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Huihui Liu, Baiquan Lin, Chenglin Jiang. *A new method for determining coal seam permeability redistribution induced by roadway excavation and its applications*. Pages 1-8.

Changes in coal seam permeability induced by roadway excavation may lead to many engineering problems, such as low gas extraction concentration in in-seam boreholes, coal and gas outburst disasters, and gas emissions in the process of coal roadway excavation. To solve these problems, this paper proposed a new method to directly determine the distribution of coal seam permeability around roadways. For this purpose, method principle was analyzed, equipment was developed, and field experiments were carried out in Baiyangling coal mine. Finally, the engineering applications of the method were analyzed, and a field application effect experiment was conducted to verify the new method. The results showed that the coal seam permeability around roadways was divided into four stages. In stages I and II, permeability increased, in stage III, permeability decreased, and stage IV maintained the initial permeability of the coal seam. These test results will aid in increasing the gas extraction concentration of in-seam boreholes and will guide the design of gas control areas. Using the verification experiment, it was concluded that the new method is able to accurately determine the redistribution of coal seam permeability caused by roadway excavation and provide theoretical guidance in solving engineering problems.

- **Keywords:** Gas disaster prevention; Coal mine gas extraction; Gas utilization; Coal seam permeability; Coal roadway excavation

Mohammad Hossein Keshavarz, Sajad Damiri, Vahid Bagheri. *Recent advances for prediction of electric spark and shock sensitivities of organic compounds containing energetic functional groups to assess reliable models*. Pages 9-15.

For organic compounds containing energetic groups, electric spark (electrostatic or electrostatic discharge) and shock sensitivities can initiate their decomposition process in chemical industries and applications. Electrostatic charges often accumulate in bulk explosives and equipment during handling and processing procedures. They may provide hazardous explosion due to tribocharging. Since more reliable experimental methods have been developed in recent years for measurements of these sensitivities, some reliable methods have also been introduced for their predictions. This work reviews the recent models for prediction of electric spark sensitivity of some classes of organic and ionic liquid energetic compounds as well as shock sensitivity. A novel easy to handle and

user-friendly computer code is also introduced to predict electric spark and shock sensitivities by suitable and reliable predictive methods for some classes of high explosives including polynitro arene and nitramine compounds. The computer code has been checked for some newly reported energetic compounds, where their experimental data were available, which provide reliable predictions.

- **Keywords:** Organic energetic compound; Electric spark sensitivity; Shock sensitivity; Hazard assessment; Computer code

Hongjun Zhu, Yuhang Qi. *Numerical investigation of flow erosion of sand-laden oil flow in a U-bend*. Pages 16-27.

U-bend comprised of two 90° elbows is widely used in offshore oil production systems to convey sand-laden oil flow and to adjust the flow direction, and hence one of the easily-worn part. The majority of this work is to investigate the erosion behavior of liquid-solid flow and the particle trajectories in a U-bend. The computational fluid dynamics-discrete phase model (CFD-DPM) based on the Eulerian-Lagrangian approach coupled with an erosion model is employed to solve the liquid-solid flow and to predict the erosion distribution. The numerical model is validated by the experimental data available in previous literature. The results indicate that the erosion mainly occurs in the extrados and the lower surface of the U-bend and the downstream tube. Particularly, two erosion spots along the extrados in sequence are caused by the impingement of particles. Compared to the impingement occurring at the first 90° elbow, more particles with higher velocity take part in the impingement on the second 90° elbow, resulting in severer erosion. The erosion rate is sensitive to the flow velocity and particle size. The growth of either of them results in the enhancement of erosion.

- **Keywords:** Flow erosion; U-bend; Liquid-solid flow; Particle tracking; CFD

Marco Chiappero, Francesca Demichelis, Xuan Lin, Chenxiao Liu, Dominic Frigon, Silvia Fiore. *Investigation of pre-treatments improving low-temperature anaerobic digestion of waste activated sludge*. Pages 28-37.

This work analyzed the feasibility of pre-treatments to improve the anaerobic digestion (AD) of waste activated sludge (WAS) at 20°C. We investigated different physicochemical pre-treatments (thermal at 115°C, thermo-alkaline at pH 10 and 70°C and ozonation at 190mg-O3L−1) by comparing their performances about COD solubilization and sludge disintegration rate. Best performances were obtained by thermo-alkaline pre-treatment, followed by thermal and ozonation; results were consistent with literature. Pre-treated WAS was fed to 12 1-L anaerobic digesters operated in semi-continuous mode. Thermal and thermo-alkaline reactors produced biogas yields (0.30–0.36m3 kg−1 VS in standard conditions, 65–70 % methane) analogous to mesophilic conditions. The economic assessment of the scale-up of the whole process demonstrated that thermo-alkaline pre-treatment made AD at 20°C economically profitable for WAS generated by a 20,000 PE WWTP.

- **Keywords:** Anaerobic digestion; Biogas; Low-temperature; Pre-treatment; Semi-Continuous; Waste activated sludge

Andreas K. Benekos, Charikleia Zampeta, Rafailia Argyriou, Christina N. Economou, Irene-Eva Triantaphyllidou, Triantafyllos I. Tatoulis, Athanasia G. Tekerlekopoulou, Dimitris V. Vayenas. *Treatment of table olive processing wastewaters using electrocoagulation in laboratory and pilot-scale reactors*. Pages 38-47.

Electrocoagulation-(EC) is investigated as an alternative, cost-efficient, method for the treatment or post-treatment of table olive processing wastewaters (TOPWs). Experiments were performed in both laboratory and pilot-scale reactors using aluminum and iron electrodes. Different initial chemical oxygen demand (COD) concentrations (3000, 5000 and 9000mgL−1) and current densities (41.7, 83.3 and 166.7mA cm-2) were tested in laboratory-scale experiments to determine maximum COD and color removal from untreated TOPWs. Pilot-scale experiments were also conducted using biologically pre-treated TOPW (COD 1000mgL-1 and current densities of 3.87 and 5.65mA cm-2) to ensure an efficient post-treatment process. Aluminum electrodes were found to be more efficient in reducing COD and color than iron electrodes in both laboratory and pilot-scale experiments. In laboratory-scale experiments the maximum COD and color removal (approximately 50% and 100%, respectively) was recorded for the lowest initial COD concentration of 3000mgL−1 at 166.7mA cm-2. In the pilot-scale reactor the maximum COD and color removal observed was 42.5% and 85.3%, respectively, for the current density of 5.65mA cm-2. Lower energy and electrode consumption was recorded when working with aluminum electrodes and optimum results were obtained with the lowest initial COD and current density values tested.

