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**Nassim Khirouni, Augustin Charvet, Dominique Thomas, Denis Bémer. *Regeneration of dust filters challenged with metallic nanoparticles: Influence of atmospheric aging*. Pages 1-8.**

The aim of this study was to evaluate the regeneration efficiency of fibrous filters clogged with metallic ultrafine particles, as several complaints have been made by industrials in the metallurgical field about difficulties linked to the cleaning of filters. Aging of the dust deposits on the filters surface was also reported to be problematic. In this work, the metallic nanoparticles were generated by a pilot thermal spraying process using electric arc. Experiments were conducted on flat filters and the cleaning was performed using reverse pulse-jet. The regeneration efficiency was evaluated according to the residual pressure drop, the removed mass and the cleaned surface. Experiments revealed, under different conditions, a patchy inefficient cleaning of the clogged filters. The cleaning efficiency did not exceed 30 % according to the removed mass. Clogging/unclogging cycles showed that the filtration process is highly instable as the residual pressure drop kept increasing very rapidly. The influence of atmospheric aging, i.e. exposure to different humidity conditions over time, on the filter cakes was investigated. Results showed that in presence of humidity a chemical reaction was responsible for making the deposit more adherent. The regeneration efficiency was reduced to 10 % according to the removed mass after aging for 15 days under 80 % humidity rate.

- **Keywords:** Filtration; Metallic nanoparticles; Pulse-jet cleaning; Regeneration efficiency

**Yutao Zhang, Yuanbo Zhang, Yaqing Li, Qipeng Li, Jing Zhang, Chaoping Yang. *Study on the characteristics of coal spontaneous combustion during the development and decaying processes*. Pages 9-17.**

Large-scale experiments could reflect the real status of coal spontaneous combustion and therefore were conducted to investigate the characteristics of coal oxidation during the development and decaying processes. Three coals with different metamorphic grades were collected and tested to acquire the information including the temperature profiles, movement of the hottest spots, gaseous products, limiting parameters and so forth. The results indicated that the trajectories of hottest spots did not overlap for the development and decaying processes. Meanwhile, compared to the development process, CO productions during the decaying process were higher in the air circumstance and lower in the nitrogen. Coupled with the changes of C2H4 and oxygen consumptions, it could be concluded that both the oxygen concentrations and the stages (development or

decaying process) must be taken into account when judging the status of coal spontaneous combustion. Additionally, the discussions about the limiting parameters of the coal spontaneous combustion showed that during the decaying process, the lower limit of coal thickness was smaller, the lower limit of oxygen concentration became less and the upper limit of air leakage turned larger. These results implied that the experience of high temperatures would raise the hazard of coal spontaneous combustion.


- **Keywords:** Spontaneous combustion; Hottest spot; Gaseous product; Oxygen consumption; Limiting parameters


### Zong-Han Yang, Francis Verpoort, Cheng-Di Dong, Chiu-Wen Chen, Shaohua Chen, Chih-Ming Kao. *Remediation of petroleum-hydrocarbon contaminated groundwater using optimized in situ chemical oxidation system: Batch and column studies*. Pages 18-26.


In this study, Fenton oxidation and activated persulfate oxidation were used to investigate the optimized in situ chemical oxidation (ISCO) process for its efficiency on petroleum-hydrocarbon contaminated groundwater cleanup. In the batch and column experiments using benzene and toluene as the target compounds, oxidant depletion, soil oxidant demand (SOD), adsorption of oxidant on soils, and oxidation kinetics were studied. Results show that Fenton oxidation process was more catalytic than activated persulfate oxidation by ferrous iron catalysis. Higher SOD value was obtained for H2O2 than persulfate because H2O2 had higher reactivity to soil organic matter. In addition, increased benzene and toluene oxidation rates were observed with increased concentrations of H2O2 and persulfate oxidants. The calculated pseudo first-order decay rate constants (k') for Fenton and activated persulfate oxidation processes were 1.65 and 0.13 1/h for benzene and 1.28 and 0.1 1/h for toluene, respectively. Compared to persulfate oxidation, results indicate that Fenton oxidation had much higher reaction rates on petroleum hydrocarbon oxidation. Results from the column experiment show that up to 5.94 pore volumes (PVs) of H2O2 solution and 12.85 PVs of persulfate solution were required to cleanup benzene and toluene contaminated groundwater with an oxidant concentration of 10wt%, ferrous iron concentration of 100mg/L, and initial contaminant concentration of 50mg/L. Results indicate that the Fenton oxidation process would be a more practical and efficient approach to remediate petroleum-hydrocarbon contaminated groundwater. The results would be useful in developing an ISCO system for a practical field application to cleanup benzene and toluene contaminated groundwater.



- **Keywords:** Fenton reaction; In situ chemica; l Oxidation (ISCO); Persulfate; Petroleum; Hydrocarbon


### Yiduo Wang, Bin Chen, Zhengqiu Zhu, Rongxiao Wang, Feiran Chen, Yong Zhao, Laobing Zhang. *A hybrid strategy on combining different optimization algorithms for hazardous gas source term estimation in field cases*. Pages 27-38.


Estimating gas source terms is essential and significant for managing a gas emission accident. Optimization method, as a kind of estimation methods, is helpful to figure out the source terms by solving the inverse problem. Significantly, the performance of optimization method on source term estimation is affected by the accuracy of forward dispersion model. To enhance the estimation accuracy, previous works have demonstrated the feasibility of using Back Propagation Neural Network (BPNN) trained by actual experimental datasets as a forward dispersion model. However, the overall accuracy of source estimation is still limited by backward estimation methods. Most related studies used a single optimization algorithm to estimate source terms, which usually fails to realize the requirements of both high calculation accuracy and satisfying computational efficiency. Therefore, a hybrid strategy was proposed in this study to

combine optimization algorithms with different characteristics, including particle swarm optimization, genetic algorithm and simulated annealing algorithm, to not only achieve high accuracy in global searching, but also converge to a stable result efficiently. Finally, extensive experiments are conducted to testify our proposed hybrid optimization algorithms. The Skill scores of hybrid optimization algorithms decrease obviously compared to those of single optimization algorithm. Hence, the proposed hybrid strategy is potentially useful for guiding the combination of optimization algorithms for gas source terms estimation, which further contributes to deal with a gas emission accident with satisfying calculation accuracy and computational efficiency.


- **Keywords:** Gas emission; Source term estimation; Neural network; Hybrid strategy; Optimization algorithms


### R.F. Lehutso, Y. Tancu, A. Maity, M. Thwala. *Aquatic toxicity of transformed and product-released engineered nanomaterials: An overview of the current state of knowledge*. Pages 39-56.


