# Process Safety and Environmental Protection

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**Niresh Behari.** ***Assessing process safety culture maturity for specialty gas operations: A case study*****. Pages 1-10.**

A process safety culture maturity assessment was conducted for the specialty gas processing sector that has the following sections: Gas-to-Liquid, Effluent and Disposal, Ammonia and Steam Utilities plants. The assessment utilised human factors dimensions related to man-machine, employee job roles and organizational culture interfaces. Numerous global process safety incidents resulted in catastrophic consequences originated from human factors and have encouraged the investigation of underlying human and organizational behaviors to manage key process safety risks. The research construct used a process safety culture assessment toolkit, perception survey and interviews, hydrocarbon leak incident history with audit results to assess implementation effectiveness of process safety management systems. Leadership behaviors that hindered process safety maturity included unwillingness to accept accountability, employee blame, fear and lack of trust were associated with inadequate process safety incident reporting and organizational learning. High level human factors risks identified from the case study were additional resources required to update operating procedures, competence of critical staff and ineffective safety communication that have created process safety incidents. Four process safety maturity models were used for the research based on commitment towards continuous improvement; incident reporting effectiveness and examining interdependent team leadership behaviors through process safety balance scorecard metrics. Process safety maturity levels in decreasing order were Gas-to-Liquid, Ammonia, Effluent and Disposal, and Steam Utilities plants.

- **Keywords:** Human factors; Hydrocarbon leaks; OSHA process safety management; Process safety culture; SWOT; Team leadership behaviors

**Chang Lu, Hongbo Wang, Rongkun Pan, Yunpeng Zhang, Minggao Yu.** ***Preventing the propagation of gas explosion in ducts using spurted nitrogen*****. Pages 11-23.**

This study discusses the use of nitrogen to prevent the propagation of an explosion in a horizontal duct in an effort to reduce the damage caused by gas explosions. Accordingly, the vent is set on the top surface of the duct. The two nitrogen nozzles are set near the vent and at a downstream location. The results show that when the nitrogen pressure reaches or exceeds 0.3 MPa, spurting nitrogen can prevent the explosion from propagating along the duct. When the nitrogen pressure is 0.1 MPa, it fails to prevent the explosion. When the nitrogen pressure is 0.2 MPa, the explosion propagation can be

prevented in most experiments but not in all of them. As the nitrogen pressure increases, the position for preventing the explosion gradually shifts forward from the second nozzle to the first nozzle. At lower nitrogen pressures (i.e., 0.2 MPa), an early spurt of nitrogen can prevent the explosion, while a delayed spurt of nitrogen may not be able to prevent it. The distribution of the speed of the explosion flame along the duct exhibits two peaks. The regularity of the overpressure is similar to that of the flame speed.


- **Keywords:** Gas explosion; Methane; Propagation prevention; Venting; Spurted nitrogen


### Bilal Hussain, Tayyaba Sultana, Salma Sultana, Khalid Abdullah Al-Ghanim, F. Al-Misned, Shahid Mahboob. *Influence of habitat degradation on the fatty acid profiles of fish, microalgae, and zoobenthos in a river ekosystem*. Pages 24-32.


This study was conducted to assess the effect of heavy metals (Cd, Hg, Cu, Mn, Zn, Pb, Cr, and Sn) on the fatty acid profiles of Catla catla, Labeo rohita, and Cirrhinus mrigala collected from two polluted sites in the Chenab River and Jhelum River (non-polluted site). The heavy-metal levels were determined using atomic absorption spectrophotometry. The results showed that the levels of Cd, Hg, Cu, Mn, Zn, Pb, Cr, and Sn in the river water exceeded the permissible limits recommended by various international agencies. Some important fatty acids were not detected in the muscle samples of the fish species collected from the highly polluted site (HPS). Caprylic acid (C8:0) and lauric acid (C12:0) were undetectable in Catla catla and Cirrhinus mrigala. Palmitoleic acid and eicosapentaenoic acid were present in Catla catla alone, and they were not found in Labeo rohita and Cirrhinus mrigala harvested from a less polluted site (LPS). More saturated fatty acids and less fatty acids were detected in the muscle samples of Catla catla, Labeo rohita, and Cirrhinus mrigala collected from HPS than in those collected from LPS. The untreated discharge of domestic and industrial waste probably causes a reduction in the fatty acids in the biomass of microalgae and zoobenthos and, ultimately, adversely affects the upper links of the food chain in the river.



- **Keywords:** Heavy metal; Fish; Muscle; Phytoperiphyton; Lipid; Fatty acid


### Ming-ming Fu, Qian Zheng, Shuai He, Yiran Yan, Xiaohui Wang. *Oxygen control mechanism in non-ventilation excavation based on the simultaneous mining of coal and gas*. Pages 33-38.


A new type of non-ventilation excavation system model, which is based on the theory of simultaneously exploiting coal resources and gas from high-gas coal seams in a closed space, is established, consisting of a central ventilation tunnel and a non-ventilated excavating roadway. The respiration and comfort of the mining personnel, as well as gas control, are investigated. The nitrogen curtain is activated prior to opening the air door to replace the gas in the air perturbation space with nitrogen. The nitrogen curtain is simultaneously activated in the barotropic zone to prevent the flow of oxygen into the excavating roadway. The gas pressure relationship between different zones is studied when the air door is closed. The gas pressure only allows nitrogen to flow from the barotropic zone to the central tunnel zone, which ensures that the oxygen is effectively controlled under the closed air door condition. The proposed mechanism for blocking oxygen in the bypass tunnel is validated via the building analogy simulation and numerical simulation model. The presented non-ventilation excavation design efficiently blocks oxygen via simultaneous control of the air door and nitrogen curtain. This study provides a theoretical foundation for the application of non-ventilation excavation processing.

- **Keywords:** Non-ventilation excavation; Nitrogen curtain; Differential pressure; Oxygen control

**Yuguo Wu, Xiaoyang Yu, Shengyong Hu, He Shao, Qi Liao, Yurong Fan. *Experimental study of the effects of stacking modes on the spontaneous combustion of coal gangue*. Pages 39-47.**

Coal gangue is a solid waste material which is generated during coal mining processes. Due to its low utilization value, it is normally discarded on gangue fields where it is stacked into very large hill formations. Spontaneous combustion is one of the major hazards which frequently occur during the long-term stacking of coal gangue. This study targeted the coal gangue stacks of the Chengzhuang Coal Mine, located in China's Shanxi Province. The results of programmed heating tests helped determine that CO and C2H4 could be used as the index gases in the predictions of the self-heating degrees of coal gangue. Four of the typical coal gangue stacking modes which were often adopted by the Chengzhuang Mine were selected as the experimental objects of this study. The corresponding coal gangue models were piled in a field, and the self-heating degrees were measured with the passage of time. The entire experiment lasted for 60 days. The results showed that the loess isolation and loess stratified stacking methods could effectively suppress the self-heating processes. Also, the CO production and O2 consumption of the coal gangue were consequently reduced. The study also indicated that in the loess stratified stacking, the inhibitory effects on the spontaneous combustion of the coal gangue had increased with the increased thicknesses of the loess layers.