- **Keywords:** Table olive processing wastewater; Electrocoagulation; Color removal; Operating cost; Pilot-scale reactor

Depeng Kong, Xu He, Hanbing Yang, Zhen Zhang. *Experimental study for flame base drag and burning efficiency of spilled crude oil during in-situ burning on water*. Pages 48-54.

In-situ burning (ISB) has been proven to be a practical way to clean oil on water. The burning behavior of spilled oil is strongly influenced by wind. The flame characteristics of flame base drag and burning efficiency affected by wind speed have been studied through a series of experiments in this study. The wind speeds varied from 0.5 m/s to 2.0 m/s and the inside diameters of the oil pools made from quartz glass were 40 mm, 90mm and 140mm. The variation of fuel vapor density was considered in the dimensionless model for predicting flame base drag length. The proposed formula was shown to correlate with the data of different pool diameters and wind speeds non-dimensionally by Froude number, fuel-air density ratio and the dimensionless heat release rate. The study helped to better understand the fire behavior under wind conditions, and most importantly the developed model would help guide better assessment of the burning in ISB operation.

- **Keywords:** In-situ burning; Crude oil; Wind; Flame base drag; Burning efficiency

Shang-Hao Liu, Yi-Ming Lu, Chin-Lung Chiang, Chen-Rui Cao. *Determination of the thermal hazard and decomposition behaviors of 2,2′-azobis-(2,4-dimethylvaleronitrile)*. Pages 55-62.

Azo compounds, which are commonly used in radical polymerization reactions, readily demonstrate their self-reactive properties. Because of their sensitive thermal decomposition properties, azo compounds have been responsible for many accidents. To avoid unexpected thermal decomposition in the workplace, information about the thermal stability and other properties of azo compounds should be provided to on-site personnel in industries that use these materials. In this study, the target substance, 2,2′-azobis-(2,4-dimethylvaleronitrile) (ABVN), is shown to have a higher reactivity than other azo compounds, and its thermal decomposition characteristics are discussed based on a literature review and results from differential scanning calorimetry (DSC) and accelerating rate calorimetry (ARC). A thermokinetic analysis of ABVN is conducted using DSC and ARC data. The results can provide process-control data and explain the effects of thermal runway for ABVN. In addition, based on applied numerical methods, critical runaway temperatures, stable temperatures, and the required heat dissipation rate for

the prevention of the thermal runaway reactions are calculated using a process deviation analysis. The results show that the reactant quantities and the process parameters must be strictly controlled to achieve the desired reaction.

- **Keywords:** Critical runaway temperatures; Differential scanning calorimetry (DSC); Numerical methods; Process deviation; 2,2'-azobis-(2,4-dimethylvaleronitrile) (ABVN)

Dwi Hantoko, Antoni, Ekkachai Kanchanatip, Mi Yan, Zhouchao Weng, Zengliang Gao, Yingjie Zhong. *Assessment of sewage sludge gasification in supercritical water for H2-rich syngas production*. Pages 63-72.

The potential of sewage sludge for hydrogen-rich syngas production from supercritical water gasification (SCWG) was evaluated through thermodynamic analysis and experimental work. The thermodynamic analysis was conducted by using Aspen Plus simulator based on Gibbs free energy minimization. The effect of temperature (380–460°C), sludge concentration (5–30wt%), and activated carbon addition (2–8wt%) on SCWG was experimentally studied. The solid and liquid residues were characterized by Fourier Transform Infrared (FTIR) spectroscopy, Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES), and Total Organic Carbon (TOC) Analyzer. The results showed that higher temperature and lower sludge concentration favored syngas production, leading to higher hydrogen yield. While pressure had no significant effect on the SCWG performance. The TOC and FTIR analyses revealed that organic matters in sewage sludge were decomposed and hydrolyzed into syngas. The addition of activated carbon increased the syngas yield and enhanced the cold gas efficiency. A syngas yield of 6.44mol/kg containing 38.43% H2 was obtained from SCWG at 400°C with the activated carbon loading of 8wt%. Moreover, the analysis of heavy metals indicated that SCWG had a positive effect on the stabilization of heavy metals and reduced the leaching toxicity of heavy metals in sewage sludge.

- **Keywords:** Sewage sludge; Supercritical water; Gasification; Syngas; Heavy metal

Yuliana K. Atroshenko, Geniy V. Kuznetsov, Pavel A. Strizhak, Roman S. Volkov. *Protective Lines for Suppressing the Combustion Front of Forest Fuels: Experimental Research*. Pages 73-88.

The article presents the results of experimental research, determining the conditions for suppressing the combustion front of forest fuels (FF) with the use of a protective water line. Integral parameters, velocities and other characteristics of the main interrelated heat and mass transfer processes, phase transformations and chemical reactions are studied. The conditions for suppressing the combustion front of typical forest fuels (needles; leaves; a mixture of needles, leaves and branches) are established. The experimental conditions are designed to be the utmost close to those of ground forest fires and parameters of fire lines: in terms of temperature, wind velocity, the forest fuel layer thickness, the size of water droplets, etc. The rational dimensions (width, length, depth) of the protective water lines, the density of water irrigation of the material surface, the volume of liquid, the time of spraying are determined. It is shown that effective conditions for forest burning localization can be achieved at almost complete thermal decomposition of a small layer of FF near the barrier line. It is established that necessary and sufficient conditions of FF combustion localization can be reliably predicted using the obtained dependences of specific water flow rate on FF volume.

- **Keywords:** Forest fuel; Combustion front; Fire suppression; Localizing the fire front; Protective water line; Experimental research

Mohammad Yazdi, Sohag Kabir, Martin Walker. *Uncertainty handling in fault tree based risk assessment: State of the art and future perspectives*. Pages 89-104.