The release of engineered nanomaterials (ENMs) into the environment is increasing at a rapid pace due to rising production and incorporation into a variety of consumer products, collectively referred to as nano-enabled products (NEPs). During the life cycle of the NEPs, ENMs can be released into aquatic environments. The ENMs released during the various life cycle stages are often not in their pristine form as they are transformed when they encounter physical, chemical and biological stressors. Upon release into the environment, it is highly likely that aquatic organisms would be exposed to these ENMs. The current review summarised recent literature on the toxicity effects of transformed ENMs and ENMs released from NEPs. The transformation processes of pristine ENMs, ENMs' release from NEPs, and toxicity effects observations are discussed; the emphasis being on the toxic effects of non-pristine ENMs. The procedures used to transform pristine ENMs and release ENMs from NEPs can exert physicochemical alterations relative to the original state of the ENMs. Findings showed that significant uncertainty continues to exist on the toxicity of the non-pristine ENMs. The uncertainty can be attributed to a multitude of factors, more likely due to the lack of coordinated efforts and standardised testing protocols for transformation, release and toxicity that limit the availability of robust data on which solid risk assessments of ENMs can be based. Nonetheless, the overall literature herein indicated that the transformed ENMs tend to be relatively less toxic to aquatic biota compared to ENMs released from NEPs that are commonly associated with traces of the product matrix. The pronounced toxicity effects of ENMs released from NEPs is widely attributed to the: (i) ENMs, (ii) released product matrix, and (iii) dissolved ions, as such, the realistic risk assessment and environmental regulation of ENMs in isolation are thus hampered. The review ends by proposing various strategies that can be adopted to improve the data limitations that were identified.



- **Keywords:** Transformed engineered nanomaterials; Engineered nanomaterials released from nano-enabled products; Nano-ecotoxicity of non-pristine engineered nanomaterials


### Lun Ma, Shenghui Yu, Qingyan Fang, Cheng Zhang, Gang Chen. *Effect of separated over-fire air angle on combustion and NOx emissions in a down-fired utility boiler with a novel combustion system*. Pages 57-66.


A novel combustion system, consisting of moving fuel-lean nozzles from the arches to the front/rear walls, rearranging staged air, and introducing separated over-fire air (SOFA), has been proposed and successfully applied in a 600 MWe Foster Wheeler down-fired boilers to reduce high NOx emissions while limiting the carbon content in the fly ash. This study comprehensively evaluates the effect of SOFA angles on flow, combustion characteristics and NOx emissions for the novel combustion system by numerical simulation and in-situ experiment. The numerical simulation shows in acceptable

consistence with the in-situ experiment. The simulated results show that significant NOx reduction is obtained for all five SOFA angles compared to the original combustion system. O2 and CO concentrations at the furnace outlet, as well as the carbon content in the fly ash decrease significantly with increasing SOFA angle from 0° to 40°. NOx emissions increase slightly and the average temperature at the re-heater entrance changes slightly with the increase of SOFA angle from 0° to 30°. However, with further increasing SOFA angle from 30° to 40°, NOx emissions increase substantially due to the smaller reducing region below the SOFA and the average temperature at the re-heater entrance falls significantly. Taking combustion, NOx and steam parameters into account, a SOFA angle of 30° is advisable. The actual industrial measurements also show that the steam can achieve the designed values when the SOFA angle is set at 30° instead of 40°. Significant NOx reduction (over 50 %) and good performance are attained after adopting the novel combustion technology of 30 °SOFA angle.


- **Keywords:** Down-Fired boiler; Novel combustion system; SOFA angle; Overall evaluation


**Bingxu Lu, Qijie Jin, Lin Chu, Youchun Pan, Xingjun Tao, Lei Yang, Yuesong Shen. *Ammonia storage/release characteristics of CeSnWBaOx/TiO2 catalyst in solving the problem of ammonia slip*. Pages 67-75.**


The ceria-based catalyst exhibited excellent storage/release characteristics of ammonia, ensuring stable deNOx efficiency under fluctuating engineering conditions, while greatly reducing ammonia slip. In this work, characteristics of ammonia storage/release of CeSnWBaOx/TiO2 catalyst were investigated. Results showed that the catalyst exhibited much higher catalytic activity than the theoretical maximum under low NH3/NO ratios. Especially, the amount of effective ammonia release reached maximum at 250 °C with increase of excess NO. Low temperature was conducive to storage and the stable storage amount was 22.97 μmol·m−2 at 50 °C, effective release of ammonia occurred mainly at the active temperature window. Ammonia storage of the CeSnWBaOx/TiO2 catalyst was affected by the activation of active sites and thermal vibration at the same time. Ammonia storage under low temperature was mainly in physical form and at weak acid sites, while high temperature enhanced activation of ammonia, resulting in an increase of ammonia storage at 350 °C. The catalyst had both weak and strong stored-ammonia, strong stored-ammonia could be effectively released only in the induction of NO. Ammonia storage of catalyst was the key to ensure stable deNOx efficiency under fluctuating engineering condition. The characteristics are of great guiding significance for dealing with ammonia slip.



- **Keywords:** DeNOx; Ammonia slip; CeSnWBaOx/TiO2 catalyst; Ammonia storage; ammonia release


**Peng Cheng, Rui Shan, Hao-Ran Yuan, Wei-jun Shen, Yong Chen. *Bioelectricity generation from the salinomycin-simulated livestock sewage in a Rhodococcus pyridinivorans inoculated microbial fuel cell*. Pages 76-79.**


In this study, a novel way to enhance the power-output performance of a Rhodococcus pyridinivorans (HR-1) –inoculated microbial fuel cell (MFC) with salinomycin was demonstrated. In the 5 mg/L salinomycin-treated MFC, the maximum power density and current density was promoted by 63.9 % and 28.1 % times, respectively. Cyclic-voltammetry (CV) analysis revealed that upon the addition of salinomycin the activity of electrochemical substances was enhanced, which resulted in the current-density promotion of the MFC. Salinomycin, as a cationic binding agent that can specifically bind to the channel protein, was responsible for electron transfer from the intracellular level to

the micro-organism's surface. Electrochemical impedance spectroscopy (EIS) results revealed that the internal resistance of the MFC was diminished after treatment with salinomycin, and thus it was speculated that the obstruction posed by the bio-membrane for electron transfer was reduced.


- **Keywords:** Microbial fuel cells; Livestock antibiotic; Salinomycin; Anode performance; Rhodococcus pyridinivorans


### Eryk Fernandes, Sandra Contreras, Francesc Medina, Rui C. Martins, João Gomes. *N-doped titanium dioxide for mixture of parabens degradation based on ozone action and toxicity evaluation: Precursor of nitrogen and titanium effect*. Pages 80-89.


