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**Meghdad Pirsaheb, Hooshyar Hossini, Pouran Makhdoumi. *Review of microplastic occurrence and toxicological effects in marine environment: Experimental evidence of inflammation*. Pages 1-14.**

Microplastics with a size lower than 5 mm are a ubiquitous plastic polymer present in almost all marine environments. Today, microplastic contamination of the marine environment has been an issue of increasing scientific concern. Due to their small size they can be easily misused by a wide range of marine biota and accumulated mainly in the gut. However, the exact consequences of microplastics exposure in the aquatic organisms are largely unknown. This paper summarizes the recent literature on the following objectives: (1) the properties, types and sources of microplastics; (2) the routes of microplastics entrance into the marine environment; (3) ingestion of microplastics by marine biota and the probable toxicological mechanisms; (4) gut microbiota alternation as an inflammation mediator in marine animal. This review focuses on experimental studies indicate histopathological evidences of size and shape dependent microplastics induced inflammation in fish.

- **Keywords:** Plastic; Microplastic; Inflammation; Gut dysbiosis; Environment; Toxicology

**Omran Ahmadi, Seyed Bagher Mortazavi, Hasan Asilian Mahabadi, Mehdi Hosseinpouri. *Development of a dynamic quantitative risk assessment methodology using fuzzy DEMATEL-BN and leading indicators*. Pages 15-44.**

In this study, barriers elements and initiating events of accidents and their risk influence factors were identified and classified according to a developed conceptual model, relationship between the risk influences factors were determined using a fuzzy DEMATEL model, the risk influence factors weight was determined using a fuzzy AHP model and conditional probability table of the risk influence factors was obtained using Røed method. The probability of the initiating events and the barrier elements failure was determined using fuzzy logic. The barrier elements and the initiating events were modeled by mapping bow-tie in Bayesian network. The Bayesian networks of risk influence factors were constructed by mapping the fuzzy DEMATEL outputs in the Bayesian network. Leading indicators were developed for the risk influence factors and their content validity, practicability and importance were assessed using the fuzzy logic and eliciting expert's opinion using a paired comparison method. Finally, this paper

employed atmospheric storage tanks as a case study for explanation and verification of the significant benefits of the methodology developed by this study.

- **Keywords:** Bayesian network; Atmospheric storage tank; Fuzzy logic; Dynamic risk assessment; Leading indicator; Fuzzy DEMATEL

**Andrés Z. Mendiburu, Christian R. Coronado, João A. de Carvalho. *Difficulties on the determination of the flammability limits of fuel mixtures by the Law of Le Chatelier*. Pages 45-55.**

In the present article the inaccuracies related to the estimation of the upper flammability limits of fuel mixtures in air by using the Law of Le Chatelier are analyzed. A derivation of the Law of Le Chatelier was provided in order to understand the necessary conditions for its applicability. A statistical analysis was applied to the available experimental data for the lower and upper flammability limit of fuel mixtures. It was observed that the direction of flame propagation has a significant effect on the inaccuracies. The fuel mixtures for which the absolute values of the relative errors were higher than 10 % were selected for further study. Through the determination of the laminar flame speeds it was shown that those deviations were related to different heat release rates at the experimental and calculated upper flammability limits, respectively. A laminar flame speed sensitivity analysis was also applied to a selected group of fuel mixtures and two competing reactions for each mixture at the upper flammability limit were identified.

- **Keywords:** Law of Le Chatelier; Flammability limits; Derivation; Validation

**Xuxu Sun, Shouxiang Lu. *Experimental study of detonation limits in CH4-2H2-3O2 mixtures: Effect of different geometric constrictions*. Pages 56-62.**

In this study, the roles of perturbation induced by different shape obstacles on the detonation limits are investigated experimentally with four pressure transducers and soot foil, and the limit pressure of successful transmission is determined. Round, triangular and square orifice obstacles with the blockage ratio (BR) of 0.556, 0.889, 0.923 and 0.96 are considered. The CH4-2H2-3O2 mixtures are tested in a 90 mm diameter circular tube. Only steady detonation regime and fast flame mode are observed, and a sharply speed jump is seen near the limits. In the smooth tube, the value of limit pressure is 3 kPa, and it is enhanced significantly when the orifice plate is guided into the tube. Moreover, the critical pressure is rarely affected by the obstacle geometries at the same blockage ratio (BR). However, more obvious differences in the detonation cellular patterns and the critical values of DH/λ can be found among three obstacle shapes. This indicates that although the critical pressure is nearly independent of orifice shapes, the propagation mechanism may be different among various obstacle geometries. Finally, the values of DH/λ approximately fluctuate around 1 near the limits.