Risk assessment methods have been widely used in various industries, and they play a significant role in improving the safety performance of systems. However, the outcomes of risk assessment approaches are subject to uncertainty and ambiguity due to the complexity and variability of system behaviour, scarcity of quantitative data about different system parameters, and human involvement in the analysis, operation, and decision-making processes. The implications for improving system safety are slowly being recognised; however, research on uncertainty handling during both qualitative and quantitative risk assessment procedures is a growing field. This paper presents a review of the state of the art in this field, focusing on uncertainty handling in fault tree analysis (FTA) based risk assessment. Theoretical contributions, aleatory uncertainty, epistemic uncertainty, and integration of both epistemic and aleatory uncertainty handling in the scientific and technical literature are carefully reviewed. The emphasis is on highlighting how assessors can handle uncertainty based on the available evidence as an input to FTA.

- **Keywords:** Process safety; Uncertainty; Fault tree analysis; Risk assessment; Bayesian theorem; Fuzzy set theory; Evidence theory

Domenica Mosca Angelucci, Daniela Piscitelli, M. Concetta Tomei. *Pentachlorophenol biodegradation in two-phase bioreactors operated with absorptive polymers: Box-Behnken experimental design and optimization by response surface methodology*. Pages 105-115.

The biodegradation of pentachlorophenol (PCP), the most toxic among chlorophenols, was extensively investigated in solid-liquid two-phase bioreactors (according to Box-Behnken experimental design) to demonstrate the feasibility of this technological platform. Process performance optimization for the subsequent scale up was also performed. The process was catalysed by an acclimated microbial consortium and the partitioning phase consisted of Hytrel 8206 polymer. The virtuous combination of polymer uptake/release and microbial biodegradation allowed achieving practically complete biodegradation efficiencies and rates in the range of 4.0–7.8mg/(L h) for PCP concentrations up to 100mg/L far above those previously tested. Detected biodegradation rates are one order of magnitude higher than the ones reported for suspended biomass reactors. A regression model based on 3 independent variables (initial PCP and biomass concentration and polymer-to-water ratio) was formulated to predict the volumetric biodegradation rate. The significance of independent variables and their interactions was tested by the analysis of variance (ANOVA) with 95% confidence limit. The model resulted adequate and the polymer-to-water ratio was identified as the most significant factor affecting the system response. Maximization of the biodegradation rate has been achieved for PCP concentration of 100mg/L, biomass concentration of 1 gVSS/L and polymer-to-water ratio of 9%.

- **Keywords:** Pentachlorophenol; Biodegradation; Absorptive polymers; Response surface methodology; Box-Behnken experimental design; Kinetics

Yogita Prabhakar, Anshu Gupta, Anubha Kaushik. *Enhanced decolorization of reactive violet dye 1 by halo-alkaliphilic Nesterenkonia strain: Process optimization, short acclimatization and reusability analysis in batch cycles*. Pages 116-126.

The study explores the efficacy of indigenously isolated halo-alkaliphilic bacterium Nesterenkonia sp. for decolorization of reactive violet 1(RV1) dye at alkaline pH. Dye

decolorization by the microbe was tested first in nutrient broth by varying initial dye concentration (50–3000mg/L), pH (7.0–12.0), inoculum size (1–10%) and temperature (4–45°C) by spectrometric determination of absorbance at 550nm, using single parameter approach. Box Behnken Design model of Response Surface Methodology (RSM) was then used to obtain optimized combination of process parameters for best dye degrading response of the microbe, based on 46 experiments. The microbe is found effective under a wide range of conditions and showed excellent reusability up to 6 batch cycles. Short term acclimatization in repeated cycles made decolorization faster and greater. Growth of the microbe was favored at high pH (11.5) and in the presence of salts (2.5–5%), decolorizing 94–100% of the dye. Decolorization of the dye by the microbe was also studied in simulated and real textile wastewaters under the optimized process conditions using 1% starch as carbon supplement. The bacterium degraded the dye and also bioremediated the wastewaters by successfully moderating the pH, removing toxic metal Cr (VI) and chemical oxygen demand (COD) during treatment.

- **Keywords:** Reactive dye; Decolorization; Process optimization; Halo-alkaliphilic bacterium; Reusability; Bioremediation

Bin Laiwang, Yun-Ting Tsai, Shang-Hao Liu, Jung Deng, Yang Xiao, Qiu-Hong Wang, Chi-Min Shu. *Effects of 1-butyl-3-methylimidazolium nitrate on the thermal hazardous properties of lignitous and long flame coal through a green approach and thermokinetic models*. Pages 127-134.

Coal, a flammable substance, is affected by spontaneous weathering and can be hazardous when exposed to thermally unstable conditions. Over the past few decades, numerous chemical disasters involving coal have occurred, resulting in many deaths. Therefore, strategies for the prevention of such disasters must be implemented to ensure human safety, avoid financial losses, and minimise adverse environmental effects. This study determined the thermal safety parameters and thermal hazards of lignitous and long flame coal by using thermogravimetry and differential scanning calorimetry. The characteristics of the functional groups in coal and treated coal were observed through Fourier transform infrared spectrometry. The structures of coal and coal treated with an ionic liquid, namely 1-butyl-3-methylimidazolium, were observed through scanning electron microscopy. Finally, theoretical kinetic models were applied to calculate thermokinetic parameters and identify the degree of thermal hazard present during periods of thermal instability. The results revealed that 1-butyl-3-methylimidazolium nitrate considerably reduced the probability of coal spontaneous combustion and the degree of hazard for long flame coal. Therefore, this ionic liquid could serve as an effective inhibitor of spontaneous combustion in long flame coal.

- **Keywords:** Flammable substance; Thermally unstable condition; Chemical disaster; Fourier transform infrared spectrometry; Thermokinetic parameter; Coal spontaneous combustion

A. Gálvez-Pérez, A. Pérez, M. Calero, M.A. Martín-Lara, G. Blázquez. *Integral exploitation from olive cake for energy production in a biorefinery scheme*. Pages 135-143.

