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Yajie Bu, Zepeng Ma, Chang Li, Paul Amyotte, Wenbo Yuan, Chunmiao Yuan, Gang Li. *Effect of admixed solid inertants on dispersibility of combustible dust clouds in a modified hartmann tube*. Pages 1-11.

Reduction of dust explosion hazards can be achieved by processing materials in less hazardous forms. Two principles are often employed to moderate explosion potential. One approach is to increase dust particle size so as to decrease its reactivity. The other involves altering the dust composition by admixture with solid inertants. An essential prerequisite for dust explosions is the formation of airborne dust clouds. Dust dispersibility (i.e., the ease of dispersion of a dust and the tendency of the particulate matter to remain airborne once a dust cloud has been formed) is therefore an important safety characteristic, certainly requiring research attention. This paper presents experimental results using a modified Hartmann tube to determine the effect of admixed solid inertants on particle size distribution of dust clouds. Nine types of combustible dust and two sizes of inert Al2O3 were tested repeatedly five times. Generally, admixing small amounts of micro-sized solid inertants caused relative improvement on the dispersibility of combustible dust, forming a better dispersed cloud, and sometimes resulted in increased ignition sensitivity. However, the addition of agglomerate nano inert particles caused a multilayer coating of combustible particles, causing an increase in the effective surface area at the particle contact points, and thereby increasing cohesion in the powder mixtures. Higher inter-particle forces in turn enhanced the combustible particle agglomeration during dispersion, leading to an increase in effective particle size distribution.

- **Keywords:** Dust explosions; Olid inertant; Particle size distribution; Dust dispersibility; Powder cohesion

Zhenyang Wang, Yuanping Cheng, Liang Wang, Hongxing Zhou, Xinxin He, Minghao Yi, Chuanpeng Xi. *Characterization of pore structure and the gas diffusion properties of tectonic and intact coal: Implications for lost gas calculation*. Pages 12-21.

Accurate calculation of the amounts of lost gas from coal are of great importance in underground mining. In this study, the effects of pore structure and the gas diffusion properties on the lost gas from tectonic and intact coals were investigated by the mercury intrusion porosimetry method (MIP), N2 (77K) and CO2 (273K) adsorption

methods, and gas adsorption equilibrium/desorption tests. The results indicated that mesopore and macropore volumes increased after tectonic damage, as did the specific surface areas (SSA) and porosities. However, there was little change for the micropore volumes. Additionally, the desorption experiments indicated that the initial desorption and gas flow capacities of tectonic coal were greater than those of intact coal. Both laboratory and field results demonstrate that there is more higher lost gas for tectonic coal, which is directly influenced by the developed mesopore and macropore structure and by the initial gas desorption capacity. The logarithmic function method is a relatively better choice. When the gas content is determined in coal mines, the sampling exposure times should be kept as short as possible. From the perspective of engineering, this study provides a reference for the calculation of lost gas in tectonic coals.

- **Keywords:** Lost gas; Pore structure; Gas diffusion; Tectonic and intact coals

Renata Mariane de Souza, Daiana Seibert, Heloise Beatriz Quesada, Fátima de Jesus Bassetti, Márcia Regina Fagundes-Klen, Rosângela Bergamasco. *Occurrence, impacts and general aspects of pesticides in surface water: A review*. Pages 22-37.

A review of the main pesticides employed in agriculture found that the pesticide groups present in the highest amounts are herbicides, fungicides, and insecticides. For this reason, their occurrence in surface waters around the world, as well as their adverse effects on non-target organisms were reviewed for the period 2012–2019. Among the most common vegetal herbicides is atrazine, followed by metalochlor, both of which are widely-used on soybean and corn crops. Insecticides are used to control insects by agonizing them. Although they present low toxicity for mammals, they are toxic to ecosystems and impact the environment when present. Fungicides are employed to prevent fungal infections by damaging the cellular membrane, causing damage to non-target organisms, tebuconazole and carbendazim were the most frequent fungicides identified in surface waters throughout the world. Once pesticides reach water bodies, they can impact the whole ecological food chain, since other animals, including humans, feed on aquatic animals that may be contaminated. Another concern is the mixing of pesticides, in which case the mixture may be more toxic than any one single compound. Because mixtures of pesticides are commonly found in surface water, the need for suitable water treatment is crucial.

- **Keywords:** Herbicide; Insecticide; Fungicide; Pesticide mixture; Water treatment

Caroline Borges Agustini, Marisa da Costa, Mariliz Gutterres. *Tannery wastewater as nutrient supply in production of biogas from solid tannery wastes mixed through anaerobic co-digestion*. Pages 38-45.

The possibility of using tannery raw wastewater as substitute for the nutrient supply in the anaerobic co-digestion of two tannery solid waste was investigated with regard to energy efficiency, waste treatment efficiency and economic efficiency. The results showed that the use of tannery wastewater as a source of nutrients for the AD of solid tannery waste proved to be adequate from the point of view that the three residues are being treated simultaneously. There was a biogas production of only 1.9±0.3mL/VSS. However, the percentage of methane in the biogas reached 33 % at the beginning of the process, proving that there was methanogenic activity and that AD established. The cost analysis showed that there is a great reduction in the cost of wastewater treatment and solid waste disposal of 23 % and 18 %, respectively, in terms of electricity consumption and 11 % and 8 % respectively in terms of thermal consumption.

- **Keywords:** Tannery waste; Anaerobic digestion; Biogas; Nutrient supply

Zujing zhang, Hongwei Wu, Kequan Wang, Rodney Day, Yanping Yuan. *Air quality control in mine refuge chamber with ventilation through pressure air pipeline*. Pages 46-58.