Degradation of a mixture of five parabens was evaluated using photocatalytic oxidation, photolytic ozonation and photocatalytic ozonation, being applied UVA radiation and N-TiO2 doped catalysts. Photocatalytic oxidation was not able to eliminate parabens, achieving less than 10 % of removal. The use of ozone and UVA radiation resulted in total contaminants abatement with a transferred ozone dose (TOD) of 46.2 mg L−1. Photocatalytic ozonation also totally removed parabens but with a considerable reduction of TOD required along with higher COD and TOC removals, up to 35.7 % and 34.1 %, respectively, for the best catalyst (ammonia-doped 10 % N-TiO2). Toxicity tests were conducted using three different species. Lepidium sativum seeds had higher growth indexes (GIs) when exposed to solutions treated by photocatalytic ozonation reactions. Nevertheless, Allivibrio fischeri and Corbicula fluminea demonstrated lower toxic responses to photolytic ozonation treated solution which may be related with the different by-products formed.



- **Keywords:** Catalytic ozonation; N-TiO2 catalysts; Parabens; Toxicity evaluation


### Jie Hou, Wen-mei Gai, Wu-yi Cheng, Yun-feng Deng. *Statistical analysis of evacuation warning diffusion in major chemical accidents based on real evacuation cases*. Pages 90-98.


Major chemical accidents may threaten the lives and health of people in the surrounding areas. Large-scale regional evacuation is a key measure for protecting the public from these accidents. In such unconventional emergency situations, the diffusion of evacuation warnings has a significant impact on the public's decision on whether to take evacuation actions. Through an investigation and analysis of evacuation cases, this paper discusses the diffusion characteristics of evacuation warning and evacuation efficiency of the public in major chemical accident cases. The results indicate that different diffusion methods of evacuation warnings affect public evacuation decisions. In addition, based on curve fitting and regression analysis, we propose a mathematical model of evacuation warning diffusion for responsive evacuation and an evaluation model of the relationship between the diffusion of evacuation warning and the evacuation rate. The results indicate that in the responsive evacuation process, the diffusion efficiency of the evacuation warning corresponds to Weibull distribution. As the diffusion of the evacuation warning continues, the evacuation rate of the people who receive evacuation warnings first decreases and then increases, when more than 50% of the people in the evacuation area receive the evacuation warning. The evacuation rate of the people who do not receive evacuation warnings increases first and then decreases. The results of the fitting analysis indicate that when ~73% of the people in the evacuation area receive an evacuation warning, the area's overall evacuation rate is the highest. This can provide a basis and reference for regional evacuation analysis and emergency planning in unconventional emergency situations.

- **Keywords:** Emergency communication; Emergency management; Major chemical accidents; Warning efficiency; Case study

**Xin Huo, Qiang Lu, Xianbo Sun, Xiaobo Shen. *Study on flash-point measurement and reduced prediction model for ternary extraction system*. Pages 99-107.**

Large quantities of volatile and flammable liquids are used in extraction process, which are recognized as having a high fire potential. The flash point is one of the major physical properties used to determine the fire and explosion hazards of liquids. The flash point variation and the fire risk were studied for the extraction system. Experimental results were firstly presented for three ternary systems (diluent being phase 1: n-dodecane, kerosene or p-xylene; phase 2: water; phase modifier: n-butanol) and the binary pairs. The diluent is almost immiscible in water and the reverse also holds. It is assumed that only phase modifier distributes between two phases so that the partition ratio was used to estimate the equilibrium liquid composition in accordance with Nernst's distribution law. A simple and reliable flash-point prediction model was developed based on the Liaw algorithm for binary miscible mixture, and the flash point prediction of the heterogeneous ternary system was reduced to that of a binary miscible system. The deviations between the predicted values and experimental data were mostly within 2.5°C.

- **Keywords:** Aqueous-organic extraction system; Flash point; Fire risk; Prediction; Nernst's distribution law

**Haihang Li, Jiahao Liu, Jianwei Ge. *Phenomenological characteristics of continuous spill fires in a tunnel with longitudinal ventilation*. Pages 108-116.**

A car accident involving the oil tank may result in continuously spreading spill fires in tunnels, which poses great threats to the entrapped cars. However, there is still no relevant work concerning this issue. This paper experimentally investigates the spill fires in a tunnel by means of a model-scale tunnel and a steel trench where the liquid fuel flows and burns. The findings show that in a quiescent environment, the burning area of the spill fires in the tunnel is notably smaller than that in open space, while the presence of wind influence the burning area significantly, largely depending on the wind speed. For all the tests, there is no obvious steady burning stage, instead a rebound in burning area is observed after a similar shrinking burning area as that in open space. Generally, the burning area initially increases and then decreases with the increasing wind speed. These findings provide a better understanding of spill fire behaviors in tunnels and can further offer guidance on the firefighting of such fires.

- **Keywords:** Spill fire; Model-scale tunnel; Burning area; Longitudinal ventilation

**Kun Wang, Jun Fang, Hassan Raza Shah, Shanjun Mu, Xuqing Lang, Jingwu Wang, Yongming Zhang. *A theoretical and experimental study of extinguishing compressed air foam on an n-heptane storage tank fire with variable fuel thickness*. Pages 117-129.**

Compressed air foam (CAF) is an environment friendly fire extinguishing technique being used around the world since the ban of halogen-based agents. In this work, its extinguishing behavior on a radiation-controlled storage tank fire was firstly investigated based on the controlling mechanism of burning rate. A formula of burning rate after foam discharge is deduced. It was found that the oleophobic effect of fluorocarbon surfactants, the increased foam layer thickness and lower diffusion coefficient had coupled chemical and physical effects on extinguishing, which outweighed the cooling effect of foam evaporation. Due to the properties of CAF, a special phenomenon of the sudden increase

in the flame temperature and radiation after foam discharge was analyzed. The increase in foam spreading length with time was found to still abide by a power law under fire conditions. A concept of effective and total extinguishing time was suggested, both of which reduce with a rising foam flow rate, but the reduction rate decreases at higher flow rate. In addition, the foam dosage with flow rate had a U-shaped curve at total extinction. For the case of lower fuel thickness, its burning rate was lower and the extinguishing time was longer.