This research aims to optimize the hydrothermal pretreatment based on previous studies, with the objective of extracting and determining value-added products from olive cake, and improve the energy solid properties. For this purpose, a hydrothermal pretreatment following of an autohydrolysis of the resulting solid were carried out in a biorefinery scheme. To the best of our knowledge this process has not been previously tested with olive cake by other authors. The conditions of the hydrothermal pretreatment were 30°C and 1h to prepare a suitable solid with mild conditions because polyphenols, water soluble extracts and tars precursors were eliminated. Sucrose was the value-added

product with the best extraction 2.48% at this conditions. Therefore, resulting solids were subjected to an autohydrolysis to improve the value-added products extractions. The autohydrolysis was based on a design of experiments with temperatures of 120, 140, 160 and 180°C and time of 30, 60 and 90min to study the influence between the independent variables and the dependent variables (yield % and calorific value from each resulting solid and saccharides extractions from liquid extracted). The saccharides extracted were glucose, xylose, fructose, sucrose and glucose and xylose oligomers. Glucose and xylose oligomers contents were highest with 4g and 19.24g per 100g of solid respectively. The solid energy properties were improved because a solid with a calorific value of 5970kcal/kg was obtained. All experimental results were fitted to neural-fuzzy and polynomial model.

- **Keywords:** Biomass; Calorific value; Olive cake; Oligomers; Saccharides

Daniele Perondi, Christian Manera, Marcelo Godinho, Ademir José Zattera. *Performance evaluation of natural catalysts during the thermochemical conversion of poultry litter*. Pages 144-151.

The thermochemical conversion may be an alternative for the final destination of poultry litter wastes. In this study, the effect of calcined eggshell (CE) and calcined dolomite (CD) on slow pyrolysis and air gasification performance of poultry litter waste was evaluated. The catalysts (CE and CD) presented potential for use in the in situ capture of the carbon dioxide produced in the pyrolysis process. In relation to the gasification tests, it can be concluded that both catalysts were effective in cracking the produced tar. Reductions in gas tar concentration of 25.47 and 54.32% were observed for CE and CD, respectively. The catalysts are effective at cracking light hydrocarbons (<C5) and increasing hydrogen production. A 214% increase in hydrogen production was observed with the use of CD.

- **Keywords:** Eggshel; Dolomite; Pyrolysis; Gasification and poultry litter wastes

Babak Aghel, Sasan Sahraie, Ehsan Heidaryan, Kambiz Varmira. *Experimental study of carbon dioxide absorption by mixed aqueous solutions of methyl diethanolamine (MDEA) and piperazine (PZ) in a microreactor*. Pages 152-159.

In this study, chemical absorption of carbon dioxide (CO2) was performed by using MDEA+PZ (aMDEA) solvent. A T-shaped microreactor mixer was used as the mass transfer device to improve the absorption rate. Operating conditions used in this study were operating temperature (15–55°C), input solvent flow rate (0–0.4lmin−1), inlet gas flow rate (1-9lmin−1), and amine concentration in the solvent (0–40 weight percent). All the experiments were carried out at atmospheric pressure and CO2 concentration of 10% in the feed gas. The central composite design method was used to set an experimental design. The results of optimization showed that the use of a microreactor for CO2 adsorption using aMDEA solvent significantly increased the total coefficient of mass transfer in the gas phase, as compared with other mass transfer devices. The maximum value obtained through the model within the range of operating variables for the response (total mass transfer coefficient in the gas phase) was 1769kmolm−3h−1kPa−1.

- **Keywords:** Absorption; Microreactor; Amine solvents; Activated MDEA

A. Azhagurajan, L. Prakash, K. Jeyasubramanian. *Prevention of explosion accidents by employing boron instead of aluminium in flash powder*. Pages 160-168.

In Fireworks Industries, Aluminium is one of the main chemicals which exhibit excellent performance in the fireworks display. However, fine Aluminium powder is pyrophoric and releases a lot of heat and becomes the cause for hazards in fireworks industries. In this research work, the composition of flash powder has been modified by blending with boron powder, in order to minimize workplace accidents and the explosive nature of fireworks. Simultaneously, the amount of aluminium in the flash powder is reduced such that the quality of the flash powder needed for making firecrackers is not affected. The boron blended flash powders are subjected to various tests in order to measure the impact energy and frictional sensitivity. The frictional sensitivity of the boron mixed flash powder is found to be higher than the frictional sensitivity of Aluminium-based flash powder. The impact energy required to induce explosion is measured and compared for both the flash powders. These results confirm that the boron-based flash powders display remarkable properties; they explode under higher frictional load and need high impact energy to ignite them. The thermokinetic characteristics of the flash powders blended with boron are also obtained using Accelerating Rate Calorimeter (ARC). The characteristics reveal that the explosive mixture containing boron exhibits higher decomposition temperature, higher self-heat rate and higher pressure during detonation than the conventional mixtures. Besides the evaluation of characteristics of flash powder, cake bombs were also fabricated using boron blended flash powders and the noise level during the explosion was also recorded. The results obtained from these tests ensure the fact that blending of boron in flash powder reduces workplace accidents since the mixture obtained possesses higher frictional sensitivity and thermal impact energy.

- **Keywords:** Boron; Fireworks; Aluminium; Safety; Hazardous

Jin-liang Li, Wei Lu, Ying-jiazi Cao, Biao Kong, Qing-song Zhang. *Method of pre-oxidation treatment for spontaneous combustion inhibition and its application*. Pages 169-177.

A method named "pre-oxidation treatment for spontaneous combustion inhibition" was proposed to proactively prevent coal spontaneous combustion. In this method, coal samples are firstly oxidized under room temperature by an oxidizer, which have an oxidizing capacity equivalent to the capability of oxidizing only active functional groups in coal. In this way, functional groups residing in the coal structure with high reactivity will be oxidized and heat will be released at the same time. With a large amount of water protection set up in advance, the heat can be released safely. After the highly active functional groups are oxidized, the reaction products left contain more stable functional groups with low activity, thus reducing the risks of spontaneous combustion. Underpinned by the theory, the method was tested by using different aqueous solutions of oxidants to pre-oxidize various coal samples. Results show that the method of pre-oxidation treatment for spontaneous combustion inhibition can significantly reduce the risk of coal spontaneous combustion. Among all the tested aqueous solutions of oxidants, the sodium persulfate solution is the most appropriate one.