- **Keywords:** Coal gangue; Spontaneous combustion; Stacking mode; Experimental

**Pratik Krishnan, Anas Al-Rabbat, Bin Zhang, Dali Huang, Lecheng Zhang, Minxiang Zeng, M. Sam Mannan, Zhengdong Cheng. *Improving the stability of high expansion foam used for LNG vapor risk mitigation using exfoliated zirconium phosphate nanoplates*. Pages 48-58.**

Natural gas consumption has increased as it is a cleaner energy source when compared to coal or petroleum. It can be stored in its liquid form as liquefied natural gas (LNG) because it has a much lower liquid volume. This has allowed ease of storage and transportation enabling it to be used as a global commodity. In case of an incident resulting in leaked LNG, the National Fire Protection Agency (NFPA) and American Gas Association (AGA) recommend high expansion foam use to mitigate the risk due to a cryogenic vapor cloud. This work investigates the role of exfoliated zirconium phosphate (ZrP) nanoplates in stabilizing high expansion foam. Experiments performed under wind induced forced convection and thermal radiation illustrate that exfoliated ZrP nanoplates can stabilize high expansion foam. Up to 40% reduction in the foam breakage rates was observed when using exfoliated ZrP nanoplate stabilized foam. Use of this foam can increase the duration over which it needs to be replenished, while allowing rising LNG vapors to become lighter by exchanging heat with the foam and ensuring effective vapor dispersion.

- **Keywords:** Liquefied natural gas (LNG); Vapor cloud; High expansion foam; Mitigation; Zirconium phosphate nanoplates

**Pricila Marin, Rosângela Bergamasco, Aparecido Nivaldo Módenes, Paulo Roberto Paraiso, Safia Hamoudi. *Synthesis and characterization of graphene oxide functionalized with MnFe2O4 and supported on activated carbon for glyphosate adsorption in fixed bed column*. Pages 59-71.**

Glyphosate removal from contaminated water using a new adsorbent material was investigated. Graphene-MnFe2O4 nanocomposite supported on vegetal activated carbon

(GO-MnFe2O4/VAC) was synthesized. Several characterization techniques such as transmission and scanning electron microscopy, N2 physisorption, energy dispersive X-ray spectrometry, Fourier transformed infrared spectroscopy, X-ray diffraction and Raman spectroscopy were used to have insights to this material. Furthermore, the point of zero charge was determined. GO-MnFe2O4/VAC material was evaluated for glyphosate adsorptive removal in fixed-bed column under different operating conditions of solution concentration and feed flow rate. The results pointed out that glyphosate adsorption using GO-MnFe2O4/VAC was favored at pH values between 2.29 and 6.14. In fixed-bed column, the best results were obtained for the solutions having higher concentrations and also for higher feed flow rates. The equilibrium experimental data were fairly described by Langmuir model with maximum adsorption capacity reaching 6.778 mg g−1. Among the mathematical models evaluated to describe the breakthrough curves, the best fit to the experimental data was obtained by model that considers the intraparticle diffusion and the internal diffusion step was considered to be the mass transfer limiting step. The present results indicated that the adsorbent material synthesized has a great capacity for adsorption and prove the potential of use of GO- MnFe2O4/VAC for glyphosate removal from contaminated water in the continuous mode of operation.

- **Keywords:** Graphene; MnFe2O4; Glyphosate; Adsorption; Fixed bed

### Chengwei Xu, Wenxia Xie, Yan Yu, Jun Zhang, Jiangang Yang. *Photocatalytic and Filtration performance study of TiO2/CNTs-Filter for oil particle*. Pages 72-78.

Carbon nanotubes (CNTs) with large aspect ratio and specific surface area have the potential in oil liquid particle filtration and catalysis substrate field. In this work, we synthesized the TiO2/CNTs-filter for removing oil particle. Compared with the CNTs-filter, we found that the TiO2/CNTs-filter has smaller pore sizes, higher specific area. TiO2/CNTs-filter shows the excellent filtration performance which is higher than the high efficiency particulate air (HEPA) filter. In addition, the initial pressure drop of TiO2/CNTs-filter is close to conventional HEPA filter and the raise ratio of pressures drop at equilibrium states is less than conventional HEPA filter. Furthermore, the degradation rate of initial state and saturation state reach to 94.5 and 724 μg cm-2 h-1 in first 20 h respectively. At last, we simply discuss the application the composite filter on filtering cooking fume.

- **Keywords:** carbon nanotubes; oil particle; filtration; photocatalytic; composite filter

### Peidong Su, Junke Zhang, Yadong Li. *Investigation of chemical associations and leaching behavior of heavy metals in sodium sulfide hydrate stabilized stainless steel pickling sludge*. Pages 79-86.

This article presents an original study on stabilization of heavy metals in SSPS using sodium sulfide hydrate. The speciation and pH dependent leaching of the target heavy metals (Cr, Cu, Ni and Zn) based on GB 5085.3 and GB 16889 in both raw SSPS and stabilized products were examined. Results indicated that Cr and Ni are the two main toxic elements in SSPS. The BCR sequential extraction indicated that 55.2% of Cr in raw SSPS exist as Fe-Mn oxides, while water soluble Cr which is mainly consists of Cr(VI) accounts for 3.50%. After stabilization, the residual fraction Cr reached to more than 60% and Cr(VI) was not detected. The leaching concentration of Ni meets the limit of reuse SSPS, meanwhile, the sum proportion of sulfides and residual Ni increased from 8.68% to a maximum value of 31.82%. pH dependent leaching tests expound that the leaching concentrations of Cr, Ni, Cu and Zn are significantly high at pH = 2. The leaching concentrations of Cu, Ni and Zn are extremely low when pH varied from 7 to 13. The best stabilization pH span is from 5.5 to 10 for SSPS. The XRD and SEM-EDS analysis showed that the major compounds in treated SSPS were bassanite and plaster of Paris (POP).

Since the extreme conditions such as pH = 2 or pH = 13 are infrequently, the stabilized SSPS can be safely reused in roadbed materials, bricks and concrete aggregates based on China HJ/T 301.