- **Keywords:** Compressed air foam; Foam spreading; Stagnant layer modelling; Oleophobic effect; Effective and total extinguishing


**Dinh Minh Nhat, Ramachandran Venkatesan, Faisal Khan. *Data-driven Bayesian network model for early kick detection in industrial drilling process*. Pages 130-138.**

Kick, or hydrocarbon influx, is one of the significant challenges during the drilling operation. A kick happens when the formation pressure exceeds the hydrostatic pressure of mud weight. Detection of a kick at an early stage spares more time to take necessary actions to prevent its growth and mitigate the potential well blowout. There are varieties of methods applied for early kick detection. The conventional method entails monitoring surface parameters which leads to delay in the detection. Some recent works show the ability to employ monitoring of downhole parameters to realize early kick detection. Data-driven Bayesian Network (BN) has shown to solve problems in complex systems where the knowledge about the system is not adequate to apply a model-based method. Data-driven BN creates a model based on historical data, which is usually available, unlike expensive, and often insufficient, expert knowledge. Using the data obtained in a laboratory-scale experiment, this paper presents the application of data-driven BN model in using downhole parameters to early kick detection.


- **Keywords:** Data-driven model; Kick detection; Blowout prevention; Bayesian model; Process safety; Risk engineering


**Peter Schmitz, Paul Swuste, Genserik Reniers, Karolien van Nunen. *Mechanical integrity of process installations: Barrier alarm management based on bowties*. Pages 139-147.**

Safety Research project was carried out in an ammonia plant of OCI Nitrogen, located at the Chemelot site in Geleen, The Netherlands. This research focused on the development of a method to monitor accident processes in the chemical industry mainly caused by mechanical integrity of static equipment like vessels, tanks and heat exchangers. A significant part of the mechanical integrity failure scenarios originates from material degradation and corrosion mechanisms which may develop over a relatively long-time period, possibly taking months, years or even longer. Mechanical failure scenarios from two process units have been worked out and visualized using a bowtie. The research project shows that the monitoring of early warnings can provide information about the current development of mechanical failure scenarios. In addition, early warnings can be used to initiate inspections if there is a likelihood that the mechanical failure scenario has been activated. Considering the shift from breakdown maintenance to preventive and predictive maintenance and risk-based inspection (RBI), inspections based on early warnings could also be a new step in the field of maintenance efficiency.


- **Keywords:** Bowtie; Mechanical failure mechanism; Integrity; Process safety indicator; Ammonia; Risk-based inspections

**Gong Cheng, Zhang Li, Liming Sun, Yazhuo Li, Jie Fu. *Application of Microwave/Electrodeless Discharge Ultraviolet/Ozone Sterilization Technology in Water Reclamation*. Pages 148-156.**

In recent years, a new water treatment technology based on microwave discharge electrodeless lamp (MDEL) has been developed. Hence, we designed an integrated system of microwave/electrodeless discharge ultraviolet/ozone (MW/UV/O3) for sewage sterilization according to the theoretical study of MDEL. The experiment was designed to test the ability to sterilize Escherichia coli and Bacillus subtilis by using different process conditions, such as single O3, MW/UV and MW/UV/O3, aiming to find an optimal process route. The results showed that the bactericidal effect of MW was mainly thermal effect, the bactericidal effect of MW/UV was significantly affected by turbidity, while the bactericidal effect of MW/UV/O3 was better than single O3 and MW/UV. In the dynamic test, when the four electrodeless UV lamps were stable, the light intensity reached 3.6mW/cm2; when the aeration rate was 50L/min, the generated O3 content was 0.30mg/L. With a water flow of 800L/h and hydraulic retention time of 1.5min, a sewage sterilization rate of >99.99% was achieved by MW/UV/O3 system, and other water quality indexes including chemical oxygen demand (COD) and total organic carbon (TOC) in effluents was also decreased to some extents.

- **Keywords:** MW/UV/O3; Escherichia coli; Bacillus subtilis; Microwave electrodeless lamp; Water reclamation; Disinfection

**Thiwa Rattanaya, Prawit Kongjan, Charun Bunyakan, Alissara Reungsang, Rattana Jariyaboon. *Upgrading biogas to biomethane: Alkaline recovery of absorbed solution by thermal decomposition*. Pages 157-166.**

A process to upgrade a biogas product to biomethane has been investigated. Recycling of an absorbent is important for low-cost upgrading of biogas by chemical absorption. This study investigated the alkaline recovery of absorbent solution by thermal decomposition at various temperatures (75, 85 and 95 °C) and various vacuum levels (0.2, 0.4 and 0.6 bar). During heating, CO2 and H2S were released from the absorbent solution, which increased the pH. The highest pH 10.58 was reached for NaHCO3 solution from initial pH 8.86 when treated at 95 °C and 0.6 bar vacuum level (gauge pressure). The mass fraction of CO32− in the solution increased from 0.06 to 0.78. Experiments on H2S removal from NaHS solution gave the highest pH 10.38 at 95 °C and 0.6 bar vacuum pressure. Moreover, the performance of the recovered alkaline solution was tested in biogas absorption. The results show that CO2 and H2S removal efficiencies of alkaline solution before and after recovery were similar, at 80 and 99 % respectively. This study demonstrated that thermal decomposition has high potential for recovering the alkaline used absorbent, for recirculation back into the absorption process.

- **Keywords:** Biomethane; Biogas upgrading; Alkaline recovery; Thermal decomposition

**S.M. Al-Salem. *Valorisation of End of Life Tyres (ELTs) in a Newly Developed Pyrolysis Fixed-Bed Batch Process*. Pages 167-175.**

This article shows a preliminary study of an end of life tyres (ELTs) use as a feedstock in a newly developed and patented reactor system that utilises a three zone heating element set-up along its fixed bed. The pyrolysis reaction was conducted between 500 to 700 °C and has yielded a maximum pyrolysis oil at 500 °C which was attributed to the promotion of secondary cracking of the oil into permanent (non-condensable) gaseous products. The oil yield and properties including estimated mass balance, sulphur content and higher heating value (HHV) shows that the pyro-oil is within fuel standards of the

market making it a green and renewable resource off of waste. In addition, The hydrocarbon (HC) range of the products obtained from the oil shows that it is within the diesel range of typical fuels. The analysis of the gaseous products from the pyrolysis showed that an increase in the average reactor bed temperature promotes the decomposition of primary HC and pyrolysis oil into secondary products. This results in the detection of tetradecanoic acid, limonene and eicosane, among other major chemical groups at temperatures above 550 °C which is the end-set temperature of feedstock examined. It can be concluded that by using such a reactor set-up and upgrading the fuels extracted from its downstream stigmatic features of fixed bed reactors might be overcome with a lucrative economical value and rate of return in a circular economy perspective.


- **Keywords:** Tyres; Energy; Waste; Circular Economy; Oil; Diesel


### Hossein Kazemi, Shahrokh Shahhosseini, Amin Bazyari, Mohsen Amiri. *A study on the effects of textural properties of γ-Al2O3 support on CO2 capture capacity of Na2CO3*. Pages 176-185.