- **Keywords:** Coal spontaneous combustion; Pre-oxidation treatment; Inhibition mechanism

Qiaoling Chen, Maureen Wood, Jinsong Zhao. *Case study of the Tianjin accident: Application of barrier and systems analysis to understand challenges to industry loss prevention in emerging economies*. Pages 178-188.

Accident analysis methods are widely used in industry to understand how companies with seemingly strong safety management systems failed to prevent a serious incident. These methods can equally be used to help governments, particularly in emerging economies, to analyse industrial incidents to understand how their institutions may be failing to

control risk, providing insight into potential improvements while also extracting lessons for other emerging economies with similar risk profiles. The fire and explosion accident of the Ruihai hazardous goods warehouse at Tianjin Port, China, that occurred on 12 August 2015 is a prime example of a common emerging economy dilemma. Emerging economies typically struggle for years, sometimes decades, to build the capacity sufficient to address the challenges of sustainability that accompany rapid and wide-spread economic development. These economies experience particularly high rates of serious and catastrophic industrial disasters, with significantly higher rates of injury, death and environmental impacts in comparison to more mature developed economies. Yet, in many of these incidents, the country may already have some, or even substantial, legal frameworks in place to address industrial risk. In the case of Tianjin, China has strengthened industrial law substantially since the early 2000s to establish more rigorous control over chemical hazard sources. In this circumstance, understanding the sequence of events, and missed opportunities by various actors to prevent the accident and mitigate its impacts could provide support to targeted improvements to risk governance in China, and also other countries who are striving to impose a higher standard of industrial risk management. This paper describes a study in which accident analysis methods based on bow tie barrier analysis and safety systems theory were used to analyse the institutional failures that contributed to the occurrence and severity of the Tianjin disaster. The resulting analysis shows that the application of accident analysis methods to industrial disasters can highlight weaknesses in the evolving governance systems of emerging economies that may also offer lessons to other countries who are also on a similar path.

- **Keywords:** Accident analysis; Hazardous chemical accident; Bow-tie; AcciMap

Andrew Fominykh, Itzhak Katra, Boris Krasovitov, Avi Levy. *Adsorption of active trace gases by ensemble of ultrafine porous particles with impermeable cores*. Pages 189-196.

In the present study, we analyze the combined influence of several factors on the rate of atmospheric trace gas adsorption by an ensemble of porous aerosol particles. The factors include the presence of a non-porous non-adsorbing inner core, kinetic effects, non-uniform distribution of concentration of adsorbed gas inside particles, inert admixtures in the atmosphere, radioactive decay, and particle number density. The particles size has the same order of magnitude as a free path length of molecules in air. The evolution of concentration of adsorbed active trace gas in solid porous particles is described by an integral equation, while the evolution of active trace radioactive gas in a gaseous phase is determined by an integro-differential equation. Numerical calculations are performed to investigate the adsorption of different isotopes of Radon and Iodine by porous particles. The comparison of rates of gas adsorption for radioactive isotopes of Iodine with a stable isotope I-127 shows that radioactive decay alters the scenario of the gas adsorption process by porous particles. The accuracy of the developed model of radioactive gas adsorption by porous particles is validated by available experimental data.

- **Keywords:** Impermeable core; Gas adsorption; Atmosphere; Kinetic effects; Radioactive gases; Porous particle

An-Chi Huang, Chung-Fu Huang, Zhi-Xiang Xing, Jun-Cheng Jiang, Chi-Min Shu. *Thermal hazard assessment of the thermal stability of acne cosmeceutical therapy using advanced calorimetry technology*. Pages 197-204.

In recent years, a number of cosmeceutical incidents have occurred both domestically and internationally. These incidents range from minor burns on the skin to the explosion

of a cosmeceutical factory. In most of these incidents, benzoyl peroxide (BPO) was reported as one of the hazardous compounds involved. Even after dilution, BPO still poses a hazard. This study examined the thermal stability parameters of BPO by using differential scanning calorimetry, thermogravimetric analyzer, and thermal activity monitor III. Advanced thermokinetic models were integrated and calculated, and complete thermal stability analysis of low concentration of BPO was conducted. The findings of this study may be used as a reference in future research on BPO decomposition.

- **Keywords:** Benzoyl peroxide; Differential scanning calorimetry; Thermogravimetric analyzer; Thermal activity monitor III; Thermokinetic models

Sunhwa Park, Hyun-Koo Kim, Deok Hyun Kim, Gyeong-Mi Lee, JongHyun Yoon, Hyojung Choi, Moonsu Kim, Kyungjin Han, Young Kim, Hyen Mi Chung. *The effectiveness of injected carbon sources in enhancing the denitrifying processes in groundwater with high nitrate concentrations*. Pages 205-211.

The single-well push–pull test (SWPPT) was adapted to quantify in denitrification rates and to assess microbial population dynamics in a highly nitrate-contaminated aquifer (105–311 NO3 mg L−1). In SWPPT through addition of fumarate as carbon source into test wells, significant NO3-consumtion was monitored in the well. The average zero- and first order rate coefficients were 7.85 and 0.82mmol L−1 day−1, respectively. Degradation rate of injected fumarate is 15.22 (zero-order) and 0.51 (first-order) mmol L−1day−1, respectively. Significant fumarate (electron donor, ED) and NO3(electron acceptor, EA) consumption, the production of dissolved CO2 during denitrification tests, and N2O production strongly indicate that the EAs consumption was mainly due to microbial activity. Therefore, SWPPT may be useful for quantifying in situ denitrification rates and for assessing microbial population dynamics in nitrate-contaminated aquifers in Silty Clay layer.

- **Keywords:** Single well push–pull test; Nitrate-contaminated aquifers; Silty clay layer; Fumarate; In-situ denitrification

Dornaz Karimipourfard, Reza Eslamloueyan, Nasir Mehranbod. *Novel heterogeneous degradation of mature landfill leachate using persulfate and magnetic CuFe2O4/RGO nanocatalyst*. Pages 212-222.