- **Keywords:** Stainless steel pickling sludge; Heavy metals; Leaching behavior; pH; Sodium sulfide


**Abdul Aziz, Salim Ahmed, Faisal I. Khan. *An ontology-based methodology for hazard identification and causation analysis*. Pages 87-98.**


This article presents a dynamic hazard identification methodology founded on an ontology-based knowledge modeling framework coupled with probabilistic assessment. The objective is to develop an efficient and effective knowledge-based tool for process industries to screen hazards and conduct rapid risk estimation. The proposed generic model can translate an undesired process event (state of the process) into a graphical model, demonstrating potential pathways to the process event, linking causation to the transition of states. The Semantic web-based Web Ontology Language (OWL) is used to capture knowledge about unwanted process events. The resulting knowledge model is then transformed into Probabilistic-OWL (PR-OWL) based Multi-Entity Bayesian Network (MEBN). Upon queries, the MEBNs produce Situation Specific Bayesian Networks (SSBN) to identify hazards and their pathways along with probabilities. Two open-source software programs, Protégé and UnBBayes, are used. The developed model is validated against 45 industrial accidental events extracted from the U.S. Chemical Safety Board's (CSB) database. The model is further extended to conduct causality analysis.



- **Keywords:** Hazard identification; Probabilistic ontology; Web ontology language; Multi-entity Bayesian network; Expert system


**Shihang Li, Fei Wang, Jie Xin, Biao Xie, Shuda Hu, Hao Jin, Fubao Zhou. *Study on effects of particle size and maximum pressure drop on the filtration and pulse-jet cleaning performance of pleated cartridge filter*. Pages 99-104.**


In recent years, pleated cartridge filters have been widely used in the process of industrial production. However, most of the existing studies are focused on the structure optimization design of filters, and there are few studies on the effects of two important factors, namely, particle size and maximum pressure drop, on the performance of filters. So, in this study, the effects of two factors on the filtration and pulse-jet cleaning performance of pleated cartridge filter were investigated through experiments. For the same maximum pressure drop, both average and average residual pressure drops are reduced with the rise of particle size, and meanwhile both the number of pulse-jet cleaning and the average dust emission concentration decrease, which improves the dust collection efficiency. For the same particle size, both average and average residual pressure drops are reduced with the decrease of maximum pressure, but both the number of pulse-jet cleaning and the average dust emission concentration are increased, which lowers the dust collection efficiency.



- **Keywords:** Pressure drop; Dust collection efficiency; Pulse-jet cleaning; Particulate matter; Filter cartridge


**Qianlin Wang, Laibin Zhang, Jinqiu Hu. *An integrated method of human error likelihood assessment for shale-gas fracturing operations based on SPA and UAHP*. Pages 105-115.**

In drilling industries, hydraulic fracturing of unconventional shale-gas wells is a highly industrialized process involving multiple equipment, substances, and operational stages. However, fracturing operations also involve extremely hazardous work relating to high-pressure chemicals, heavy equipment, and flammable gases. During the fracturing process, human error frequently causes sand blockages, equipment damage, and fracturing fluid leakage. An assessment of human error likelihood is essential for the prevention of resulting incidents, and thereby improving the safety and stability of the entire shale-gas fracturing operations. However, due to the latency, unpredictability, and variety of human errors in fracturing operations, previous studies have not sufficiently considered uncertainties. Hence, an integrated method that applies the UAHP-SPA model is proposed to assess human error likelihood in the fracturing process. The indexes of human error likelihood assessment in fracturing operations are first established based on 4M theory. Then, the Set Pair Analysis (SPA) technique is used to consider epistemic uncertainties from assessed objects, assessment procedures, assessor subjectivities, and incomplete data. Furthermore, the SPA-based Uncertainty Analytic Hierarchy Process (UAHP) is applied for reducing aleatory uncertainties in the index weight optimization. The proposed method is able to effectively provide static likelihood states and dynamic likelihood trends of various human errors. To illustrate its validity, an on-site fracturing operator is selected as a test case. Results show that this UAHP-SPA model is more accurate and practical compared to conventional approaches.


- **Keywords:** Human error likelihood assessment; Shale-gas fracturing operations; Uncertainties; Set Pair Analysis (SPA); Uncertainty Analytic Hierarchy Process (UAHP)


**Shing Ching Khoo, Xue Yee Phang, Chia Min Ng, Kar Loke Lim, Su Shiung Lam, Nyuk Ling Ma. *Recent technologies for treatment and recycling of used disposable baby diapers*. Pages 116-129.**

The disposal of used diapers is a critical eco-technological problem aggravated by the exponential increase of global consumption rate each year. The global production of disposable used diapers increases exponentially and is expected to exceed US$ 71 billion/year by 2022. It was revealed that about 20 billion pieces of the used diapers were dumped in landfills yearly, generating more than 3.5 million tonnes of diaper waste that require almost 500 years to be fully decomposed. The resource-consuming production and disposal of used diaper waste have led to many environmental issues and poses a threat to public health. This review provides an in-depth discussion of the challenges, strategies, and the recent breakthrough in rectifying problems arising from generation and disposal of used diapers. The use of various technologies for treatment and recycling of used diaper were highlighted, particularly on the use of potentially safer and cleaner technologies such as biodegradation and thermal pyrolysis in maximizing the recycling of used diapers with minimal cost. It was established that useful end products that have wide applications can be obtained through biodegradation and pyrolysis of used diapers, hence providing a future research direction to enhance the efficiency of these process in recycling of used diaper.


- **Keywords:** Recycling; Diaper; Waste; Biodegradation; Pyrolysis


**Pingfang Yan, Maoyou Ye, Zhijie Guan, Shuiyu Sun, Yanping Guo, Jingyong Liu. *Synthesis of magnetic dithiocarbamate chelating resin and its absorption behavior for ethylenediaminetetraacetic acid copper*. Pages 130-139.**

As an efficient metal-trapping agent, conventional dithiocarbamate is prone to poor flocculation, and difficult recovery, and it is challenging to reuse it in applications. In our study, to address these problems, a novel and efficient chelating agent was developed in

the form of a magnetic dithiocarbamate chelating resin. This resin was used to adsorb EDTA-Cu from wastewater. Furthermore, the Cu absorption mechanism of the new resin was investigated. The magnetic dithiocarbamate chelating resin is a composite polymer material with dithiocarbamate functional groups and a good magnetic response. The resin showed a high Cu removal efficiency of 99.19%, and an improved sedimentation performance. Moreover, the resin can be effectively recycled, and it was reused twice after desorption with 4% thiourea, it retained an absorption rate of 89.95%. The adsorption mechanism was based on chemical adsorption. The sulfur atoms of the resin had coordinated with the Cu of EDTA-Cu and formed a stable coordination compound. This research of the resin not only enriches the metal-trapping agent, but also provides a new idea for treating low concentration complex metal pollutants.


