periods of previous years, highlighting a significant decrease in NO2 concentration due to traffic (London: 71.1 % - 80.8 %; Milan: 8.6 % - 42.4 %; Paris: 65.7 % - 79.8 %). In 2020 the contribution of traffic in London, Milan and Paris dropped to 3.3 ± 1.3 μg m−3, 6.1 ± 0.8 μg m−3, and 13.4 ± 1.5 μg m−3, respectively. Despite the significant reduction in the NO2 concentration, in UT stations average NO2

concentrations higher than 40 μg m−3 were registered for several days. In order to reduce the pollution, the limitation of road traffic could be not enough, but a vision also aimed at rethink the vehicles and their polluting effects should be developed.

- **Keywords:** Urban environment; Nitrogen dioxide; Road traffic emissions; Traffic emissions; SARS-CoV-2; Low emission zones

Chunxiang Liu, Long Ding, Jie Ji. *Experimental study of the effects of ullage height on fire plume centerline temperature with a new virtual origin model*. Pages 961-967.

Investigating the evolution of the fire plume centerline temperature has both fundamental and practical importance to process safety, risk analysis and disaster control. In practice, ullage height (distance between the fuel surface and the container upper rim) is a common boundary condition that affects the burning intensity and the flaming characteristics. In this study, a series of experiments were conducted to reveal the effects of ullage height on the evolution of the heptane fire plume centerline temperature. The tested ullage height was systematically changed from zero to the value at which the flame self-extinguished. Results showed that, as ullage height increased, the fire plume centerline temperature first decreased and then slightly increased. By comparing the model predictions of previous classic models with the tested results, this study proved that previous classic models are not capable in predicting temperature profiles under high ullage height conditions. Based on physical and dimensionless analysis, a new virtual origin model was established to quantify the effects of ullage height on the virtual origin. A more universal plume centerline temperature model, which is capable to predict the centerline temperature profiles with any ullage height conditions, was proposed and validated by literature experimental data.

- **Keywords:** Ullage height; Virtual origin; Fire plume centerline temperature; Pool fire; Process safety