Na2CO3/γ-Al2O3 is one of the most promising sorbents to capture CO2 from industrial flue gas streams due to its high efficiency in low-temperature and low cost. The textural properties of the γ-Al2O3 support, such as specific surface area and pore volume play key roles in performance of the sorbent. Therefore, the aim of this study was to improve the sorbent performance, using several γ-Al2O3 supports, prepared through a modified sol-gel process in the presence of polyethylene glycol (PEG). N2 adsorption-desorption analysis showed that the pore volume and specific surface area of the sample with the PEG/Al(OPri)3 mole ratio of 0.05 were, respectively, about 340 % and 38 % higher than the sample synthesized in the absence of PEG. In addition, improving the specific surface area and pore volume of γ-Al2O3 enhanced the total CO2 capture capacity of a Na2CO3/γ-Al2O3 sorbent by 34 %. Moreover, the effect of Na2CO3 loading on the best γ-Al2O3 sample was investigated, and the optimum loading of Na2CO3 and the corresponding total CO2 capture capacity were observed to be 50 wt.% and 131.6 mg CO2/gsorbent, respectively. Finally, the regeneration conditions of the sodium-based sorbent were determined using chemical kinetic study and temperature programmed desorption (TPD) analysis.



- **Keywords:** CO2capture; Na2CO3/γ-Al2O3 sorbent; Specific surface area; Pore volume; Regeneration temperature


### Lian Li, Na Li, Du Wen, Yashu Yao, Qulan Zhou, Yunjin Ao. *Experimental study on heat transfer process in boilers to predict thermal strain/stress distribution and deformation risk of membrane walls*. Pages 186-198.


As boilers are designed with higher parameters and larger capacity, deformation failure caused by thermal stress seriously threatens the safety of heating surfaces, especially membrane walls. In this paper, thermal strain/stress distribution on membrane walls, and its relationship with heat transfer process in the furnace were experimentally investigated in a laboratory-scaled arch-fired boiler. Tension strain and compression stress were detected on membrane walls, with definite directionality decided by wall structure. The measured high stress and high temperature zones coincided well with the location of deformation failure in the prototype boiler. Temperature on membrane walls links the heat transfer process and strain/stress distribution. A high level of wall temperature enhanced the directionality of strain/stress, while dispersive temperature gradient weakened such directionality. Additionally, significant correlations were found between wall temperature and corresponding thermal strain/stress. By defining constraint coefficients (β1, β2) and stress coefficients (ke, kт), a model was proposed to quantitatively predict the strain/stress distribution on membrane walls. It provides a way to reduce the deformation risk of membrane walls via improving heat transfer process.

Furtherly, the temperature-strain/stress correlations found in the arch-fired boiler were validated in another wall-fired boiler, thus provide great value in safety precaution to various boiler types.

- **Keywords:** Boiler; Deformation risk; Thermal stress; Heat transfer; Heating surface; Membrane wall

**Soleyman Sahebi, Mohammad Sheikhi, Bahman Ramavandi, Mehdi Ahmadi, Shuaifei Zhao, Adeyemi S. Adeleye, Zhara Shabani, Toraj Mohammadi. *Sustainable management of saline oily wastewater via forward osmosis using aquaporin membrane*. Pages 199-207.**

The hypothesis that petrochemical oily wastewater containing high amounts of total dissolved solids (TDS), chemical oxygen demand (COD) and total organic carbon (TOC) can be effectively treated by a new biomimetic forward osmosis (FO) membrane for fertigation purposes was assessed. The biomimetic FO membrane was characterized, and its intrinsic properties were evaluated. The fertilizer-driven FO (FDFO) process was evaluated in terms of water flux (WF), reverse solute flux (RSF), specific RSF (SRSF), and oil rejection at various draw solution (DS) concentrations and cross-flow velocities. Under optimized conditions, deionized water was used as feed and 3 M KCl, the most widely used potassium fertilizer, was used as DS at a cross-flow velocity of 0.1 m·s−1. WF and RSF of 67.22 Lm-2 h−1 and 48.3 gm−2 h−1, respectively, were obtained. Using saline oily wastewater as the feed, the orientation of the feed facing the membrane support layer exhibited a lower WF due to oily layer fouling within the membrane support. Apart from almost complete rejections of organic chemicals, the biomimetic FO membrane demonstrated a better performance (WF = 11.31 Lm−2 h−1) than the typical polyamide thin film composite (TFC) membrane (WF = 5.23 Lm−2 h−1) during mid-term fouling tests. This study demonstrates that FO process is an effective strategy for sustainable management of hazardous petrochemical oily wastewater by recycling the diluted fertilizer solution for direct fertigation without further treatment.

- **Keywords:** Forward osmosis; Oil/water separation; Aquaporin membrane; Saline oily wastewater treatment; Biomimetic membrane

**Wende Tian, Chenyang Fan, Zhe Cui, Haoran Zhang. *Conceptual design of a treatment process for centrifugal mother liquor wastewater in the PVC industry*. Pages 208-219.**

The centrifugal mother liquor (CML) discharged by polymer enterprises is a typical refractory organic wastewater with a variety of pollutants. This paper proposes a novel homogeneous and heterogeneous mixed Fenton oxidation strategy for the degradation of phenol and other organic compounds in CML. First, two promising CML treatment schemes are selected from six alternatives. Second, with the minimal equipment investment cost as object, a better CML treatment scheme is selected from these two alternatives using reactor network synthesis method. This optimal scheme is further modeled and simulated by Aspen Plus, and the effect of Fe2+ and H2O2 flowrate on organic compound removal rate is studied by sensitivity analysis. The removal rate of organic compound is found increasing from 71 % to 82.6 % under the optimal flowrate of Fe2+ and H2O2. Finally, the importance of each variable in CML treatment process is evaluated based on mutual information. Three variables including the temperature of homogeneous reactor, the liquid level of homogeneous reactor, and the temperature of heterogeneous reactor are selected as key variables in the stability control study by Aspen Dynamics. The dynamic simulation results prove that the CML treatment process has high stability in the face of disturbances.