Landfill leachate is a contaminated liquid containing an extensive range of organic and inorganic pollutants. Therefore, it could pose serious risks to the environment by polluting soil and groundwater. In this study, the application of magnetic CuFe2O4/RGO nanocatalyst for persulfate activation was investigated in mature landfill leachate remediation. In this regard, CuFe2O4/RGO was synthesized through straightforward sonochemical co-precipitation method, and was characterized by different analysis approaches (FTIR, XRD, EDX, Raman, VSM, and TEM). A reaction mechanism for persulfate activation in this process was elucidated, and the influence of initial pH, persulfate concentration and catalyst loading were evaluated on the efficiency of the process as well. Under optimum condition, final COD, NH3-N and color removal efficiencies reached to 65.1%, 65%, and 58% respectively, and regenerability of the catalyst was assessed during five consecutive runs. Furthermore, a comparison between functional groups of the initial and degraded leachate samples was performed using ATR-FTIR analysis. In this way, the degraded products after the oxidation process were studied, and the results showed that the treatment system was capable of degrading aromatic compounds to aliphatic ones.

- **Keywords:** Landfill leachate; Degradation; COD; NH3-N; Persulfate; CuFe2O4/RGO nanocatalyst

Sun Yong, Wang Shugang, Wei Lu, Ying-jiazi Cao, Jinliang Li. *Coal spontaneous combustion characteristics based on constant temperature difference guidance method*. Pages 223-234.

Safety and environmental problems caused by coal mining and utilization are becoming increasingly serious. Studies in the coal spontaneous combustion characteristics based on constant temperature difference guidance method, which is of great significance for mine safety prevention and environmental protection. In this paper, a new method, Constant Temperature Difference Guidance Method, was developed in this paper for studying coal spontaneous combustion characteristics. By creating a constant temperature difference between coal temperature and ambient temperature, self-heating of coal is guided in this new method, which largely improves the efficiency and success rate of coal spontaneous combustion testing. Through analysis, this method was proved capable of providing a comprehensive description of coal's low-temperature oxidation characteristics. Besides, through changing different values of the temperature difference, various factors of low-temperature coal oxidation under adiabatic environment can be calculated. Additionally, spontaneous combustion point and ignition point can be obtained by analyzing time-temperature curve of coal oxidation. These two points along with the duration to achieve these two points were used in this paper to develop a risk index for evaluating coal spontaneous combustion propensity.

- **Keywords:** Spontaneous combustion of coal; Low-temperature oxidation; Temperature rising with guiding; Risk of spontaneous combustion

A.B. Mpofu, O.O. Oyekola, P.J. Welz. *Co-digestion of tannery waste activated sludge with slaughterhouse sludge to improve organic biodegradability and biomethane generation*. Pages 235-245.

A novel approach was used to overcome inhibition of anaerobic digestion of tannery waste activated sludge by co-digesting with slaughterhouse sludge. The seasonal characteristics of the tannery sludge varied significantly. Macronutrient ratios were typically not ideal for anaerobic digestion, mainly due to an over-abundance of nitrogen. In addition, potentially inhibitory concentrations of metals were present. Optimal co-digestion with 50% (vol./vol.) slaughterhouse sludge achieved a CH4 yield of 215mLCH4/gVS, and biodegradability of 55.7% VS, 45.5% TS and 48.2% COD. This resulted in a synergistic increase of ≥59.4% in biodegradability and 156% in CH4 yield compared to mono-digestion of tannery waste activated sludge. Furthermore, the regression of the cumulative CH4 yield using the Logistic, Cone and modified Gompertz model (adj R2≥0.998) showed an increase of 20.4–21.9%, 58.6–252%, and 164% in the ultimate CH4 yield, maximum CH4 production rate and the specific rate constant respectively, and 59.3% reduction of the lag phase. An alternative cleaner production technique that vertically integrates the value chain improves solid waste management and provides an income stream was demonstrated through this co-digestion strategy.

- **Keywords:** Co-digestion; Tannery waste activated sludge; Slaughterhouse sludge; Inhibition; Optimization; Kinetics

Hui Zhuo, Botao Qin, Qinghe Qin, Zhiwei Su. *Modeling and simulation of coal spontaneous combustion in a gob of shallow buried coal seams*. Pages 246-254.

The pore and fracture are the path of energy, mass and momentum transfer and conduction in the gob, determine its reasonable distribution is the basis for studying the

coal spontaneous combustion hazardous area and migration law of gas products. A discrete fracture-pore model of gob in shallow buried coal seams is being proposed, which is based on the periodic pressure of the overburden, the key strata theory and the compression deformation of the broken rock mass. The model consists of a porous medium media and a discrete fracture network, and calculation equation for the porous medium and the crack width is granted. Taking the Bulianta mine as the background, the model was introduced into FLUENT to simulate the oxygen concentration field, the carbon monoxide concentration field and wind velocity field in the gob. The simulation results agreed well with the measured oxygen concentrations in the field. The spontaneous combustion danger zone and the law of carbon monoxide accumulation in gob are obtained by simulation. In the lower coal seam gob, the maximum width of the spontaneous combustion hazard zone is 108.67m, and the maximum width is 104.94m from the return air side of the gob, and its area is calculated to be 14,645 m2. In the upper coal seam gob, there is basically no spontaneous combustion danger zone that simultaneously meets wind speed and oxygen concentration. However, the oxygen concentration in most areas of the upper gob is between 8% and 18%. In order to prevent the formation of spontaneous combustion danger zone, it is necessary to take corresponding measures for the location with large surface cracks. The concentration of carbon monoxide in the lower gob is greater than the concentration of carbon monoxide in the upper gob. For upper gob, the distribution of carbon monoxide concentration is mainly affected by ground air leakage; for the lower gob, the distribution of carbon monoxide concentration is mainly affected by air leakage of working face.

- **Keywords:** Discrete fracture-pore model; Shallow buried coal seams; Spontaneous combustion hazard zone; Air leakage; Numerical simulation

Daiana Seibert, Heloise Quesada, Rosângela Bergamasco, Fernando Henrique Borba, Leandro Pellenz. *Presence of endocrine disrupting chemicals in sanitary landfill leachate, its treatment and degradation by Fenton based processes: A review*. Pages 255-267.