A combined experimental and numerical study was performed to improve the performance of the ventilation system in a mine refuge chamber (MRC). In the experiment, CO2 cylinders and dispersion pipes were used to simulate the CO2 release of 50 people, and 0.1L/min per person of fresh air was provided by an air compressor. A new analytical model for a 50-person MRC was proposed and validated against the experimental data. Sensitivity analysis was carried out to investigate the effects of several control factors. The results indicated the following: (1) The ventilation system layout has a significant influence on the CO2 concentration distribution in an MRC, while the uniformity of the CO2 concentration distribution in the MRC may not be effective with increased number of air inlets. (2) Under a well-arranged ventilation system in the 50-person MRC, the average CO2 concentration can be controlled at less than 0.5 % with a ventilation rate of 0.1m3/min per person, and less than 0.2 % with a ventilation rate of 0.3m3/min per person. (3) A quantitative correlation exists between the CO2 concentration and ventilation volume rate, as well as the CO2 release rate, for an MRC under a well-arranged ventilation system.

- **Keywords:** Underground; Mine refuge chamber; Ventilation; CO2 concentration; Air quality

Mengmeng Chen, Kai Wang, Xiangluan Dong, Haili Li. *Emergency rescue capability evaluation on urban fire stations in China*. Pages 59-69.

Fire station plays an important role in ensuring the safety of people, property and environment. In order to improve the emergency rescue capability of the fire station, its influence factors are distinguished and a capability evaluation system is established in the present paper. The system is composed of goal layer, criteria layer and sub-criteria layer. The goal layer is the evaluation objective, namely, the emergency rescue capability of urban fire station. The criteria layer and sub-criteria layer contain five indexes and 25 indexes, respectively. Within the established evaluation system, the fuzzy comprehensive evaluation (FCE) method is chosen to analyze the decision problem. The weight of each index included in the system is determined based on the Analytical Hierarchy Process (AHP) method. Thus, the level of the emergency rescue capability of the fire station can be evaluated quantitatively. At last, a fire station in Zhengzhou city is taken as an example to verify the effectiveness of the established system. The results reveal that the emergency rescue capability of the fire station is in general level. Accordingly, the measures to strengthen the rescue capacity of the referred fire station are put forward.

- **Keywords:** Fire station; Emergency rescue capability; Influence factors; FCE

Arko Ghosh, Salim Ahmed, Faisal Khan, Risza Rusli. *Process Safety Assessment Considering Multivariate Non-linear Dependence Among Process Variables*. Pages 70-80.

Nonlinear dependencies among highly correlated variables of a multifaceted process system pose significant challenges for process safety assessment. The copula function is a flexible statistical tool to capture complex dependencies and interactions among process variables in the causation of process faults. An integration of the copula function with the Bayesian network provides a framework to deal with such complex dependence. This study attempts to compare the performance of the copula-based Bayesian network with that of the traditional Bayesian network in predicting failure of a multivariate time dependent process system. Normal and abnormal process data from a small-scale pilot unit were collected to test and verify performances of failure models. Results from

analysis of the collected data establish that the performance of copula-based Bayesian network is robust and superior to the performance of traditional Bayesian network. The structural flexibility, consideration of non-linear dependence among variables, uncertainty and stochastic nature of the process model provide the copula-based Bayesian network distinct advantages. This approach can be further tested and implemented as an online process monitoring and risk management tool.

- **Keywords:** Process safety analysis; multivariate process system; nonlinear dependency; copula function

Qing Zhao, Jingyu Li, Kaiwen You, Chengjun Liu. *Recovery of calcium and magnesium bearing phases from iron– and steelmaking slag for CO2 sequestration*. Pages 81-90.

Large amounts of iron– and steelmaking slag and greenhouse gas are annually produced by the steel industry worldwide. Using Ca/Mg in the slag to capture and store the CO2 via mineral carbonation is a promising approach to the reduction of waste emissions. Since iron– and steelmaking slags are a mixture of numerous types of minerals, understanding the dissolution behavior of various phases in solution system is of critical importance for Ca/Mg recovery. In this work, seven Ca/Mg–bearing phases and four typical solutions were prepared and studied. Theoretical results indicated that the order of mineral solubility in aqueous solution is as follows: (CaO and Ca2SiO4) > (Ca3MgSi2O8, Ca2MgSi2O7, and MgO) > Ca2Al2SiO7 > MgCr2O4. A batch of leaching tests was conducted at room temperature, and the recovery yield of Ca/Mg was investigated. It was found that minerals show different dissolution behavior in various systems, and the metallic oxide phases exhibited a relatively higher solubility than silicate phases. The solubility of minerals in various systems was illustrated by radar plots. Moreover, leaching tests for silicate briquettes were performed to investigate the transformation mechanism. On the basis of the results, it was proposed that a silicic acid layer generated on the surface of briquettes in the leaching process, and could transform into porous silica phase via dehydration process. The formed Si–rich layer obstructed the dissolution of inner mineral leading to a low recovery efficiency of Ca/Mg.

- **Keywords:** CO2 sequestration; Metallurgical slag; Indirect carbonation; Cleaner production; Waste management

Zhiyun Ji, Haoyu Zhou, Xiaohui Fan, Min Gan, Qian Liu, Xiaoxian Huang, Xuling Chen, Haorui Li. *Insight into the application of hydrogen-rich energy in iron ore sintering: Parameters optimization and function mechanism*. Pages 91-100.

H2-rich gas has been widely regarded as a promising energy to substitute fossil energy in iron ore sintering process for CO2 reduction. This investigation mainly focused on researching the influences of H2-rich gas injection parameters over sintering bed on sintering performance, and elucidated the potential function mechanism through both experiment and numerical simulation. Results indicated that increasing injection concentration and prolonging injection time within a proper range improved sinter quality, and the recommended value was 0.6~0.8 % and 8 min, respectively. Injecting H2-rich gas at earlier sintering stages achieved greater improvement in sintering quality compared with the ones injecting at later sintering stages, and the recommended injection area was 5~13min. Both experiment and numerical simulation results indicated that injecting H2-rich improved the thermal patterns of sintering bed, with extended high-temperature areas for increasing the generation of high-strength calcium ferrite. Especially when injecting H2-rich gas under the recommended parameters, the heat distribution in sintering bed was optimized and the sintering quality of upper sintering layer was obviously improved. Finally, an injection method for guiding the industrial

application with its essence to inject H2-rich at earlier sintering stages was proposed. The research findings provide a promising way for the efficient utilization of clean energy in iron ore sintering plants.