- **Keywords:** Perturbation; Critical pressure; Detonation limits; DH/λ

**Kirti Sharma, Pankaj Raizada, Ahmad Hosseini-Bandegharaei, Pankaj Thakur, Rajesh Kumar, Vijay Kumar Thakur, Van-Huy Nguyen, Singh Pardeep. *Fabrication of efficient CuO / graphitic carbon nitride based heterogeneous photo-Fenton like catalyst for degradation of 2, 4 dimethyl phenol*. Pages 63-75.**

Considering the drawbacks of iron-based Fenton process, this work was aimed at designing of an efficient photo-Fenton like process via coupling of CuO/g-C3N4 photocatalyst with H2O2. The photo-Fenton like catalytic process was used for degradation of 2, 4-dimethyl phenol (DMP). The X% CuO/g-C3N4 Z-shceme

photocatalyst samples were fabricated by thermal calcination method, varing the CuO percentage (X = 2 %, 4 % and 8 %) loaded on g-C3N4. A lab-scale photoreactor was used to assess and select the optimal removal efficiency for DMP degradation. The photocatalyst was characterized by advanced spectral techniques. Coupling of CuO/GCN system with H2O2 significantly improved photocatalytic activity via photo-Fenton process. The kinetics of photo-degradation was found to exhibit pseudo-first order reaction rules. The rate of photodegradation was strongly influenced by pH and different concentrations of H2O2. 4%CuO/g-C3N4/H2O2 system proved to be the most efficient and exhibited much higher photo removal efficiency than CuO/g-C3N4 system and permitted attaining 99 % degradation of DMP in reaction time of 120 min. The successful implementation of this work was effective and of significance for the economical decomposition process of pollutants present in water under visible light irradiation. Overall, utilization of the studied system leads to high catalytic efficiency in a relatively short degradation period, which is of immense potential in water purification.

- **Keywords:** CuO/g-C3N4; H2O2; Photo-Fenton like system; 2, 4-dimethyl phenol degradation; Hydroxyl radical formation; Recyclability

### Deliang Luo, Nengwu Zhu, Wen Zhu, Rumsha Hassan, Pingxiao Wu, Yingyi Zhong. *Study on preparation and performance of biocarriers using waste liquid crystal display glass after extracting indium*. Pages 76-82.

A large amount of waste liquid crystal display (LCD) glass becomes a secondary waste after extracting the scarce metal indium from waste LCD by acid leaching. The feasibility of preparing biocarriers from waste LCD glass as raw materials was studied. The effects of different types and contents of foaming agents, foaming temperature and time on the biocarriers were studied. Under the condition of foaming temperature of 1050 ℃ and foaming time of 20 min, a suitable biocarrier was prepared by adding 5 % CaCO3 as a foaming agent into the waste LCD glass (denoted as Biocarrier-CaCO3). The technical indicators, which including void fraction, specific surface area, compressive strength and others of the Biocarrier-CaCO3, met the standard of CJ/T 299-2008 for water treatment. When Biocarrier-CaCO3 was applied for Shewanella cultivating, the biomass of the biofilm reached as high as 38 mg/g. In contrast, Na2CO3 was not suitable for the preparation of biocarriers for its porcelainization; SiC also failed as a foaming agent because the strength of the biocarrier could not reach the technical requirements of the product. In all, this study provided a novel strategy to recycle waste LCD glass as biocarrier to support the development of microbes and biofilm.

- **Keywords:** Waste LCD glass; Foaming agent; Biocarriers; Shewanella

### Feng Li, Abbas Hemmati, Hamed Rashidi. *Industrial CO2 absorption into methyldiethanolamine/piperazine in place of monoethanolamine in the absorption column*. Pages 83-91.