- **Keywords:** Magnetic dithiocarbamate chelating resin; Ethylenediaminetetraacetic acid copper; Absorption behavior; Absorption mechanism


**Vanessa A. Jiménez-Silva, Fortunata Santoyo-Tepole, Nora Ruiz-Ordaz, Juvencio Galíndez-Mayer. *Study of the ibuprofen impact on wastewater treatment mini-plants with bioaugmented sludge*. Pages 140-149.**

The determination of the peak volumetric removal rate of ibuprofen in batch culture was used to select a microbial community utilizable for augmentation. For a continuous removal process, this rate, particularly the peak value of the volumetric removal rate is an essential factor reflecting the catabolic behavior (metabolic quotient qS) and the physiological state of a microbial community which depends on environmental conditions. Thus, if stable environmental conditions are maintained in a homogeneous continuous regime, a high metabolic quotient and volumetric removal rate could be maintained for the selected microbial community. Using equations derived from the material balance of ibuprofen in a wastewater treatment mini-plant (WTMP) operating in a homogeneous condition, the beginning and end of an acclimatization period after an IBP toxic shock were estimated by comparison of the experimental values of IBP accumulated to its theoretical accumulation. Using the experimental values of IBP accumulated within the WTMP, the actual transient change in the volumetric removal rate along the acclimatization period was calculated from another derived equation. This procedure allows to measure the change in the volumetric removal rate, showing the kinetic response of the system and the acclimatization time of a microbial consortium after a toxic shock.


- **Keywords:** Emerging pollutant; Ibuprofen degradation; Toxic shock; Microbial acclimatization; Activated sludge; Microbial community


**Maryam Dastoorpoor, Kambiz Masoumi, Mostafa Vahedian, Hamidreza Aghababaeian, Zohreh Sekhavatpour, Narges Khanjani, Esmaeil Idani. *Associations of short-term exposure to air pollution with respiratory hospital admissions in Ahvaz, Iran*. Pages 150-160.**

Air pollution is likely to have adverse effects on human health. This study was conducted to determine the effect of air pollution on respiratory disease hospital admission in Ahvaz, one of the most polluted cities in the Middle East. Daily information about respiratory disease admissions and air pollutants during 2008–2018 were inquired. Adjusted Quasi-Poisson regression combined with linear distributed lag models were used. There was a significant relation between increased O3 and respiratory hospital admissions for 65–74 year olds, ≥75 year olds, and pyothorax-abscesses of the lung and mediastinum; between increased NO and respiratory hospital admissions for ≥75 year olds, chronic lower respiratory diseases, diseases of upper respiratory tract and respiratory diseases principally affecting the interstitium; between increased NO2 and respiratory hospital admissions for ≥75 year olds; between increased CO and respiratory

hospital admissions and between increased SO2 and respiratory hospital admissions for ≥75 year olds. The risk of respiratory hospital admissions increased in both males and females for increase in PM2.5. Ambient O3, NO, NO2 CO and SO2 can increase admission for respiratory diseases on the same day and at short lags in Ahvaz. This evidence emphasizes the need to implement policies for reducing air pollution.


- **Keywords:** Air pollution; Air pollutants; Particulate matter; Nitrogen oxides; Respiratory hospital admissions; Time-series regression; Ahvaz


**James I. Colades, Mark Daniel G. de Luna, Mona Freda N. Secondes, Chin-Pao Huang. *Electrochemical in-situ hydrogen peroxide generation in a packed-bed reactor for Fenton oxidation of p-nitrophenol in aqueous solution*. Pages 161-168.**


Advancements in electrochemical generation of hydrogen peroxide (H2O2) in Fenton systems hasten the realization of a "chemical-free" treatment of organic pollutants in water. The present study used a novel air-sparged, packed-bed electrode configuration with reticulated vitreous carbon (RVC) as packing material for electrochemical H2O2 generation. The effects of initial pH, applied current, sparging rate, mass of RVC and electrolyte concentration on cumulative H2O2 generation and current efficiency were evaluated. From the results, the operating conditions that gave the optimal cumulative H2O2 generation and current efficiency were pH0 = 2.0, applied current = 50 mA, air sparging rate = 0.5 L min−1, mass of RVC = 0.75 g, and electrolyte concentration = 100 mM Na2SO4. The same reactor configuration was used for the treatment of the model contaminant from aqueous solution and caused the complete removal of p-nitrophenol (pnP) within a 2 h duration. Mineralization of aromatic intermediates was confirmed by gas chromatography – mass spectroscopy analyses of samples and supported by the reduction in chemical oxygen demand and total organic carbon.



- **Keywords:** Electro-Fenton; Hydrogen peroxide generation; Packed-bed design; p-nitrophenol; Reticulated vitreous carbon


**Wen Song, Baoyu Gao, Xu Zhang, Feifei Li, Xing Xu, Qinyan Yue. *Biological reduction of perchlorate in domesticated activated sludge considering interaction effects of temperature, pH, electron donors and acceptors*. Pages 169-178.**


This study investigated the direct microbial reduction of perchlorate using domesticated activated sludge and showed the interaction effect of water quality factors on perchlorate bio-reduction. The dominant perchlorate-reducing bacteria belong to Dechloromonas sp., which was successfully acclimated from regular activated sludge after 20 days domestication. Batch reduction experiments indicated that high bio-reduction efficiency of perchlorate could be achieved at 303–313 K and pH = 6.5–7.5. Perchlorate-reducing bacteria can more efficiently utilize acetate and butanedioic to reduce perchlorate compared with the other electron donors that significantly affect the microbial community structure and dominant bacteria of activated sludge. The three-level and three-variable Box-Behnken Design response surface method predicted a maximum perchlorate reduction efficiency of 100% under the following optimal conditions: pH = 7.5, 308 K, and 0.51 mg/L of acetate. Furthermore, the influence of two factors on perchlorate reduction was in this order: interaction between pH and acetate > interaction between pH and temperature > interaction between temperature and acetate.



- **Keywords:** Perchlorate; Microbial reduction; Electron donors; BBD

**Hui Wang, Ayako Yajima, Homero Castaneda. *A stochastic defect growth model for reliability assessment of corroded underground pipelines*. Pages 179-189.**

A stochastic corrosion growth model is established for underground pipeline structures. The model has been developed with the concept in mind that the evolution of localized corrosion damage is time-dependent following an activation stage (nucleation) – growth stage (propagation) – steady state stage (passivation) mechanism. The temporal correlation of the defect evolution is able to be well represented by a geometric Brownian bridge process. The variation of activation time is taken into consideration. Two applications are illustrated: 1) predicting the evolution of the probability density function (PDF) of the corrosion depth, and 2) assessing the reliability of a pipeline structure.

- **Keywords:** Underground pipeline; Pitting corrosion; Reliability assessment

**Eng Kein New, Ta Yeong Wu, Cornelius Basil Tien Loong Lee, Zi Yet Poon, Yu-Loong Loow, Luther Yang Wei Foo, Alessandra Procentese, Lee Fong Siow, Wen Hui Teoh, Nik Norsyahariati Nik Daud, Jamaliah Md. Jahim, Abdul Wahab Mohammad. *Potential use of pure and diluted choline chloride-based deep eutectic solvent in delignification of oil palm fronds*. Pages 190-198.**

The existence of deep eutectic solvents (DESs) has improved the process of biomass transformation and valorization due to its ability to break down the recalcitrant structure of biomass via delignification. However, the high viscosity of DES is one of the factors that restraints its effectiveness in delignification of biomass. The addition of water was expected to reduce the viscosity of DES and improve the process consequently. This study investigated the effects of water content in the DES (choline chloride:urea in 1:2 M ratio) on delignification of oil palm fronds (OPF), which are underutilized but available abundantly in Malaysia. The pretreatment was carried out at 120 °C for 4 h using DES at a solid-to-liquid ratio of 1:10 (w/v). In terms of lignin removal, 30 vol% of distilled water in DES was determined to achieve the optimal result at 16.31% in delignification of OPF. Delignification of OPF was further confirmed via a series of characterization tests. In comparison with pure DES, the aqueous DES enabled more favorable improvement of lignin removal in a biomass pretreatment.