- **Keywords:** Iron ore sintering; Hydrogen energy; Thermal pattern; Function mechanism; Numerical simulation

Yunfei Zhu, Deming Wang, Zhenlu Shao, Xiaolong Zhu, Chaohang Xu, Yutao Zhang. *Investigation on the overpressure of methane-air mixture gas explosions in straight large-scale tunnels*. Pages 101-112.

To investigate the overpressure of methane-air explosions in straight large-scale tunnels, the computational fluid dynamics (CFD) code of Flame Accelerator Simulator (FLACS) was used and validated against experiments conducted at three different scales, and the effects of the volume concentration of methane in air, the blockage ratio (BR), the tunnel length, and the cross-section were studied. When analysed using the GaussAmp mathematical model, the maximum peak overpressure appears at a volume concentration of 10.30 % of methane in air. Blockage ratios (BR) of 0.15 and 0.3 resulted in the combustion of methane-air mixtures with the volume concentration of 6.5 % and 14.0 % of methane in air, producing a fatal overpressure of 21 kPa. When the BR increases up to 0.75, both the lean and rich mixtures cause a peak overpressure of over 60 kPa. Combustion of the same methane-air mixture produces the same overpressure, which decays approximately linearly at the same slope owing to a smooth wall roughness before travelling near the outlet, independent of the specific tunnel length. A method to characterise the cross-sections was proposed, and the maximum peak overpressure of different lengths of methane-air mixtures in different cross-sectional tunnels was found, presenting various regimes from a hump shape to a wave-like uplift and bowl shape. The cross-section parameters determine the degree of confinement and further control the maximum peak overpressure in the modelled tunnels. An exponential asymptotic model can be used to conveniently obtain the maximum peak overpressure. These phenomena indicate that approximately square-shaped cross-sections should be selected to avoid an extremely high overpressure in large-scale tunnels with the potentially significant accumulation of methane-air mixtures.

- **Keywords:** Methane-air explosion; Overpressure; Cross-section; Safety; CFD

Hahyung Pyun, Kyeongsu Kim, Daegeun Ha, Chul-Jin Lee, Won Bo Lee. *Root causality analysis at early abnormal stage using principal component analysis and multivariate Granger causality*. Pages 113-125.

As fault detection technologies have been developed, process fault diagnosis at early abnormal stage has come to be considered a major problem. In this work, a method to analyze the root cause of faults is developed to provide proper information at the early abnormal stage. First, principal component analysis (PCA) is used for the early detection of the process fault. Then, the contributions, from which the normal portion is removed, are decomposed by singular value decomposition (SVD) method to select the hierarchical sensors. Finally, the multivariate Granger causality (MVGC) method is used to construct the sensor causalities using the hierarchical sensors. The developed methodology is verified using the liquefied natural gas fractionation process model, which embeds a sufficient number of highly correlated sensors. The results are compared with the conventional principal component analysis method and amplification of the residual contribution method to verify the advantages of the proposed method.

- **Keywords:** Principal component analysis (PCA); Multivariate Granger causality (MVGC); Fault magnitude; Root causality

Xiaobin Wei, Hetang Wang, Ying Xie, Yunhe Du. *An experimental investigation on the effect of carboxymethyl cellulose on morphological characteristics of dust-suppression foam and its mechanism exploration*. Pages 126-134.

Foam dust suppression is an efficient method to control dust hazards, in which the foam morphology is closely related to its dust-suppression performance. As a commonly used foaming agent auxiliary, water-soluble polymer (e.g. carboxymethyl cellulose) is believed to be able to change foam morphology. To explore the effect of carboxymethyl cellulose (CMC) on the foam morphological characteristics, CMC was added in alpha-olefin sulfonate (AOS) solution at different concentrations and tested for the influence on bubble size, distribution and uniformity of AOS foams. The results showed that both during the foam formation and decay, the average bubble size decreased, and the foam uniformity simultaneously increased with an increase of AOS concentration, and furthermore, the size and uniformity gradually stabilized when the AOS concentration was higher than 0.1 %. After CMC addition, there is an optimal turning point (0.1 % AOS) where the effect of 800mg/L CMC addition on foam morphology is most pronounced, the average radius of bubbles could reach a minimum of 0.13mm, and the uniformity reaches the highest. Adding CMC of 800mg/L in 0.1 % AOS solution is an effective way to optimize the morphology of dust-suppression foam. This study provides important reference for using water-soluble polymer to improve the performance of dust-suppression foam in engineering.

- **Keywords:** Dust suppression; Foam; Polymer; Morphology; Bubble size; Foam uniformity

Jian Wang, Yong Wu, Ligang Zheng, Minggao Yu, Rongkun Pan, Weiwei Shan. *Study on the propagation characteristics of hydrogen/methane/air premixed flames in variable cross-section ducts*. Pages 135-143.

The flame propagation characteristics of hydrogen/methane/air mixtures with different hydrogen addition ratios (φ=0, 10 %, 20 %, 30 %, 40 % and 50 %) in different variable cross-section ducts were studied. A high-speed camera and pressure sensors were used to collect flame images and determine the overpressure dynamics. The results show that the smooth flame front will be twisted and folded, when the flame propagates to the abrupt position of the cross-section area of the duct. The larger the abrupt change rate of the duct cross-section is, the more obvious the disturbance to the flame and the more severe the turbulence. With increasing hydrogen addition ratio, the flame propagation speed and overpressure in the four kinds of variable cross-section ducts studied increase. The time for the flame front to reach the downstream end is gradually shortened, and the flame propagation time when the flame propagates from the smaller cross-section tube to the larger cross-section tube is more severely shortened with increasing hydrogen addition ratio than that when the flame propagates from the larger cross-section tube to the smaller cross-section tube. The increase of the overpressure caused by the addition of hydrogen is more significant when the flame propagates from the smaller cross-section tube to the larger cross-section tube. When the flame propagates from the smaller cross-section tube to the larger cross-section tube or from the larger cross-section tube to the smaller cross-section tube, the larger the abrupt change rate of the duct cross-section is, the larger the maximum overpressure.