Various studies concerning sanitary landfill leachate (SLL) characteristics and toxicity identified the presence of endocrine disrupting chemicals (EDCs). A review of the detected EDCs in SLL was performed, in which the 12 most frequent EDCs identified in sanitary landfill sites over the world were ranked: BPA, DBP, DEHP, DEP, NP, BBP, DOP, DMP, 4OP, DiBP, DTBP and nicotine. The presence of these compounds is related to the activities on the dumping site, especially by the presence of plastic and personal care products, insecticides and cleaning agents in the waste bulk. Many diseases in human and animals have been associated with exposure to EDCs, as examples can be cited: disorder in metabolic processes that might end in diaseases, reduction of fertility, bioaccumulation and a high cancer potential. Among the treatment strategies applied to SLL degradation, processes based on Fenton reaction have received increasing attention due to its non-selective oxidation performed by hydroxyl radicals (•OH). Thus, they are able to oxidize/mineralize compounds which are not removed in conventional wastewater treatments. Degradation pathways and byproducts produced after the oxidative process may provide important information around the applicability of these techniques. Integrated treatments are also studied to obtain biosafety of treated wastewater samples. For the SLL treatment, the most employed strategy coupled to Fenton-based processes is the biological oxidation. The integration strategy relies on the SLL characteristics, being two modalities allowed: Fenton-based processes followed by biological systems or the opposite one. Future researches are needed to advance our understanding of the behavior of EDCs in human and animals bodies, as well as its critic concentrations. Also, there still is a lack of research regarding the degradation pathway of EDCs by OH in a SLL matrix, the ecofriendly disposal of iron sludge, the handle of the chemical solution wastes and the economic aspects of these treatments in order to meet a large scale application of this technology. Therefore, these topics have been discussed in this review article.

- **Keywords:** Emerging contaminants; Endocrine disruptoring chemicals; Advanced oxidation process; Sanitary landfill leachate treatment

Fengming Zhang, Jiulin Chen, Chuangjian Su, Shunquan Chen, Zhiyu Chen, Yaxin Ding. *Combined effects of protective film and oxidant on the performance of the supercritical water oxidation system with a film protective reactor: A simulation study*. Pages 268-281.

Supercritical water oxidation (SCWO) is a promising technology for treating organic waste and recovering energy. Water film protective reactor (WFPR), which is also referred to as transpiring wall reactor, provides a solution to corrosion and salt plugging issues. Three novel film protective reactors (FPRs) using air, nitrogen, and hydrogen peroxide as protective fluids were proposed to improve the corrosion and cost issues in WFPRs. Detailed optimized process parameters and flow field characteristics within the FPRs were obtained using Aspen Plus and computational fluid dynamics, respectively. The anti-corrosion performance and prevention of salt plugging in the FPRs were analyzed, and economic analyses for SCWO systems with different FPRs were conducted. Results indicate that the WFPR and hydrogen peroxide FPR present good solubility for inorganic salts but a high probability of corrosion. An SCWO system with the WFPR or nitrogen FPR is more competitive for industrial plants compared with other SCWO systems.

- **Keywords:** Supercritical water oxidation; Film protective reactor; Protective film; Oxidant; Economic analysis

Ankit Sharma, Kirti Bhushan Mishra. *Experimental set-up to measure the maximum mass burning rate of storage tank fires*. Pages 282-291.

The correct measurement of the maximum mass burning rate of flammable liquids in real sized storage tanks in industrial facilities is necessary to develop appropriate safety measures. Burning a fixed quantity of fuel in small diameter pans may not reflect the actual burning behaviour of different flammable liquids stored in large tanks. To overcome this, an experimental set-up by imposing realistic boundary conditions replicating tank fires and burning duration is demonstrated in this work. Fully developed steady burning conditions in model storage tanks of diameters d=0.05m and 0.10m, with 0.10m constant fuel filling height, are established to report the maximum mass burning rate. Flammable liquids used for the present study are diesel, gasoline, ethanol and biodiesel. The mass burning rates are measured by using two methods being the conventional method of using a fixed amount of fuel and hence decreasing fuel height and the present method in which the model tanks are continuously fed with fuel so that a steady state is achieved in terms of fuel height and burning rate. The measured higher flame lengths and higher temperatures in the liquid phase indicated that higher heat flux was transferred from the fire to the liquid surface in the present set-up compared to earlier method which resulted in higher maximum mass burning rates. Furthermore, to achieve wind boundary conditions in present model tanks, swivel fan at 0.5m distance from the fire was placed. With such an equivalent air entrainment and using proper scaling techniques, it is possible to measure the maximum burning rates of flammable liquids in real-sized storage tanks in the present set-up itself. These maximum mass burning rates can further be used to establish proper safety measures such as plant layout and storage group determinations for different flammable liquids.

- **Keywords:** Storage tank; Flammable liquid; Model tank; Maximum mass burning rate; Steady-burning; Safety measure; Pool fires

M.J. Luján-Facundo, J.A. Mendoza-Roca, J.L. Soler-Cabezas, A. Bes-Piá, M.C. Vincent-Vela, L. Pastor-Alcañiz. *Use of the osmotic membrane*

***bioreactor for the management of tannery wastewater using absorption liquid waste as draw solution*. Pages 292-299.**

The performance of an osmotic membrane bioreactor (OMBR) for treating tannery wastewater at laboratory scale has been evaluated in this study. The forward osmosis (FO) membrane tested was CTA-NW from HTI. As draw solution, actual waste water from an absorption column for ammonia separation, which consists mainly of ammonium sulphate was used. The study was focused on the salt reverse flux during the OMBR operation, membrane water flux, biomass characteristics and membrane fouling. Regarding membrane water flux change with the time, the measured values diminished from 3.44 to 0.72 LMH due to the membrane fouling and the salt accumulation in the biological reactor. The stable mixed liquor conductivity value at the end of the experiment was 29.8mS·cm−1. The chemical oxygen demand (COD) removal efficiencies were maintained near 80% until the first 50 days of operation, considering the soluble COD in the reactor instead of the COD in the membrane permeate for the performance calculation. Thence, COD removal efficiencies decreased progressively due to the accumulation of non degradable COD coming from the tannery wastewater. Concerning to the membrane fouling, FESEM/EDX analysis corroborated that organic fouling was predominant on the membrane active layer.