- **Keywords:** Biomass valorization; Biorefinery; Green solvent; Lignin; Lignocellulosic biomass; Waste management

**Rohini C. Kale, K. Ravi. *Influence of thermal history on swell pressures of compacted bentonite*. Pages 199-205.**

The deep geological disposal system is an internationally adopted option for the disposal of high-level nuclear waste (HLW). It consists of a highly expansive bentonite, which is used as a buffer material and as a part of an engineered barrier system. Bentonite provides sufficient swelling pressure and low hydraulic conductivity to the barrier system giving long-term stability. The high-temperature waste canister in DGR and the variation in temperature due to thermal gradient impose a thermal loading on the compacted bentonite buffer and may alter the swelling pressures of the compacted bentonite. Hence it is necessary to investigate the influence of thermal loading on the swelling pressure of compacted bentonite. The paper discusses an assessments of swell pressures of two compacted bentonites (Barmer 1 (B1) and Barmer 2 (B2)) from Barmer district of Rajasthan, India with initial dry densities of 1.5 Mg/m3, 1.75 Mg/m3, and 2 Mg/m3 and subjected to 110 °C and 200 °C, hydrated with distilled water. The swelling load is recorded and compared with non-heated samples of same densities. Experimental and theoretical evidences indicated that the swelling pressure of heated compacted bentonite

decreased with an increase in the temperature. Statistical analysis is also presented with the help of analysis of variance (ANOVA).

- **Keywords:** Deep geological repository; High-level waste; Nuclear waste disposal; Buffer; Swelling pressure; Cation exchange capacity; Time-swelling curve

**Zhao Wang, Giang Nguyen Song Thuy Thuy, Varsha Srivastava, Indu Ambat, Mika Sillanpää. *Photocatalytic degradation of an artificial sweetener (Acesulfame-K) from synthetic wastewater under UV-LED controlled illumination*. Pages 206-214.**

The photocatalytic degradation of an artificial sweetener, acesulfame-K (ACE) was investigated using an ultraviolet light emitting diode (UV-LED) based irradiation in presence of titanium dioxide (TiO2), zinc oxide (ZnO), hydrogen peroxide (H2O2), peroxomonosulfate (PMS, HSO5−) and peroxodisulfate (PDS, S2O82−). The pH of ACE solution showed significant effect on the degradation of ACE. It was observed that low pH value enhanced the ACE degradation rate. After 120 min by UV-LED/TiO2 treatment, the degradation of ACE reached up to 90%, while in UV-LED/ZnO, UV-LED/H2O2, UV-LED/PMS, and UV-LED/PDS degradation rate were found to be 63%, 87%, 76% and 86% respectively. PMS and PDS both oxidant showed good results without the generation of any secondary sludge like other heterogeneous catalysts. The present study showed that in presence of catalysts and oxidants, UV-LED illumination significantly enhanced the degradation rate of ACE in comparison to direct photolysis by UV-LED. Possible degradation pathway of ACE was determined by gas chromatography-mass spectrometry (GC–MS) which confirmed the ACE degradation by generation of three byproducts.

- **Keywords:** Acesulfame-K; Artificial sweetener; Photocatalytic; UV-LED

**Patrick Amoatey, Hamid Omidvarborna, Mahad Said Baawain, Abdullah Al-Mamun. *Emissions and exposure assessments of SOX, NOX, PM10/2.5 and trace metals from oil industries: A review study (2000–2018)*. Pages 215-228.**

Rapid urbanization and industrial growth have caused massive increase in the number and the production capacities of oil industries. Such industries release a wide-range of ambient acidic gases, particulate matters (PMs) and trace metals into the environment. They can also undergo chemical transformation and nucleation to form new chemical species and secondary aerosols. These pollutants are potentially carcinogenic and may cause cardiorespiratory, pulmonary mortalities and morbidities to the exposed population through inhalation, ingestion and dermal contact. Hence, the main objective of this review study was to identify various approaches used in monitoring, measurement, and control of ambient acidic gases, PMs and trace metals from oil industries. The review study revealed that PM10/2.5, SO2, NO2, and trace metals were the widely reported ambient air pollutants released from oil industries. Cancer and respiratory diseases were the major health effects associated with such emissions. Air quality monitoring stations, samplers and dispersion models were found as the main approaches used to determine the emissions. Moreover, recommendations on ultrafine particles, Nano-particle and long-range transportation exposure assessments of pollutants were explored. Apart from that, the fate of pollutants, properties, routes of exposure, human health risk assessments and new approaches of emerging control technologies (Fenton and Ultrasonic reactions mainly on SO2, NOx and Hg reductions) were systematically reviewed. Finally, additional research on exposure assessment of oil industry emissions by private companies and government agencies was discussed.

- **Keywords:** Air quality measurements; Oil industry; Exposure assessment; Health effects; Emission control technologies

**Majid Bagheri, Ali Akbari, Sayed Ahmad Mirbagheri. *Advanced control of membrane fouling in filtration systems using artificial intelligence and machine learning techniques: A critical review*. Pages 229-252.**

This paper critically reviews all artificial intelligence (AI) and machine learning (ML) techniques for the better control of membrane fouling in filtration processes, with the focus on water and wastewater treatment systems. Artificial neural networks (ANNs), fuzzy logic, genetic programming and model trees were found to be four successfully employed modeling techniques. The results show that well-known ANNs such as multilayer perceptron and radial basis function can predict membrane fouling with an R2 equal to 0.99 and an error approaching zero. Genetic algorithm (GA) and particle swarm optimization (PSO) are optimization methods successfully applied to optimize parameters related to membrane fouling. These optimization techniques indicated high capabilities in tuning various parameters such as transmembrane pressure, crossflow velocity, feed temperature, and feed pH. The results of this survey demonstrate that hybrid intelligent models utilizing intelligent optimization methods such as GA and PSO for adjusting their weights and functions perform better than single models. Clustering analysis, image recognition, and feature selection are other employed intelligent techniques with positive role in the control of membrane fouling. The application of AI and ML techniques in an advanced control system can reduce the costs of treatment by monitoring of membrane fouling, and taking the best action when necessary.