- **Keywords:** Variable cross-section tube; Hydrogen/methane; Turbulent combustion; Premixed flame; Overpressure

Yifan Zhang, Shengyong Hu, Tongqiang Xia, Yingke Liu, Zhuo Pan, Fubao Zhou. *A novel failure control technology of cross-measure borehole for gas drainage: A case study*. Pages 144-156.

Chinese coal mines, which are generally of complex mining conditions, are threatened by serious coal and gas outburst and explosion accidents. Cross-measure borehole (CMB) gas drainage is one of the widely applied prevention measures, but, unfortunately, it faces some serious problems such as low gas concentration, low gas flow rate and short effective drainage period. Thus, in this study, a new in-situ failure control technology that uses fine particles to seal leakage fractures around the CMB was proposed to improve the gas drainage effect. Based on the geological background in Luling coal mine, this new technology was researched in detail. First, an air-leakage network model was established for the CMB gas drainage, and the results reveal that the gas pressure and the characteristics of leakage fracture around the borehole notably affect the gas concentration. Then, based on the in-situ failure control technology, a pneumatic conveying experiment was performed to investigate the blockage characteristics of particles in narrow straight fractures, and the optimal blockage parameters, including conveying pressure, particle mass flow rate, air flow rate and blockage particle size, were obtained for engineering application. Finally, reasonable schemes for gas drainage were designed and implemented at the new and old drilling fields to evaluate the effect of this technology. Field test results show that gas concentration grows by 40–450% for the old drilling fields and 20–280% for the new drilling fields, and gas flow rate increases by 40–90% and 60–70%, respectively. Meanwhile, the high-concentration gas drainage time is extended for approximately 2−3months. These results indicate that this new technology for CMB gas drainage is a promising measure to significantly improve the gas drainage effect in Chinese coal mines.

- **Keywords:** Gas drainage; Cross-measure borehole; Air leakage; Fracture sealing

Ahmad BahooToroody, Mohammad Mahdi Abaei, Ehsan Arzaghi, Guozheng Song, Filippo De Carlo, Nicola Paltrinieri, Rouzbeh Abbassi. *On reliability challenges of repairable systems using hierarchical bayesian inference and maximum likelihood estimation*. Pages 157-165.

Failure modelling and reliability assessment of repairable systems has been receiving a great deal of attention due to its pivotal role in risk and safety management of process industries. Meanwhile, the level of uncertainty that comes with characterizing the parameters of reliability models require a sound parameter estimator tool. For the purpose of comparison and cross-verification, this paper aims at identifying the most efficient and minimal variance parameter estimator. Hierarchical Bayesian modelling (HBM) and Maximum Likelihood Estimation (MLE) approaches are applied to investigate the effect of utilizing observed data on inter-arrival failure time modelling. A case study of Natural Gas Regulating and Metering Stations in Italy has been considered to illustrate the application of proposed framework. The results highlight that relaxing the renewal process assumption and taking the time dependency of the observed data into account will result in more precise failure models. The outcomes of this study can help asset managers to find the optimum approach to reliability assessment of repairable systems.

- **Keywords:** Repairable system; Failure modelling; Time dependency; Hierarchical Bayesian analysis; Maximum likelihood estimation

Huadao Xing, Qiming Xu, Xianzhao Song, Yongxu Wang, Bin Li, Lifeng Xie. *The effects of vent area and ignition position on pressure oscillations in a large L/D ratio duct*. Pages 166-170.

Experiments were conducted in a 2m large duct with an internal diameter of 70mm, to investigate the effects of the vent area and ignition position on pressure oscillations with different methane concentrations. The results showed that violent pressure oscillations occurred when methane concentrations were between 9.5 and 12vol. % in the closed duct. End ignition was shown to dampen the pressure oscillations to a significant extent. In addition, vented explosions could also reduce the pressure oscillations where the amplitude of the pressure oscillations decreases with increasing vented area. For a vent area of 38.5 cm2, no pressure oscillations occurred in all tests. Central ignition produced the larger pressure peak only when the vent area was small.

- **Keywords:** Pressure oscillations; Explosion venting; Methane concentration; Vent area; Ignition position

Samira Alahyaribeik, Seyed Davood Sharifi, Fatemeh Tabandeh, Shirin Honarbakhsh, Shokoufe Ghazanfari. *Bioconversion of chicken feather wastes by keratinolytic bacteria*. Pages 171-178.

Rhodococcus erythropolis, Geobacillus stearothermophilus and two Bacillus species (Bacillus pumilis, and Bacillus licheniformis) were evaluated for protease production using feathers as the sole carbon and nitrogen source. The B. licheniformis produced enzymes optimally at 40°C and pH 10.0, while B. pumilis performed optimally at 37°C and pH 7.0. Furthermore, the optimum conditions for enzyme production by G. stearothermophilus were 55°C and pH 7.0–8.0, while for R. erythropolis they were 37°C and pH 7.0. The maximum proteolytic activities of the protease produced by B. licheniformis, G. stearothermophylus and B. pumilis were 50.41, 9.91 and 35.41 U/ml after 48, 72 and 48h of culture, respectively. With R. erythropolis, the maximum enzyme activity was 33.39 U/ml after 96h of culture. Also, the production of soluble protein showed the same pattern as that of proteolytic protease. When the initial pH value was 10.0, culturing the feathers (30g l−1) for four days at 40°C resulted in the maximum production of soluble proteins (8.28mg/ml) by B. licheniformis. These results suggest that new strategies for waste management have emerged after the introduction of keratinases in sustainable material development, which has industrials applications in green technologies.

- **Keywords:** Protease activity; Biodegradation; Poultry waste; Rhodococcus erythropolis; Bacillus licheniformis

Paul R. Amyotte. *What went right*. Pages 179-186.

Learning from process industry case histories is most often centred on management system elements, equipment components (including safety devices), and the actions of personnel that led to failure in achieving intended outcomes. Hence there can be a tendency to focus on things that went wrong. In this paper we explore the idea of focusing on things that went right – on events, resources, and concepts in which there is strong evidence of process safety success. It is concluded that learning lessons in this manner can serve as a helpful complement to the more traditional avenue of learning from process safety failure.