The goal of the study is to assess the use of MDEA + PZ in place of MEA solvent in industrial conditions. In the first part of the paper, a concise package of the models and the correlations in the Rate-based model is introduced to simulate the capture processes. For this purpose, Onda, Bravo-Fair, and, Billet-Schultes mass transfer correlations are evaluated to determine the one with a precise prediction of CO2 absorption. The results show that Bravo-Fair mass transfer correlation has a lower average error, 10.24 %, compared to Onda, 16.41 %, and Billet-Schultes, 27.02 %. In the second part of this paper, different operational and process sensitivity analyses have been performed to investigate the capabilities of the MDEA + PZ in place of the prevalent solvents such as MEA in the industrial environment with the use of the data obtained from Kermanshah petrochemical's Carbon Dioxide Recovery plant (CDR). According to the sensitivity analysis, which determines the influence of design parameters and operational conditions on CO2 absorption percentage, rich solvent temperature, liquid temperature profile, and

CO2 mole fraction profile in the gas phase inside the CO2 absorption tower, the total solvent concentration is the most influential one in CO2 absorption (%) and rich solvent temperature (°C). Hence, in optimal conditions, the absorption percentage can be raised from the base case 64.62 % to 87.44 % for MDEA + PZ compared to 82.86 of MEA. In addition, the rich solvent temperature can be lifted to 53.61 °C in comparison with 47.24 °C for MEA.


- **Keywords:** Rate-base model; Post-combustion CO2 capture; Methyldiethanolamine; Piperazine; Monoethanolamine; Sensitivity analysis


**Guanghui Li, Jian Wang, Mingjun Rao, Jun Luo, Xin Zhang, Jingxiang You, Zhiwei Peng, Tao Jiang. *Coprocessing of Stainless-Steel Pickling Sludge with Laterite Ore via Rotary Kiln-Electric Furnace Route: Enhanced Desulfurization and Metal Recovery*. Pages 92-98.**

Stainless-steel pickling sludge (SSPS) is a hazardous solid waste, which mainly contains CaSO4, CaF2 and a high level of metals such as Fe, Cr and Ni. The high-content of sulfur in the SSPS hinders its adequate treatment and deteriorates the quality of hot ferronickel when the SSPS was used as a feed to the rotary kiln-electrical furnace process (RKEF). Thus, the desulfurization behaviors of the SSPS, including thermodynamics, phase transformation and off-gas emission characteristics during pre-reduction were primarily investigated in this work. Pre-reduction temperature and carbon content were essential for the desulfurization, and the reduction temperature should be higher than 850°C for sufficient sulfur removal. The presence of laterite ore enhanced the desulfurization of SSPS, and on the other hand, the presence of SSPS facilitated the subsequent reduction smelting. Under optimal conditions, almost all of the sulfur within SSPS could be removed by pre-reduction, and 94.72% Fe, 81.90% Ni and 46.14% Cr were recovered by reduction smelting.


- **Keywords:** Stainless-steel pickling sludge; Desulfurization; Laterite ore; Calcium sulfate; RKEF process


**Wei Qin, Bing Zhang, Rui Xu, Xianghua Wen. *Process safety and environmental protection: An optimized solid phase denitrification filter by using activated carbon fibers for secondary effluent treatment*. Pages 99-108.**

This study investigated the denitrification potential of an optimized solid-phase filter with activated carbon fiber (ACF) setting at the top and bottom under hydraulic retention time (HRT) shorter than 60 min from the synthetic secondary effluent. The results showed that, high nitrate removal efficiencies (>99 %) were obtained in reactors filled with poly (3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) 3020 at initial stage of start-up. During stable operation under either HRT 40 min or 30 min, the reactor with PHBV 3020 as carrier achieved 90 %–100 % nitrate removal without nitrite accumulation. Moreover, it reached the maximum denitrification rates of 41.8 mg-N/Lh at HRT of 30 min which was significantly higher than that of the reactors filled by ACF/quartz grains and quartz grains at top and bottom. Microbial community in this reactor was dominated by the phylum Proteobacteria as well as Bacteroidetes. The ACF worked as favorable habitat for denitrifying bacteria Hydrogenophaga, Thiothrix, Desulfomicrobium and Sulfurimonas. The genera Ottowia, Limnohabitans, and Propionivibrio attached to ACF at top tended to degrade remaining organics. The optimized solid-phase denitrification filter with ACF showed good application potential for nitrate removal from the secondary effluent.