- **Keywords:** CML treatment process; Chemical degradation; Reactor network synthesis; Mutual information; Dynamic simulation

**Syed Ali Mehdi Naqvi, Muhammad Raza, Saima Ghazal, Saeed Salehi, Ziho Kang, Catalin Teodoriu. *Simulation-based training to enhance process safety in offshore energy operations: Process tracing through eye-tracking*. Pages 220-235.**

Systemic risks and human errors are the root causes of process safety incidents in offshore operations. Human factor amounts for more than 70 % of offshore incidents and among those 75 % of them are due to perceptual errors involving rich information displays. Offshore drilling console is one such area where a display of hundreds of parameters and alarms maintains a constant cognitive load on the driller and upon his slight oblivion, severe consequences can follow. One way to study these errors is through a cognitive approach that focuses on the information accusation patterns rather than a behaviorist approach of focusing on the decision outcomes. In this research, we attempt to apply process tracing through eye-tracking methodology to look at information acquisition patterns of participants during a well control simulation. The simulation was designed on a commercial well control drilling simulator to observe the difference in performances by tracking information acquisition patterns of expert and novice participants. Fourteen (n=14) participants were paired into eight teams with each comprising of a driller and a supervisor. Eye-tracking glasses were used to record the fixation and saccade pattern of the participants over the simulator console and displays. For the analysis phase, four time of interests (TOIs) were selected as drilling break detection, kick detection, kick control, and kick circulation. For these TOIs the fixation and saccades pattern of participants on various areas of interest (AOIs) were analyzed through heat and gaze plots. Significant differences in information acquisition patterns of the novice and expert participants were linked to their performance to reveal valuable insights. Such insights are useful in identifying the dominating factors behind performance and can be used for targeted feedback to improve well control training and evaluation.

- **Keywords:** Energy operations; Eye tracking; Simulation-Based training; Well control; Process safety

**Chengkang Gao, Chengbo Gao, Kaihui Song, Yuhong Xing, Weiwei Chen. *Vehicle emissions inventory in high spatial–temporal resolution and emission reduction strategy in Harbin-Changchun Megalopolis*. Pages 236-245.**

Harbin-Changchun Megalopolis (HCM), as one of the vehicle production centers in China, has rapidly increasing vehicles on road supported by people's increasing purchasing power, having directly and indirectly led to air pollution. This study systematically analyzes tempo-spatial characteristics of vehicle emissions by combining International Vehicle Emissions (IVE) model with the Technical guidelines for road motor vehicle emission inventory of air pollutants (Guideline) in HCM. This research further analyzes emissions from various emissions sources and projected emissions based on scenarios. The results show that the CO and HC emissions from mini passenger cars (MiniPC) and ordinary motorcycles using gasoline account for 86.4 % and 82.3 % of total emissions. Diesel-fueled heavy-duty trucks (HDT) are the main sources of NOX and PM, accounting for 86.5 % and 89.7 % of the total emissions, respectively. Three emission reduction scenarios are developed to analyze the vehicle emissions in HCM in 2020. This study concluded that phasing out the old vehicles is an effective strategy to mitigate air pollutions in HCM, with reduction rates of pollutants CO, HC, NOX, PM2.5 and PM10 being 19.8 %, 19.6 %, 8.6 %, 18.3 % and 18.8 %, respectively.

- **Keywords:** Harbin-Changchun Megalopolis; On-road movement source; High temporal and spatial resolution; Temporal and spatial distribution; Emission reduction strategy

**Kai Wang, Zhen Lou, Lianhe Guan, Xiang Zhang, Binbin Qin, Yantao Huang. *Experimental study on the performance of drilling fluid for coal seam methane drainage boreholes*. Pages 246-255.**

Adopting in-seam boreholes for gas pre-drainage is an important method for ensuring safety coal mine operation. However, borehole collapse often occurs during the process of construction in soft coal seams, especially in downward boreholes. The main purpose of this study is to develop an efficient drilling fluid for coal seam methane drainage boreholes. First, a drilling fluid with a formula of 1 wt.% xanthan gum, and 1.2 wt.% Na-CMC, 0.6 wt.% cellulase and 4 wt.% bentonite, which is simply referred to as the drilling fluid, was developed based on the actual requirements of the construction site. Then, five property tests (viscosity, fluid loss resistance, cuttings carrying capacity, anti-collapse performance and degradability) of the drilling fluid were conducted in the laboratory. Finally, engineering application performances were carried out in Tangshan Mine, China. The results indicate the following: (1) When the xanthan gum concentration is fixed, the viscosity of the drilling fluid improves with increasing Na-CMC concentration. The API filtrate loss of the drilling fluid decreases with increasing bentonite concentration, while the filter cake thickness increases and then stabilizes. (2) The drilling fluid has an efficient performance in the carrying capacity of drill cuttings and the anti-collapse performance of a coal mass. Thorough degradation is completed 300 min after adding cellulase. (3) Compared with traditional clear water, the effective drilling distance of downward core drilling using the drilling fluid increases by two times, and the anti-collapse performance for coal seam methane drainage boreholes is remarkable.

- **Keywords:** Drilling fluid; In-seam boreholes; Viscosity; Anti-collapse

**Daisuke Tanikawa, Taiki Kataoka, Yuga Hirakata, Masashi Hatamoto, Takashi Yamaguchi. *Pre-treatment and post-treatment systems for enhancing natural rubber industrial wastewater treatment*. Pages 256-262.**

A pre-treatment system, circulation tank was proposed for residual rubber removal from natural rubber (NR) wastewater. The main treatment system consisted of an anaerobic baffled reactor (ABR) and a down-flow hanging sponge (DHS) reactor. An additional DHS reactor (post-DHS) was installed after ABR-DHS system as a post-treatment for nitrogen removal. In the pre-treatment circulation tank, the contact numbers with seed rubber was considered a key factor in the coagulation of residual rubber. Furthermore, the aerobic conditions enhanced the NR wastewater biodegradability in both ABR and DHS reactors. The post-DHS achieved single-stage nitrification-denitrification, using sodium acetate solution as a carbon source, under non-aeration conditions. Finally, the water quality of the final effluent met the quality standards of NR producing countries. In the ABR, hydrogen-utilizing methane-producing archaea, as well as syntrophic VFAs degrading bacteria, were the main bacteria contributing to the organic matter degradation in NR wastewater. On the other hand, most of the residual rubber in the NR wastewater was degraded in the DHS reactor by aerobic rubber-degrading bacteria (Gordonia).