- **Keywords:** Case histories; Lessons learned; Process safety communication; Process safety success

Jason Gill, Graham Atkinson, Edmund Cowpe, Herodotos Phylaktou, Gordon Andrews. *Experimental investigation of potential confined ignition sources for vapour cloud explosions*. Pages 187-206.

Electrical control boxes are common on high vapour cloud hazard sites, and in the case of the Buncefield explosion the ignition source was inside such a box, that was sited in an emergency pump house building. There has, however, been relatively little previous

research into this type of ignition mechanism and its effect on the explosion severity. Commercially available electrical control boxes measuring 600mm high, 400mm wide and 250mm deep were used to explore the pressure development, venting processes and flame characteristics of stoichiometric propane/air explosions using aluminium foil and the supplied doors as vent coverings. In some tests, the boxes were empty in order to establish a baseline for the effect of the internal congestion of the boxes. In other tests a congestion array was added. It was found that, in both the empty and congested box tests, the door produced a flat petal shaped flame, which differed drastically from the mushroom flame shape and associated rolling vortex bubble venting that is traditionally observed with large orifice vented explosions.

- **Keywords:** VCE; Vapour cloud explosion; Vented explosion; Bang-box ignition; Nested ignition; Confined ignition sources; Buncefield

Min Li, Hetang Wang, Deming Wang, Zhenlu Shao, Shan He. *Risk assessment of gas explosion in coal mines based on fuzzy AHP and bayesian network*. Pages 207-218.

Gas explosion is one of the most deadly hazards in underground coal mining. Risk assessment has played an effective role in avoiding gas explosions and revising coal mine regulations. However, the traditional methods are deficient in quantitative evaluation, dynamic control and dealing with uncertainty. In this paper, a method of quantitative assessment the risk of gas explosion in underground coal mine using Bayesian network was proposed. A fuzzy analytic hierarchy process (FAHP) method based on subjective and objective information of experts was developed in the process of fuzzification. Through the Bayesian inference, the probability of occurrence of potential risk events and the probability distribution of risk factors can be calculated in real time according to on prior knowledge and evidence updating. Meanwhile, the most likely potential causes of accidents can be determined. A sensitivity analysis technique was utilized to investigate the contribution rate of each risk factor to a risk event, so as to determine the most critical risk factor. Taking Babao Coal Mine in China as the case, this study conducted a gas explosion risk assessment. The results show that the mothed of fuzzy AHP and Bayesian Network is feasible and applicable. It can be used as a decision-making tool to prevent coal mine gas explosions and provide decision makers with a technical guide for managing the coal mine gas explosion risk.

- **Keywords:** Bayesian network; Fuzzy number; Gas explosion; Risk assessment

Bin Zhang, Shang-Hao Liu, Jie Liu, Zhi-He Zhang, Bin Laiwang, Chi-Min Shu. *Thermal stability and flammability assessment of 1-ethyl-2, 3-dimethylimidazolium nitrate*. Pages 219-227.

1-Ethyl-2, 3-dimethylimidazolium nitrate [C2mmim][NO3] is a typical solvent for industrial applications. Under inappropriate temperatures, [C2mmim][NO3] may present a flammability hazard due to thermal decomposition. This study investigated the thermal stability and flammability of [C2mmim][NO3] via simultaneous thermogravimetric analyzer, homemade combustion test device (CTD) with high speed camera, and thermogravimetry coupled with Fourier transform infrared spectroscopy (TG-FTIR). The thermal decomposition of [C2mmim][NO3] was divided into two parts based upon the dynamic experiments, and the maximum operating temperature was determined to comprehensively estimate the thermal stability of [C2mmim][NO3]. CTD experiments indicated that [C2mmim][NO3] could produce intense combustion when heated. Further TG-FTIR experiments confirmed that [C2mmim][NO3] decomposed to produce a large number of flammable gases, such as ethylene, which might be the reason that [C2mmim][NO3] has prominent flammability.

- **Keywords:** Flammability hazard; Thermal decomposition; Simultaneous thermogravimetric analyzer; Combustion test device; Maximum operating temperature

Xiangyang Xing, Xue Han, Lei He, Jiali Cheng, Fuyong Zhong, Jiazheng Sun, Zhenwu Tang. *Organic ultraviolet-absorbing materials in street dust from Hefei, China: Concentrations, profiles, and human health risks*. Pages 228-235.

Organic ultraviolet absorbents (UVAs) are widely found in the environment. However, little is known about UVA distributions in street dust and the risks they pose to human health. We determined the concentrations of 12 UVAs in street dust from cultural, residential, traffic, and industrial areas in Hefei, China. 4-Methylbenzylidene camphor was not detected in the street dust samples. The total concentration range of the 11 other UVAs (Σ11UVAs) in the street dust samples was 6.42–94.2ng/g. Octocrylene was the dominant UVA, contributing 53.8 % of the Σ11UVA concentrations. The UVA concentrations were higher in dust from the industrial area than in dust from cultural, residential, and traffic areas. Source analysis was performed, and industrial activities and the use of cosmetics and personal care products were found to be the main sources of UVAs in street dust. The health risks posed to humans exposed to UVAs in street dust in Hefei were generally low. More research is required to improve our understanding of the health risks posed to humans exposed to UVAs through other pathways.

- **Keywords:** Organic ultraviolet absorbent; Street dust; Distribution; Source; Health risk

Omid Pourehie, Javad Saien. *Homogeneous solar Fenton and alternative processes in a pilot-scale rotatable reactor for the treatment of petroleum refinery wastewater*. Pages 236-243.

Applicability of the solar Fenton process for the treatment of a real refinery wastewater was investigated. A novel solar-reactor was used with the capability of automatic rotating against the sun, enabling maximum utilization of direct and single reflective sunlight beams. The COD and TOC criteria were measured to follow the pollutants removal. Results revealed optimal operating conditions of 694.7mg/L hydrogen peroxide, 67.3mg/L ferrous salt and solution pH of 3.2. Under these conditions, COD and TOC were, respectively, decreased to 79.6 and 73.2 % after 180min sunlight envision. For comparison, alternative H2O2 / Fe2+, S2O82- / Fe2+, NaOCl / Fe2+, NaOCl, S2O82- and H2O2 processes, all activated with sunlight, were performed. The present pollutants were identified by means of the GC/MS headspace technique, showing significant removal of the majority of petroleum aliphatic and aromatic hydrocarbons and that biodegradability was feasible since BOD5/COD reached from 0.36 to 0.62. The process performance was compared with the previously reported similar processes for treating specified pollutants and wastewaters. High preference of the employed process using the particular solar-reactor was probed based on different criteria. Meanwhile, the total operating costs was estimated to be quite low, compared to other processes.