- **Keywords:** Membrane bioreactors; Membrane fouling; Artificial intelligence; Machine learning; Control system

**Rodrigo Poblete, Ernesto Cortes, José Bakit, Yolanda Luna-Galiano. *Landfill leachate treatment using combined fish scales based activated carbon and solar advanced oxidation processes*. Pages 253-262.**

The depuration of landfill leachate (LL) was evaluated by solar advanced oxidation processes (AOPs) (photo-Fenton + O3 and photo-Fenton + O2) and adsorption processes, using activated carbon made from fish scales, as either post-treatment or pre-treatment of advanced oxidation process. Also, the effect in the reduction of toxicity of LL depurated under these methods was evaluated. The activated carbon Brunauer-Emmett-Teller (BET) surface area is 1.8329 m2/g and the adsorption average pore width is 12.79833 nm, considered as a mesoporous material. When AOPs were used as treatment and adsorption was used as post-treatment of the LL, a removal of 67%, 98%, 98.9%, 83.3% and 99.6% of chemical oxygen demand (COD), colour, copper, iron and ABS254, respectively, was obtained. When the adsorption process was applied as AOP pre-treatment, the removal of organic matter was better in comparison to the results of the adsorption process as AOPs post-treatment. This resulted in a removal of COD, colour, copper, iron and ABS254 of 75.4%, 99.4%, 94.4%, 68.3% and 98.1%, respectively. When the AOPs were followed the adsorption process, a germination index (GI) of 126%, 122% and 116% was obtained. This was higher than the results obtained by LL treated with PF + O2 in a solution concentration of 1%, 3% and 10%, respectively. When PF + O3 was used at a concentration solution of 1%, 3% and 10%, similar GI values were obtained (122%, 113% and 114%, respectively). The EC50 is very low for raw LL, but this value increases as the LL is treated. A very high EC50 is obtained for the adsorption process and for AOPs following the adsorption process, going from 1.8 to 21.0 V/V. Adsorption as pre-treatment helps removing colour and metals from LL, thus enhancing the performance of solar AOPs.

- **Keywords:** Landfill leachate; Solar photo-Fenton; Activated carbon; Fish scales; Toxicity

**Amir Sheikhmohammadi, Ahmadreza Yazdanbakhsh, Gholamreza Moussavi, Akbar Eslami, Mohammad Rafiee, Mahdieh Sardar, Mohammad Almasian. *Degradation and COD removal of trichlorophenol from wastewater using sulfite anion radicals in a photochemical process combined with a biological reactor: Mechanisms, degradation pathway, optimization and energy consumption*. Pages 263-271.**

This study proposes the combination of UV/sulfite with a biological reactor (USPB) for the degradation, dechlorination and mineralization of 2, 4, 6-trichlorophenol (TCP). The effects of pH, sulfite dosage, co-existing water anions and quenchers on the performance of the UV/sulfite process (USP) were investigated. The rate of degradation, dechlorination and mineralization of TCP under optimum experimental conditions of pH, 7.0; [sulfite]/[TCP] = 3.13; UV irradiation, 87 μW cm−2; dissolved oxygen (DO), 2 mg L-1 and an 80 min reaction time, were 100, 98 and 30.2%, respectively (initial TCP concentration was 250 mg L-1 and initial COD was 363 mg L-1). Investigation of the reaction mechanism revealed the superiority of sulfite radicals (SO3-) in the degradation and dechlorination of TCP. The co-existing water anions did not significantly affect the performance of TCP degradation. The intermediates derived from TCP degradation included: 1,3-cyclohexadiene, 2-chloro-1-benzoquinone, 2-chlorophenol, benzene, 2-hydroxy benzoquinone and cyclohexene. The (BOD5)/(COD) ratio (the solution biodegradability index) was obtained as 0.57 after 80 min of UV/sulfite reaction time. The effluent obtained from UV/sulfite after 80 min of reaction time (with COD of 253 mg L-1) was efficiently post-treated in a batch biological reactor (MLSS = 5000 mg L-1), and the COD reduced to 37 mg L-1 after 720 min (12 h) of aeration. Therefore, it was found that the combination of the UV/sulfite with a biological process might be an efficient method for the treatment of wastewater containing high concentrations of toxic compounds.

- **Keywords:** Degradation; Dechlorination; Mineralization; UV/sulfite; Biodegradation; 2,4,6-trichlorophenol

**Saikat Chowdhury, Geon-Ha Kim, Nanthi Bolan, Philip Longhurst. *A critical review on risk evaluation and hazardous management in carcass burial*. Pages 272-288.**

Carcass disposal from livestock disease outbreaks or on-farm, routine mortalities present a number of challenges. Proper management of carcasses can no longer be addressed as an incidental occurrence, as they represent a persistent pathway of infectious agricultural wastes with potential to harm the environment. The long-term management of carcass disposal sites is essential irrespective of the cause of mortality. Critically this ensures eradication of disease and environmental protection from a range of biological and chemical hazards. Strategies for large-scale carcass disposal require preparation and coordinated, proactive planning in advance of emergencies to meet environmental protection guidelines and maximize the efficiency of response. Carcass disposal methods include burial, incineration, composting, alkaline hydrolysis, lactic acid fermentation and anaerobic digestion. Burial techniques include trench burial, landfill, and notably mass burial as one of the most common methods of disposal. However, there are concerns about possible impacts to the environment and subsequent risk to human health regardless of the initial logistical and economic advantages. This review provides an overview of our current understanding of the potential threats of carcass burial and possible management options. The environmental implications of terminating burials is discussed as is the role of biochar and phytoremediation which can contribute to the management of burials. These examples are considered in the case study context of Korea where long-term considerations remain a priority. The outcome of the review is structured to provide information to decision-makers that is of value when equipping themselves with comprehensive guidelines for the sustained management of carcass burials. Finally, recommendations that address future research needs are outlined.

- **Keywords:** Carcass burial; Groundwater remediation; Livestock disease; Mortality disposal; Risk assessment

**Mahdi Tanha Ziyarati, Nader Bahramifar, Gholamreza Baghmisheh, Habibollah Younesi. *Greenhouse gas emission estimation of flaring in a gas processing plant: Technique development*. Pages 289-298.**

Drastic growth in greenhouse gas (GHG) emissions in the last few decades, due mainly to the development of industrial activities, is one of the most important parameters that greatly influence global warming and climate change. While oil and gas industry contribute significantly to global GHG emissions because of their rate of flaring, it is practically impossible to measure and monitor the composition and amount of the gas streams sent to a flare and their combustion products. In the present study, a model is proposed to estimate the flow rate and composition needed for calculation of GHG emission from the flare network of a natural gas processing plant in Asalouyeh, southern Iran, based on the sources of flared gas. This model also makes it possible to determine the source of each flared gas mixture and the reliability and availability of the processing units. The comparison between cumulative flow rates of flared gas from the model and field measurement shows an agreement with the correlation coefficient of more than 0.98. The accuracy of the model in the prediction of the flared gas composition was validated against actual compositions using gas chromatography. The error of less than 8% between actual results measured by gas chromatography and the results predicted by the proposed model for main components such as methane and carbon dioxide shows the acceptable accuracy of the proposed model. The model not only makes online monitoring of the flare network possible but also facilitates decision making about flare gas reduction.