- **Keywords:** Natural rubber industry; Rubber recovery; Nitrogen removal; Anaerobic baffled reactor; Down-flow hanging sponge

**Sheng Xue, Chunshan Zheng, Xiaoliang Zheng, Bingyou Jiang, Yaobin Li, Zhigen Wang. *Experimental determination of the outburst threshold value of energy strength in coal mines for mining safety*. Pages 263-268.**

An outburst of coal and gas is defined as a rapid release of a large quantity of gas in conjunction with an expulsion of coal into the mine workings in coal mines. It is a major

dynamic hazard during coal mining and has to be controlled for mining safety. Despite significant advances made in outburst studies, the outburst incidence continues to occur. A variety of indices have been developed in assessing outburst risk such as gas content, gas desorption rate and coal strength. However these indices are empirical or based mainly on localized experience. Aiming to develop a more scientifically solid index in outburst risk assessment, energy approach was adopted in this study to explain the outburst process, i.e. the outburst is treated as a rapid energy release process in coal. Experimental investigations on outbursts with respective gas pressure of 0.4MPa, 0.6MPa, 0.8MPa, 0.9MPa and 1.0MPa were conducted. The mass and size distributions of ejected coal were analyzed. Based on testing results, the outburst effective energy in coal (including expansion energy of free gas in pore and the energy of desorption gas in coal structure), and the outburst energy of fragmenting and moving coal particles were both calculated. Finally, the outburst threshold value of energy strength was determined. Results show that: (1) the outburst effective energy and the energy for coal fragmentation and movement both positively correlate with gas pressure; (2) the minimum energy strength of about 1.1MJ/m3 in gas-bearing coal is required for an outburst to occur; (3) compared with free pore gas energy, the desorption gas energy from coal plays a decisive role in outburst initiation and propagation, which is in good agreement with the popular view that coal and gas outburst is gas-driven. Outcomes of this study indicate that the risk of outbursts could be effectively minimized through reduction in coal seam gas energy.


- **Keywords:** Mining safety; Outbursts; Energy strength; Outburst threshold value; Desorption gas energy


### M. Farsi, M. Fekri Lari. *Methanol production based on methane tri-reforming: Process modeling and optimization*. Pages 269-278.

In this research an process flowsheet is introduced for carbon dioxide conversion to methanol and a mathematical framework is prepared to analyze the operability of proposed plant. The main steps in the designed process are syngas production through methane tri-reframing, syngas purification, methanol synthesis in the isothermal reactor and syngas recycling. To develop a detail framework, the methane and syngas conversion sections are heterogeneously simulated based on the energy and mass conservation laws, and integrated with the considered equilibrium-based model for separation sections. To prove the correctness of developed model, the simulations results are compared with the experimental data at the same condition. Then, an optimization problem is formulated to determine the optimal operating condition of designed process considering methanol production capacity as objective. Since feeding policy is a key strategy to shift tri-reforming reactions toward the desired condition, the applied single-bed tri-reformer in the designed process is substituted by a multi-bed reactor and methanol production capacity is calculated. It concludes that applying the multi-bed reformer changes the tri-reforming reactions toward the hydrogen synthesis side and increases the methanol production rate from 200 to 265 ton day−1.


- **Keywords:** Process development; Methanol; CO2 conversion; Mathematical framework; Process optimization


### Audrey Santandrea, Alexis Vignes, Arne Krietsch, David Brunello, Laurent Perrin, André Laurent, Olivier Dufaud. *Evaluating the explosion severity of nanopowders: International standards versus reality*. Pages 279-291.

The maximum explosion overpressure and the maximum rate of pressure rise, which characterize the dust explosion severity, are commonly measured in apparatuses and under specific conditions defined by international standards. However, those standards conditions, designed for micropowders, may not be fully adapted to nanoparticles.

Investigations were conducted on different nanopowders (nanocellulose, carbon black, aluminum) to illustrate their specific behaviors and highlight the potential inadequacy of the standards. The influence of the sample preparation was explored. Various testing procedures were compared, focusing on the dust cloud turbulence and homogeneity. Dust dispersion experiments evidenced the importance of the characterization of the dust cloud after dispersion, due to the fragmentation of agglomerates, using metrics relevant with nanoparticles reactivity (e.g. surface diameter instead of volume diameter). Moreover, the overdriving phenomenon (when the experimental results become dependent of the ignition energy), already identified for micropowders, can be exacerbated for nanoparticles due to their low minimum ignition energy and to the high energy used under standard conditions. It was evidenced that for highly sensitive nanopowders, pre-ignition phenomenon can occur. Finally, during severe explosions and due to a too long opening delay of the 'fast acting valve', the flame can go back to the dust container.


- **Keywords:** Dust explosion; Nanoparticles; International standards; Explosion severity; Ignition


**Yi Lu, He Li, Jiexin Lu, Shiliang Shi, Geoff G.X. Wang, Qing Ye, Runqiu Li, Xiangnan Zhu. *Clean up water blocking damage in coalbed methane reservoirs by microwave heating: Laboratory studies*. Pages 292-299.**


Water blocking damage is one of the most serious formation damages that restricts the development of low-permeability coalbed methane (CBM) reservoirs. Characterized by the conversion of the electromagnetic energy into heat, microwave heating may be a promising method to remove water blocking damage. In this study, contact angle tests and permeability tests were performed to investigate the effects of microwave heating on water blocking damage in CBM reservoirs. The results indicate that microwave heating can lead to hydrophobization of coal. The permeability of coal first decreases after water intrusion and then increases after microwave heating. The permeability sensitivity of the moist coal to microwave heating is much greater than that of the dry coal. Furthermore, the increase in the water content of coal promotes the microwave recovery effect of permeability. Theoretical analysis shows that the petrophysical evolution of coal during microwave heating involves gas desorption, dehydration, pore damage, fracturing and decomposition. Outcome of this study implies that microwave heating can be used as a supplemental measure of hydraulic fracturing to enhance CBM recovery by removing the water blocking damage.



- **Keywords:** Coalbed methane; Microwave; Water blocking damage; Contact angle; Permeability


**Ghada Makhlouf, Aksam Abdelkhalik, M.A. Hassan. *Combustion toxicity of polypropylene containing melamine salt of pentaerythritol phosphate with high efficiency and stable flame retardancy performance*. Pages 300-311.**


Melamine salt of pentaerythritol phosphate (MPP) was synthesized through the reaction between phosphoric acid, pentaerythritol and melamine with molar ratios 0.8:0.2:0.6. MPP was mixed with polypropylene (PP) at different weight percentages. The advantages of the new way of preparing MPP appeared in the thermal stability and flammability properties of PP composites. TGA results showed that MPP increased the thermal stability of PP to high temperatures. UL94v test indicated that PP composites can achieve V0 at 20 % MPP loading level. Another remarkable advantage of the new method of preparing MPP is the sample containing 25 % MPP loading level could withstand without ignition when the flame was applied continuously for 30s. Limiting oxygen index (LOI) of PP increased to 36.8 % in PP/25 % MPP composite. Cone calorimeter (CC) results showed that

addition of MPP to PP greatly reduced the peak of heat release rate and total heat release values. FTIR gas analyser connected to CC showed that the addition of MPP to PP caused massive reductions in the production rates of CO and CO2 gases of PP. Fractional effective dose (FED) calculations indicated that combustion products of PP composites are less toxic than pure polymer. LOI and UL94v tests were repeated after one year on the same samples and they presented nearly the same results. The new data of MPP is expected to increase its industrial applications.