- **Keywords:** Solar Fenton; Solar-reactor; Refinery wastewater; Biodegradability; Operating costs

Peipei Sun, Zhirong Wang, Yawei Lu, Shuoxun Shen, Rongrong Yang, Anxue Xue, Trent Parker, Jian Wang, Qingsheng Wang. *Analysis of the corrosion failure of a semiconductor polycrystalline distillation column*. Pages 244-256.

Distillation column is a fundamental device for the production of the semiconductor polysilicon. Therefore, investigating corrosion leakage protection of the distillation column is of great significance because of the undetectable yet very significant consequences of corrosion leakage to the column. In this work, corrosion investigation of a polycrystalline silicon rectification tower is presented. The composition and crack morphology of the distillation column (316L austenitic stainless steel) were detected and analysed using component and hardness analysers. The effects of pH and temperature on the corrosion rate were studied by conducting electrochemical experiments. According to the macroscopic test results, the surface of the tower was covered with a large number of pits and cracks of different depths. Furthermore, based on the metallographic analysis, SEM analysis, and energy spectrum analysis results, it was determined that the crack morphology was mostly intergranular and transgranular. Combined with the test data and process environment, it has been determined that the main forms of corrosion for rectification towers are pitting corrosion and stress corrosion caused by chloride ions. According to the results of electrochemical experiments, the corrosion rate of 316L stainless steel is negatively correlated with pH value for a pH range of 4–6at constant temperatures. However, the corrosion rate is positively correlated with temperature for the range of 60°C–90°C at constant pH values. From the analysis of the corrosion morphology, the corrosion failure mode of 316L stainless steel is largely attributed to pitting corrosion when the column is operated at low temperatures (60°C and 70°C). However, at high temperatures (90°C), a transformation from pitting corrosion to stress corrosion occurs along the crystalline form. To ensure the stable operation of the polysilicon rectification tower, this paper proposes corrosion protection measures based on the results of the analysis as described.

- **Keywords:** Stainless steel; Stress corrosion cracking; Electrochemical experiment; Influence factor; Corrosion measures

Mingyao Wei, Enyuan Wang, Xiaofei Liu. *Assessment of gas emission hazard associated with rockburst in coal containing methane*. Pages 257-264.

The stress field and gas seepage field of methane react upon each other in the process of rockburst in coal seam containing methane. Therefore, it is important to reveal the coupling mechanism between them. Due to the fact that volumetric strain describes the development of fracture, damage evolution equation for coal is built by accounting volumetric strain as an internal factor. The evolution models for porosity and permeability are built by considering the effect of shear dilation on fracture deformation. A gas-solid simulation software called TOUGH2(CH4)-FLAC is developed based on effective stress equation and permeability model which is coupled by linking two existing simulators (TOUGH2 and FLAC3D). A simulation case for gas flow in process of rockburst is carried out. The simulated result indicates that several bands of failure zone were caused by dynamic disturbance forming spall in deep coal. Methane in sorption state turns into desorption and flows out rapidly through damage-induced path that result in a rise of methane concentration in roadway shortly. The simulation results reveal the mechanism of extreme gas emission after disturbance induced by rockburst.

- **Keywords:** Rockburst; Gas emission hazard; Numerical simulation; Gas-solid coupling model; Damage constitutive model

Bárbara Maria Borges Ribeiro, Tânia Miyoko Fujimoto, Bianca Gvozdenovic Medina Bricio, Ursula Luana Rochetto Doubek, Edson Tomaz. *Gas-phase aromatic compounds degradation by a partially TiO2 coated photoreactor assisted with ozone*. Pages 265-272.

Heterogeneous photocatalysis with TiO2 have been studied for VOCs degradation; however, aromatic VOCs degradation lead TiO2 deactivation. The objective of this study was to degrade aromatic VOCs by heterogeneous photocatalysis avoiding TiO2 deactivation. The experiments were conducted using a UV-C lamp (254nm), relatively humidity (RH – 26–60 %), and ozone (O3 – 2.38 to 5.35 %). Due to O3 addition, it was necessary to have uncoated regions in the quartz tube around the lamp to allow UV photons to reach the gas bulk and generate radicals from O3. Different quartz tube coating fractions were tested to analyze its influence on VOCs degradation. The highest toluene degradation was 99.2 % for the reactor with 90 % of coating, 3.4 % of O3, space time of 123s, and RH of 26 %. It was observed RH greater than 26 % affected the degradation achieved. Ozone addition allowed TiO2 use for 77h avoiding early catalyst deactivation. Besides that, the requirement of uncoated regions indicated that VOC oxidative reactions occur both on solid and gas phases. This suggested that the addition of O3 combined with the reactor configuration is a promising alternative for aromatic compound degradation by heterogeneous photocatalysis.

- **Keywords:** Volatile organic compound; Aromatic compound; Heterogeneous; p Hotocatalysis; Ozone; Titanium dioxide

Zhenwei Han, Dan Wang, Peng Jiang, Hong Sui, Lin He, Xingang Li. *Enhanced removal and recovery of binary mixture of n-butyl acetate and p-xylene by temperature swing–Vacuum pressure swing hybrid adsorption proces*. Pages 273-281.