- **Keywords:** Osmotic membrane bioreactor; Tannery wastewater; Forward osmosis; Reverse salt flux

Javad Saien, Shahin Seyyedan. *High performance homogeneous photo-activated persulfate for nicotinic acid removal, intensified with copper ions and ultrasonic waves*. Pages 300-306.

Aqueous solutions of nicotinic acid (NA) were treated using a low consumption UV light source and the potassium persulfate reagent (UV/KPS) in a falling thin film photo-reactor. Under determined optimum conditions of [KPS]=1400mg/L and pH 4, degradation of NA reached to 82.2% after 90min. Presence of conventional water contained bicarbonate, chloride and nitrate anions caused unfavorable effect; however, adding only 0.5mg/L of Cu2+ ion, as promoter, gave rise to the system capability to 97.1% degradation. Enhancement in degradation efficiency could also be achieved by using 28kHz ultrasonic waves in combination with the UV/KPS process. The intermediates of formic acid, malonic acid and oxalic acid were identified by GC/MS analysis and a reaction pathway was proposed. The scavenging role of ethanol and tert-butanol reagents was followed and it was revealed that HO• and SO4•− radicals had, respectively, 53.7 and 46.3% contribution in the process degradation. In addition, the reaction kinetic was followed and a pseudo first order reaction was appropriate within conventional temperature range of 15–40°C. Meanwhile, the electrical energy consumption was determined and the total operating costs, for one order of magnitude degradation, was estimated as 2.92 $/m3.'

- **Keywords:** Nicotinic acid; Activated persulfate; Process promotion; Mechanism; Operating costs

Ahmed O. Babaleye, Rafet Emek Kurt, Faisal Khan. *Hierarchical Bayesian model for failure analysis of offshore wells during decommissioning and abandonment processes*. Pages 307-319.

Risk analysis of offshore wells decommissioning, and abandonment processes is challenging due to limited life-cycle information of the well, and failure data of safety barriers in place. To this end, it is essential to capture and implement the variability associated with the sparse data for conducting risk analysis with considerable confidence level. The hierarchical Bayesian analysis provides a viable alternative to address the

uncertainty of the data through aggregation for each causation. Bayesian network, through its robust computation engine, is used to define dependence of causations and uses Bayes' theorem to update the analysis as new information becomes available. In addition, the Bayesian network helps to represent complex dependencies among causations through appropriate relaxation strategy to minimize uncertainty in the data, link parameter of interest, and overall accident scenario modelling. This paper presents the integration of Hierarchical Bayesian model with a Bayesian network to conduct the risk analysis of well decommissioning and abandonment processes. The proposed methodology is illustrated using a well plugging and abandonment operational failure reported by the Department of Mineral Management Service (MMS). The results demonstrate the potential of the proposed approach as a robust means to study complex well decommissioning activities.

- **Keywords:** Bayesian networks; Hierarchical Bayesian model; Failure analysis; Well plugging and abandonment; Decommissioning

Shengjian Li, Fang Jiang, Ting Lei, Zixuan Ren, Shixiong Wang, Xiangjun Yang. *Phosphorus removal by in situ sprayed ferric chloride in Dianchi Lake: Efficiency, stability, and mechanism*. Pages 320-328.

In this work, ferric chloride was applied to remove phosphorus from natural water bodies of Dianchi Lake. The feasibility and efficiency of phosphorus removal using ferric chloride are reported. The factors that influence the stability of Fe-P coprecipitates formed during the phosphorus removal process (including temperature, pH, coexisting ions, fast mixing speed (FMS), and fast mixing time (FMT)) were studied in detail. Results show that ferric chloride can efficiently remove phosphorus, and Fe-P coprecipitate exhibits high stability. In a water temperature range of 10–35°C and pH range of 3–11, the phosphorus in the Fe-P coprecipitates is stable and is not released. The maximum phosphorus release efficiency is 9.2% at a pH of 3, and 16.10% at a pH of 11. The presence of Ca2+ and CO32− has little effect on the stability of Fe-P coprecipitates, and the differences in fast mixing speed and time have little effect on the stability of Fe-P coprecipitates. Furthermore, on the basis of Fourier transform infrared spectroscopy (FTIR), X-ray photoelectron spectroscopy (XPS), transmission electron microscopy (TEM) and X-ray diffraction (XRD) analysis, adsorption and ligand exchange were identified as the main phosphorus removal mechanisms by ferric chloride. These findings demonstrate that ferric chloride is a promising candidate for highly efficient and stable phosphorus removal from water of Dianchi Lake.

- **Keywords:** Phosphorus; Ferric chloride; Fe-P coprecipitates; Stability; Eutrophication

Abbas Zaranezhad, Hasan Asilian Mahabadi, Mohammad Reza Dehghani. *Development of prediction models for repair and maintenance-related accidents at oil refineries using artificial neural network, fuzzy system, genetic algorithm, and ant colony optimization algorithm*. Pages 331-348.

This study presents an accident causation model for repair and maintenance related accidents at oil refineries and proposes the best model for early accident prediction through the integration of artificial neural networks, fuzzy systems, and metaheuristic algorithms. The main factors affecting the occurrence of accidents were classified into six categories: external, internal, executive, behavioral, situational, and work features. These factors were regarded as the input variables. Then three other factors, namely accident type prediction, consequence type prediction, and population density were added to the input variables. Then, the collected data on accidents were reanalyzed by the predefined variables. They were then prepared, quantified and normalized to enter

the networks. Regarding non-hybrid models, the perceptron neural network obtained the highest prediction accuracy of 90.9% and the highest rate of prediction precision of 96.19%. Regarding hybrid models, the neural-GA network obtained the highest prediction accuracy of 95.9% and a precision of 96.7%. Among all models, the neural-GA hybrid was the best prediction model. Thus, it is suggested to employ the neural-GA hybrid model to predict the accidents caused by repair and maintenance.

- **Keywords:** Accident causation; Accident prediction; Artificial neural network; Fuzzy system; Metaheuristic algorithms