- **Keywords:** Greenhouse gas; Gas processing plant; Flared gas; Flow rate; Gas emission estimation

**Hakimeh Mahdizadeh, Mohammad Malakootian. *Optimization of ciprofloxacin removal from aqueous solutions by a novel semi-fluid Fe/charcoal micro-electrolysis reactor using response surface methodology*. Pages 299-308.**

The aim of this research was to investigate the removal efficiency of ciprofloxacin (CPX) from aqueous solutions by a novel semi-fluid Fe/charcoal micro-electrolysis reactor and process optimization using response surface methodology (RSM). Effective factors in the removal process including CPX initial concentration, pH, amount of Fe/charcoal, aeration amount and contact time were investigated. The total organic carbon (TOC) removal was determined under optimum conditions of the reactor. The maximum removal efficiency of 95.5% was obtained in optimal conditions as follow; initial concentration of CPX: 17.27 mg/L, pH: 5.38, Fe/charcoal mass: 22.70 g/300 mL, aeration rate: 4.33 L/min and contact time: 105.36 min. The quadratic equation was obtained with a high degree of fit. TOC concentration in optimal conditions decreased from 16 mg/L to 4 mg/L. As a result of this, the Fe/charcoal semi-fluidized micro-electrolysis reactor has a high efficiency in removing drug compounds such as CPX from aqueous solutions.

- **Keywords:** Micro-electrolysis; Fe/charcoal; RSM; Galvanic cells; CPX

**Juan Li, Qiang Zheng, Zhihong Qian, Xiaoping Yang. *A novel location algorithm for pipeline leakage based on the attenuation of negative pressure wave*. Pages 309-316.**

Numerous types of liquid, such as water, oil, and so on, are transported via pipelines. Thus, leakage in the pipelines can cause severe hazards to liquid transportation and pose

great risks to industries, environment and dwellers. For the purpose of an accurate identification of the leakage location, a novel location algorithm is proposed in this paper based on the attenuation of negative pressure wave (ANPW). As such, this paper presents some of the first efforts in the investigation of the relationship between the pressure difference and leakage location. This is in direct contrast with the traditional method, which relies on the use of the time difference and the velocity of NPW for leakage detection and location. Accordingly, the ANPW method avoids the potential problems of the traditional NPW method – the difficulty for pinpointing the time difference and the disturbance of the velocity of NPW by the liquid flow rate in the pipeline. To explore this new method, this paper firstly deduces the propagation equation of NPW along with the pipeline using the momentum equation and the continuity equation. This is followed by proposing that the ANPW method depends on the change of pressure in place of the time difference. Thirdly, a test of the method in the actual pipeline and comparison between the ANPW method and the time difference method are conducted. Yielding the largest error of 1.161% and the smallest error of 0.355%, the experiment leads to the conclusion that the new method can be applied to the location of pipeline leakage.


- **Keywords:** Pipeline leakage; Negative pressure wave; Leakage localization; Pressure difference; Time difference


### Chuanqi Guo, Faisal Khan, Syed Imtiaz. *Copula-based Bayesian network model for process system risk assessment*. Pages 317-326.

Risk assessment is an essential exercise for process systems from early conceptual design to operation and subsequently during decommissioning. Risk assessment methods have evolved over the past two decades from index-based methods to detailed quantitative methods. The Bayesian network (BN) is a recent developed technique used for risk assessment that utilizes updating, adapting and discrete-time-based analysis properties. Although the BN is a powerful technique, it continues to face the challenge of modelling non-linear complex correlations of process components. This paper proposes a copula-based Bayesian network model that assists in overcoming the challenge of non-linear relationships. In addition to defining conditional probabilities, the copulas are also used to describe the joint probability densities of the network nodes in the BN. Application of the proposed model is demonstrated using a process accident case study. The results reveal that the proposed model is effective in estimating more reliable accident probabilities. A sensitivity analysis is also conducted to identify important factors that need to be monitored to prevent accident occurrence. Moreover, the focus of the present study is on process systems. However, the proposed model is applicable to most engineering systems.


- **Keywords:** Risk assessment; Bayesian network; Dependence; Copula; Process safety; Accident model


### Nadeem Baig, Fahd I. Alghunaimi, Hind S. Dossary, Tawfik A. Saleh. *Superhydrophobic and superoleophilic carbon nanofiber grafted polyurethane for oil-water separation*. Pages 327-334.

The oil contamination in water and industrial wastewater is a concern for the environment. The role of carbon nanofiber (CNF) grafted onto polyurethane (PU) for oil absorption was investigated under ambient conditions. Superhydrophobic and superoleophilic materials based on CNF grafted PU were synthesized by a dip coating for oil/water separation. The synthesized materials were characterized by SEM, FTIR, BET and by a dynamic oil separation setup. Surface grafting with CNFs substantially increased the surface area of PU by nearly 31X (9 m2/g to 276 m2/g), which also decreased the average pore size in the PU matrix from 2567 Å to 36 Å. The decrease in pore size significantly improved the capillary action of the synthesized CNF grafted PU and

provided almost no chance for water to pass. CNF grafted PU has successfully separated oil from different oil/water models and displayed absorption capacity up to 50 times to its own weight. The absorbed oil can be recovered by squeezing CNF grafted PU, which retains its original shape after releasing the pressure, and thus it was successfully used multiple times. The flexibility and the mechanical stability of the material allows it to be used for the continuous separation of oil from oil-contaminated water.


- **Keywords:** Oil cleaner production; Sustainable technical processes; Hydrophobic; Oleophilic; Nanofiber


### Ahmad BahooToroody, Mohammad Mahdi Abaei, Farshad BahooToroody, Filippo De Carlo, Rouzbeh Abbassi, Saeed Khalaj. *A condition monitoring based signal filtering approach for dynamic time dependent safety assessment of natural gas distribution proces*. Pages 335-343.


Condition monitoring of natural gas distribution networks is a fundamental prerequisite for evaluating safety of the operation during the lifetime of the system. Due to the high level of uncertainty in the observed data, predicting the operational reliability of the networks is complicated. Moreover, there is a fluctuation in most of the monitoring data in different time scales, as most of the derived data tend to be of non-stationary nature and are complex to model or forecast. Therefore, a more realistic data driven approach for developing a reliability framework needs to be considered. This paper aims at proposing a probabilistic model to predict the complexity of the non-stationary behaviour in monitoring data. It also aims at developing a novel framework for the time dependent reliability assessment of a natural gas distribution system using condition-monitoring data. To this end a methodology by integrating Empirical Mode Decomposition (EMD) and Hierarchical Bayesian Model (HBM) is developed. The advantages of the methodology are demonstrated through a case study of a Natural Gas Regulating and Metering Station operating in Italy. Based on pressure data acquired from the case study, the model is able to predict overpressure thus directly avoiding unnecessary maintenance and safety consequences.