The adsorption and desorption behaviors of two polar-nonpolar typical VOCs (n-butyl acetate and p-xylene) on activated carbon have been investigated by a temperature swing -vacuum pressure swing adsorption (TS-VSA) hybrid process. This hybrid process allows the maximal concentration enrichment (desorbed concentration to feed concentration ratio) of n-butyl acetate (BAC) and p-xylene (PX) to increase from 9.6 to 22.7 and 9.0 to 18.6, respectively. This enrichment could not only significantly improve the desorption efficiency of the total adsorbed VOC mixture (over 30 %) compared with those of single TSA (Temperature swing adsorption) or VSA (vacuum pressure swing adsorption), but also reduce the desorption time and energy consumption. Based on the thermodynamic adsorption properties of n-butyl acetate and p-xylene, the optimized desorption conditions are determined to be at 65°C, 7.0kPa and 0.85L/min of stripping gas. The recycling tests further show that the activated carbon could stably run for the removal and recovery of VOCs using this hybrid process with over 85 % of adsorption capacity being kept. This test suggests that the TS-VSA hybrid process would be promising process for the engineering removal and recovery of VOCs (single component or mixtures) using activated carbons or other adsorbents.

- **Keywords:** VOCs; Hybrid adsorption; n-Butyl acetate; p-Xylene; Activated carbon

Long Ding, Faisal Khan, Jie Ji. *Risk-based safety measure allocation to prevent and mitigate storage fire hazards*. Pages 282-293.

Fire is a main threat to property and human safety in materials storage of process industry plants as well as other industrial sectors, and risk management of materials storage fires is challenging due to potential accident causes and various safety measures. Complex accident causes, severe consequences, and effective safety measures have been the main concerns of industrial companies and researchers. However, for storage fires, a generic risk management model is absent. Bow-tie is an effective method to reveal causal relationships of accident causes, safety barriers, and possible accident consequences. In this study, based on bow-tie analysis, a generic framework for quantitative risk management of storage fires is established via analysis of previous storage fires. Pertinent safety measures are presented, allocation and efficacy of these safety measures to reduce storage fires risk is investigated. Finally, the methodology and

proposed generic framework is applied to a major storage fire accident for a case study, the probabilities of fire accident and consequences are reduced significantly, which shows the efficacy and applicability of the proposed approach. The generic framework established in the present study can be tailored to various storage fire accidents with limited manipulation; and also, allocation and implementation of pertinent safety measures can reduce storage fires risk significantly.

- **Keywords:** Storage fire; Risk management; Risk analysis; Bow-tie; Safety measure

Lei Ni, Jiawei Cui, Juncheng Jiang, Yong Pan, Hao Wu, Chi-Min Shu, Zhirong Wang, Shanjun Mou, Ning Shi. *Runaway inhibition of styrene polymerization: A simulation study by chaos divergence theory*. Pages 294-300.

We attempted to prevent the thermal risk of a runaway reaction of polymerization in a batch reactor and to realize online monitoring and emergency inhibition of the thermal runaway behavior. Styrene thermal initiation of bulk polymerization was studied. A full-size model of the styrene polymerization reactor was constructed by referring to the reactor model of the Mettler Toledo automatic calorimeter, which was combined with the kinetic and thermodynamic models of styrene polymerization. The DIV thermal runaway critical criterion based on chaos divergence theory was used to judge the thermal runaway reaction. The critical point of the runaway reaction was determined and used to inhibit the thermal runaway of styrene polymerization by injecting cooling diluents at the liquid surface. The influence of injection rate (vc=0.5、0.8、1m/s), injection position (in-1、in-2、in-3), and amount of cooling diluents (no add、50 %、70 %、100 %) injected on the thermal runaway inhibition of the reaction was investigated and elucidated. The results indicated that a better inhibiting effect can be obtained by injecting the inhibitors at higher rates near the edge of the paddle blade. Moreover, appropriately increasing the injection amount of the inhibitors can achieve better inhibition of the runaway reaction.

- **Keywords:** Thermal risk; Full-size model; Automatic calorimeter; Critical point; Injection rate

Hossein Mashhadimoslem, Ahad Ghaemi, Amir Hossein Behroozi, Adriana Palacios. *A New simplified calculation model of geometric thermal features of a vertical propane jet fire based on experimental and computational studies*. Pages 301-314.

Jet fires and their consequences are one of the significant factors responsible for catastrophic events in industrial process units. In this research, various types of turbulence models were investigated to simulate a vertical propane jet fire using computational fluid dynamics (CFD). CFD was applied to evaluate the following turbulence models of k-ε, SST, BSL, BSL RS and the Realizable k-epsilon (RNG k-ε), the Eddy Dissipation Concept (EDC) for combustion, and the Monte Carlo model for radiation. All the above-mentioned turbulence models are used for a temperature range of 1500–1700K. The results showed that the SST turbulence model is the best option, with average error of 4.7 % for a jet fire simulation, with a lower computational time. The simulation of the jet fire shape at surface temperature of 800K was also compared with the experimental data obtained under the same conditions. By taking into account the time parameter in the simulation, the predicted ratio of flame length and equivalent flame diameter results are in good agreement with the experimental jet fire data.

- **Keywords:** Jet fire; Flame length; Turbulence model; Propane; CFD simulation; Radiation model

E. Rivas, M.A. Martín-Lara, G. Blázquez, M.J. Muñoz-Batista, A. Pérez, M. Calero. *Toward an efficient multi-step separation protocol to recover metallic components from waste leachates*. Pages 315-322.

This work presents a study of the separation and recovery of metal elements, through a multi-step protocol based on solvent extraction, stripping and chemical precipitation processes. The waste leachate was produced during the treatment of the mixed solid waste from the decommissioning of a coal-fired power plant. The organophosphorus acid, di-(2-ethylhexyl) phosphoric acid (DEHPA) was investigated as organic extracting agent during the solvent extraction (Step 1). A factorial design with three levels for the organic phase/aqueous phase ratio (O/W), DEHPA concentration and contact time were carried out and a prediction model obtained using a neural-fuzzy approach. Optimized extraction values for Ti (93.4 %), (V) 94.6 % and (Zn) 89.8 % were obtained using 60min of contact time, a DEHPA concentration of 0.5M and O/W ratio of 4. Stripping tests were performed using HCl, H2SO4, NaOH and KOH as stripping agents. The stripping step (step 2) showed optimum results (82 % of Zn and 31 % of V) using 1M H2SO4 solution as stripping agent. A selective precipitation step (step 3) allowed the final separation of metals in aqueous solutions produced in Step 1 and 2. The results showed that an effective separation of Mn and Ni could be carried out at pH 9, while the best separation results for the solution obtained during the stripping step, which contains V and Ti, was obtained at pH 12.