- **Keywords:** Melamine salt of pentaerythritol phosphate; FTIR gas analyser; Toxic gases; FED

### V. Godoy, M.A. Martín-Lara, M. Calero, G. Blázquez. *The relevance of interaction of chemicals/pollutants and microplastic samples as route for transporting contaminants*. Pages 312-323.

Microplastics have been converted a very important issue during current time. In addition, their capacity to adsorb other pollutants implies an additional problem. In this work, the potential of five types of microplastics derived from plastic waste, that include polyethylene, polyethylene terephthalate, polypropylene, polystyrene and polyvinyl chloride, to act as transporters of amoxicillin, atrazine, diuron, paracetamol, phenol and vancomycin was studied. Results suggested that microplastics, especially polyethylene, polyethylene terephthalate, polystyrene and polyvinyl chloride, revealed an essential protagonist as carriers of amoxicillin and phenol. The kinetic study showed that the sorption processes (from water to plastic) was slow and needs more than 28 days (amoxicillin) or about 21 days (phenol) to reach equilibrium. The modelling of equilibrium showed a better fit of the Langmuir model. The maximum Langmuir sorption capacities reached values between 4.03 and 8.80mg/g for amoxicillin and between 1.25 and 2.80mg/g for phenol. With respect to release tests, the liberation of the loaded pollutants was minor at the lower tested temperature (T =25°C) and lower tested pH (pH=2). Percentage of chemicals released increased between 1.3 and 7.9 times as the temperature increased until 40°C. Similarly, the results revealed that release was greatly pH dependent. In these experiments, a singular behaviour was observed for amoxicillin at 25°C, a combined effect of adsorption-release seems happen.

- **Keywords:** Microplastics; Adsorption; Release; Amoxicillin; Phenol

### Petru Apopei, Corina Orha, Mina Ionela Popescu, Carmen Lazau, Florica Manea, Cezar Catrinescu, Carmen Teodosiu. *Diclofenac removal from water by photocatalysis- assisted filtration using activated carbon modified with N-doped TiO2*. Pages 324-336.

The aim of this study was to develop powdered and granular activated carbon modified with N doped TiO2, namely PAC-TiO2N and respective, GAC-TiO2N by sol-gel method, starting from commercial activated carbon, for the removal from water of diclofenac (DCF), an emerging pollutant. The synthesized materials were characterized systematically and morphostructural, light absorption and electrical charge properties were determined. The sorption and photocatalytic capacities of both materials were determined by batch experiments based on the kinetic models and the effect of operational parameters. GAC-TiO2N was selected for further testing in fixed bed-column experiments envisaging its potential integration with real drinking water treatment technology. The GAC-TiO2N tested in UV irradiation-assisted fixed bed-column filtration for DCF removal exhibited a great potential for practical application, by testing in simulated coexisting DCF and humic acids (HAs) and real surface water spiked with DCF (Bega River, Timisoara city, Romania). About 80% removal efficiency was noticed for both DCF and HAs and about 70% of the organic matter was removed (expressed as total organic carbon- TOC indicator). UV irradiation during filtration allowed the activation

of the GAC-TiO2N filtration layer without TiO2 loss, which led to longer life-times due to the potential "self-cleaning" effect and its good stability.


- **Keywords:** Diclofenac; Emerging pollutant; Drinking water; Activated carbon modified with TiO2; UV irradiation-assisted filtration


**Manoj Jose Kalathil, V.R. Renjith, Nitty Rose Augustine. *Failure mode effect and criticality analysis using dempster shafer theory and its comparison with fuzzy failure mode effect and criticality analysis: A case study applied to LNG storage facility*. Pages 337-348.**


Failure mode effects and criticality analysis (FMECA) is widely used, by developing a Risk Priority Number (RPN), to identify the failure modes and to prioritize them. But this has been extensively criticized due to several drawbacks in the literature. This issue can be solved partly by using Fuzzy FMECA (FFMECA) although Fuzzy logic itself has been criticized of having a direct bearing on subjectivity. This paper makes use of Dempster-Shafer Theory (DST) of evidence-a proper mathematical framework to deal with the epistemic uncertainty often affecting the input evaluations of risk parameters. DST based FMECA is capable of providing an appropriate, precise and fault-free, failure mode prioritization. Belief and Plausibility distributions are used to synthesize the obtainable information and to make them useful for the purpose. The results obtained from DST-FMECA is compared to the results drawn from the FFMECA applications (already conducted in the liquefied natural gas (LNG) storage facility) to validate FFMECA and vice versa. The comparative results presented in this paper establish the capabilities of both the approaches, especially in a complex system like the LNG storage and similar facilities where even a minor failure may lead to catastrophic effects.



- **Keywords:** Failure mode effect and criticality analysis (FMECA); Fuzzy failure mode effect and criticality analysis (FFMECA); Fuzzy risk priority number (FRPN); Dempster-shafer theory (DST)


**Claudia Díaz, Marisol Belmonte, José Luis Campos, Oscar Franchi, Martín Faúndez, Gladys Vidal, Lucía Argiz, Alba Pedrouso, Angeles Val del Rio, Anuska Mosquera-Corral. *Limits of the anammox process in granular systems to remove nitrogen at low temperature and nitrogen concentration*. Pages 349-355.**


When partial nitritation-anammox (PN-AMX) processes are applied to treat the mainstream in wastewater treatment plants (WWTPs), it is difficult to fulfil the total nitrogen (TN) quality requirements established by the European Union (<10g TN/m3). The operation of the anammox process was evaluated here in a continuous stirred tank reactor operated at 15°C and fed with concentrations of 50g TN/m3 (1.30±0.23g NO2−-N/g NH4+-N). Two different aspects were identified as crucial, limiting nitrogen removal efficiency. On the one hand, the oxygen transferred from the air in contact with the mixed liquor surface favoured the nitrite oxidation to nitrate (up to 75 %) and this nitrate, in addition to the amount produced from the anammox reaction itself, worsened the effluent quality. On the other hand, the mass transfer of ammonium and nitrite to be converted inside the anammox granules involves relatively large values of apparent affinity constants (kNH4+app: 0.50g NH4+-N/m3; kNO2-app: 0.17g NO2−-N/m3) that favour the presence of these nitrogen compounds in the produced effluent. The careful isolation of the reactor from air seeping and the fixation of right hydraulic and solids retention times are expected to help the maintenance of stability and effluent quality.



- **Keywords:** Anammox; Dissolved oxygen; Granular biomass; Nitrogen; SRT; Temperature