- **Keywords:** Condition monitoring; Time dependency assumption; Empirical Mode Decomposition (EMD); Hierarchical Bayesian Model (HBM); Noise


### Ya-Qi Hu, Wei Wei, Ming Gao, Ying Zhou, Guo-Xiang Wang, Yong Zhang. *Effect of pure oxygen aeration on extracellular polymeric substances (EPS) of activated sludge treating saline wastewater*. Pages 344-350.


This study aimed to investigate the effects of pure oxygen aeration on extracellular polymeric substances (EPS) of activated sludge treating saline wastewater in a sequencing batch reactor (SBR). Activated sludge with pure oxygen aeration was more effective for TOC removal than that with air aeration when salinities were less than 3.0%. The soluble microbial products (SMP) concentrations with pure oxygen aeration were higher at low salinities (0.5%, 1.0%), while the opposite occurred at high salinities (2.0%, 3.0%, 4.0%). The EPS concentrations of the two aeration methods were similar when salinities were at 0.5% and 1.0%, while higher amount of total EPS would be produced in pure oxygen aeration reactor when the salinities were above 2.0% ($p < 0.05$). The fluorescence peaks in both loosely bound EPS (LB-EPS) and tightly bound EPS (TB-EPS) of activated sludge with pure oxygen aeration at 3.0% salinity were attributed to tryptophan PN-like substances and humic acid-like substances. The sludge volume index (SVI) showed linear correlations with EPS ($R2 = 0.9057$), PN ($R2 = 0.9741$) and PS ($R2 = 0.8833$) at 3.0% salinity, respectively. In pure oxygen aeration system, SVI was more sensitive with EPS and PN, which may worsen settling performance of the sludge.

- **Keywords:** Activated sludge; Pure oxygen aeration; Saline wastewater; Extracellular polymers substances; Soluble microbial products

**Hetang Wang, Xiaobin Wei, Yunhe Du, Deming Wang. *Experimental investigation on the dilatational interfacial rheology of dust-suppressing foam and its effect on foam performance*. Pages 351-357.**

Foam dust suppression is an effective technique for controlling dust at its source. Dilatational interfacial rheology is an important property of aqueous foam. It characterizes the strength and toughness of liquid film and acts on the foaming process and drainage, affecting foaming capacity (FC) and foam stability (FS). The interfacial viscoelastic properties of anionic and nonionic surfactants commonly used were studied by testing the viscoelastic properties with different foaming agent concentrations (FAC) and their effects on foam performance were investigated. The results show that increasing FAC from 0.1 wt. ‰ to 1.0 wt. ‰ generally decreased the viscoelastic modulus, which was negatively correlated with FC: 6501 had a highly linear relationship between FC and viscoelastic modulus. The viscoelastic modulus of K12 and AES were positively correlated with FC in the low-modulus range, then negatively correlated at higher viscoelastic modulus values; the turning point was defined as the optimal viscoelastic modulus. The viscoelastic modulus had a significant positive effect on FS. The surface viscoelasticity contributed greatly to improving FS before the critical micelle concentration (CMC) was reached. After reaching CMC, micelle properties of bulk phase mainly affected the foam life.

- **Keywords:** Dust suppression; Foam; Interfacial rheology; Viscoelastic modulus; Foaming capacity; Foam stability

**Ricardo Luiz Fernandes Oliveira, Gustavo Doubek, Sávio S.V. Vianna. *On the behaviour of the temperature field around pool fires in controlled experiment and numerical modelling*. Pages 358-369.**

This paper attempts to evaluate how the Fire Dynamics Simulator (FDS) correlates with experimental flame heights and temperature profiles around a small scale pool fire. Experimental studies were conducted in a 6 cm diameter burner inside an exhaustion hood with three liquid fuels largely used in industry: commercial hexane, hydrous ethanol and type C gasoline. The simulated fuels were defined as mixture of molecules from FDS fuel library. The burning rates were prescribed in the calculation routine and compared with the results when the burning rate is predicted by the simulator. FDS predicts flame heights with errors below 16% when the burning rate is prescribed as boundary condition. Good agreement with experimental data is observed for a given number of probe locations. However, FDS struggled to describe the temperature profile around the flame area in the region close to the pool rim, between X/D=0.25 and X/D=0.75, and with heights below 5.0 diameters.

- **Keywords:** Computational fluid dynamics (CFD); Fire modeling; Pool fire; FDS; Temperature profile

**Sunil S. Suresh, Smita Mohanty, Sanjay K. Nayak. *Effect of nitrile rubber on mechanical, thermal, rheological and flammability properties of recycled blend*. Pages 370-378.**

The recycled polymeric constituents have a huge potential to be reformed into new products. However, due to the lower toughness of the recycled plastic blends limits it from the further industrial applications. Therefore, current work analyses the potential of nitrile rubber (NBR) on property enhancement of recycled blend, prepared from poly(vinyl chloride) (PVC) and poly(methyl methacrylate) (PMMA). The effect of NBR on

the mechanical properties of the recycled blend especially toughness, flexural strength and surface hardness were studied in detail. 9 wt% of NBR in the recycled blend has shown a higher toughness value as compared to other systems. Similarly, flammability analysis results reveals that NBR can potentially enhances the flame retardancy of the recycled blend. In addition, NBR effectively changes the rheological properties such as storage modulus, loss modulus and complex viscosity of the recycled blend system. Scanning electron microscope (SEM) and transition electron microscopy (TEM) analysis suggests the possible toughening mechanism present in the recycled blend.

- **Keywords:** Toughening; Recycled blend; Flammability; Nitrile rubber; Rheology

**Omran Ahmadi, Seyed Bagher Mortazavi, Hadi Pasdarshahri, Hassan Asilian Mohabadi. *Consequence analysis of large-scale pool fire in oil storage terminal based on computational fluid dynamic (CFD)*. Pages 379-389.**

In this study, the Fire Dynamics Simulator (FDS) is adopted to simulate tank and dike pool fires in a tank farm. These simulations are performed in order to evaluate the potential for secondary fire events in nearby storage tanks based on the resulting incident radiative heat flux. As a precursor to the tank farm fire scenario case studies, the model is compared with experimental data of 1 m crude oil pool fire and 30 m and 50 m diameter kerosene pool fires. These comparisons are made to validate the modeling approach ahead of the application of the modeling to a problem of practical interest. The results of the FDS are consistent with experimental data. The FDS results indicate that the studied dike pool fire has the potential of triggering the domino effects in the tank farm, but not so true in the case of the tank fire. Quantitative results obtained by FDS modeling can be used in quantitative risk assessment of a tank farm and determination of safe inter-tank separation distances.

- **Keywords:** Pool fire; CFD; Consequence analysis; Radiation; Heat flux; FDS