- **Keywords:** Leachates; Solvent extraction; Stripping; Chemical precipitation; Metal recovery

Imen Khouni, Ghofrane Louhichi, Ahmed Ghrabi, Philippe Moulin. *Efficiency of a coagulation/flocculation–membrane filtration hybrid process for the treatment of vegetable oil refinery wastewater for safe reuse and recovery*. Pages 323-341.

Treatment of real (RVORW) and synthetic (SVORW) vegetable oil refinery wastewaters using membrane filtration system was experimentally studied. Experimental runs with SVORW were used to identify the best conditions to perform with RVORW treatment. The bench-scale experiment was carried out using a commercial ceramic 0.245m2 ultrafiltration (UF) membrane (150kDa) in cross-flow filtration (CFF) mode at a flow rate of 3000 L·h−1 and a trans-membrane pressure (TMP) of 1.2bars. However, such membrane is vulnerable to fouling and it is insufficient to give water of good quality suitable for reuse. This investigation, aims to improve the purification performances of UF by exploring its combination with other treatment options, i.e. optimized coagulation/flocculation (CF) as pre-treatment and dead-end filtration (DEF) as post-treatment for better treated-water quality. According to the results, when using CF as pre-treatment under optimal conditions (2.4 g·L-1of aluminium sulfate, 60.05 mg·L-1 of CHT flocculant, under initial pH of 9.23), the hybrid CF/UF process allows to achieve the best treated RVORW water quality with turbidity, COD and TOC removals reaching 100 %, 98 % and 97 % respectively compared to those of CF and UF used separately, with membrane permeability of 135 L·h−1·m-2·bar−1 which is in agreement with an industrial application.

- **Keywords:** Coagulation/Flocculation; Hybrid process; Membrane filtration; Oily wastewater

Yueping Qin, Yipeng Song, Wei Liu, Jun Wei, Qianlong Lv. *Assessment of low-temperature oxidation characteristics of coal based on standard oxygen consumption rate*. Pages 342-349.

To investigate the low-temperature oxidation characteristics of coal, programmed heating and oxidation experiments were conducted on single-particle-size coal samples from different mines. The inlet and outlet oxygen concentrations of the coal sample tank were measured to calculate the standard oxygen consumption rate (SOCR) of each coal sample at different temperatures. The relationship between the SOCR and temperature was fitted by an exponential function, and two regression coefficients (A and B) related to the spontaneous combustion characteristics of coal were obtained, and the effects of both A and B on the spontaneous combustion of coal was analyzed. The results show that the A and B values are related to the physical structures and chemical properties of coal, respectively. Accordingly, taking the A and B values of single-particle-size coal samples as the basic parameters, a new identification index describing the spontaneous combustion of coal is proposed. Compared with the chromatographic oxygen absorption method, the newly proposed identification index can reflect the degree of difficulty of spontaneous coal combustion more truly and intuitively. This research is of theoretical and practical significance for evaluating the characteristics of spontaneous coal combustion.

- **Keywords:** Coal; Granularity; Heating and oxidation experiment; Standard oxygen consumption rate; Spontaneous combustion tendency

Dingli Liu, Zhisheng Xu, Zhengyang Wang, Chuangang Fan. *Regional evaluation of fire apparatus requirements for petrol stations based on travel times*. Pages 350-363.

The safety of petrol stations is critical because it stores flammable and explosive gasoline and diesel. Therefore, appropriate fire apparatuses should be deployed to petrol stations in case of a fire emergency. In this work, we proposed a regional evaluation model to predict the fire apparatus requirements of petrol stations based on travel times extracted from online maps. The travel time of the minimum fire apparatus requirements (1 water truck and 1 foam truck) are determined to be within 4min. To validate the model, 37 fire stations and 458 petrol stations in Changsha, China were considered as case studies leading to 144 evaluation scenarios. The results showed the fire apparatus requirement scores of 144 scenarios were ranged from 47.69 to 56.69 (less than 60) out of 100, which were in bad levels. Furthermore, results from visualization showed that the worst part of scores were petrol stations in rural areas. Therefore, these petrol stations in rural areas should be equipped with more fire extinguishers and foam extinguishing systems.

- **Keywords:** Petrol station; Fire apparatus requirement; Evaluation; Travel time

Imen Khouni, Ghofrane Louhichi, Ahmed Ghrabi. *Assessing the performances of an aerobic membrane bioreactor for textile wastewater treatment: Influence of dye mass loading rate and biomass concentration*. Pages 364-382.

Textile industry is being a very demanding consumer of high-quality water with highest wastewater discharge. Membrane bioreactor (MBR) was employed widely to treat dying effluents due to its distinct advantages over conventional techniques. This study investigated the potential of biological treatment employing a microbial community 'IHK22' under MBR laboratory-scale conditions to decolourize reconstituted textile wastewater in order to be reused. First, the bioreactor was conducted at a low biomass concentration of 4 gMLVSS·L−1. Decolourization performances were maintained at very high rates (91–100 %) for dye mass loading rates in the range of 1.25–2.5 mg·gMLVSS-1·d-1. Then, the dye concentration was increased to 7.5 mg·gMLVSS-1·d-1, the decolourization performances of the MBR have been affected (80–87 %). When the biomass concentration has been increased to 8gMLVSS·L−1, thus, a total MBR decolourization was then observed (100 %). Under 320 mg·gMLVSS-1·d-1 and regardless

of the operating period of the MBR, all the microorganisms and microfiltration membrane allow the elimination of most soluble organic matter of the treated effluent (80–90 %). Obtained results indicate that the dye mass loading rate can influence the efficiency of dye removal through an MBR. The use of an appropriate biomass concentration significantly improves the MBR performances for an effective textile wastewater treatment.

- **Keywords:** Membrane bioreactor; Textile wastewater; Reactive dye; Decolourization; Organic matter removal