- **Keywords:** Denitrification; Nitrate removal; PHBV; Activated carbon fibers; Microbial community

**Wei Zhao, Kai Wang, Yang Ju, Huzi Dong, Zhen Lou, Fenghua An, Bin Feng. *Influence of the roadway exposure time on the accuracy of gas content measurements in reconstructed and extended mines*. Pages 109-117.**

The 100-year global warming potential of methane is 28 times higher than the value of carbon dioxide. Accurate gas content measurement is a precondition of coal mine reconstruction and extension designs for reducing methane emission due to that in these scenarios the stress and gas pressure distributions were unpredictably disturbed by previous mining activities. Longer roadway exposure time induce lower gas content and high measurement error. In this study, a coupling model considering the influence of gas transport, solid mechanics, and permeability evolution was established to predict the gas pressure distribution in coal seams. Based on this model, the influence of the roadway exposure time on the gas pressure distribution in an extended mine, Hulonggou Mine, was numerically studied with the software of COMSOL. The results show that the stress concentration area near the roadways can reduce the rate of gas emission. In addition, the gas pressure relief zone becomes increasingly larger as the emission time increases. For the studied coal seam, the boundary of the gas pressure relief zone is about 25–30 m to the center line after 25 years' gas emission. At last, actual gas content measurements validated the simulated results. The results can help scholars properly predict the gas content and design the gas drainage plans for coal seams that have been excavated for several years.

- **Keywords:** Greenhouse gases; Plastic zone; Dual-porosity medium; Borehole length

**Ting Li, Shugen Liu, Xiaofei Yao. *Addition of reactive oxygen scavenger to enhance PH3 biopurification: Process and mechanism*. Pages 118-125.**

Biopurification has been employed to purify PH3 offgas. However, the removal efficiency is not very high owing to the PH3 biotoxicity. In this study, the reactive oxygen scavenger was introduced for the first time to enhance the PH3 biopurification. The process could be divided into two main stages, biosorption and bioconversion. The capacity of PH3 adsorption was 0.062 mg per gram of biomass; however, the final conversion of PH3 depended on the microbial metabolism. The oxidase activities increased when fulvic acids and tea polyphenols were added to the bioreactors denoted as R1 and R2, respectively. The two systems exhibited lower O2− contents, alleviating the excessive oxidation of intracellular organic matter, and the content of malondialdehyde in microbial organisms largely decreased. The PH3 removals in R1 and R2 fluctuated in the range of 79.4–82.7 % after 20 d, and were considerably higher than that in the control. A pathway via reactive oxidation scavenger enhancement of PH3 biopurification is proposed to clarify the correlation between the oxidation stress and biochemical process.

- **Keywords:** Phosphine; Biopurification; Reactive oxygen; Oxidase activity; Phosphorus transformation

**Augustine Osarogiagbon, Somadina Muojeke, Ramachandran Venkatesan, Faisal Khan, Paul Gillard. *A new methodology for kick detection during petroleum drilling using long short-term memory recurrent neural network*. Pages 126-137.**

Kick is a downhole phenomenon which can lead to blowout, and so early detection is important. In addition to early detection, the need to prevent false alarm is also useful in order to minimize wastage of operation time. A major challenge in ensuring early detection is that it increases the chances of false alarm. While several data-driven

approaches have been used in the past, there is also ongoing research on the use of derived indicators such as d-exponent for kick detection. This article presents a data-driven approach which uses d-exponent and standpipe pressure for kick detection. The data-driven approach presented in this article serves as a complementary methodology to other stand-alone kick detection equations, and uses d-exponent and standpipe pressure as inputs. This paper proposes a methodology which uses the long short-term memory recurrent neural network (LSTM-RNN) to capture temporal relationships between time series data comprising of d-exponent data and standpipe pressure data with the aim of increasing the chances of achieving early kick detection without false alarm. The methodology involves obtaining the slope trend of the d-exponent data and the peak reduction in the standpipe pressure data for training the LSTM-RNN for kick detection. Field data is used for training and testing. Early detection was achieved without false alarm.

- **Keywords:** Drilling; Kick detection; Machine learning; Long short-term memory (LSTM); Recurrent neural network (RNN); Time series data

**Zujin Bai, Caiping Wang, Jun Deng, Furu Kang, Chi-Min Shu. *Experimental investigation on using ionic liquid to control spontaneous combustion of lignite*. Pages 138-149.**

Coal spontaneous combustion (CSC) has become a safety topic and has been widely debated. This study investigated the inhibiting effect on CSC by using a series of novel ionic liquids (ILs) as chemical inhibitors. The microstructure and thermokinetic characters were observed and evaluated by Fourier transform infrared spectroscopy and synchronous thermal analyser. The results indicated that ILs could destroy reactive groups on relatively active coal surfaces, such as OH, aliphatic CH, and O-containing groups. However, as aromatic CH is the main chain of coal molecule, damaging it is difficult. Different anions and cations found in ILs exhibited different abilities for destroying the groups on the surface of coal molecules. The damage was caused by the properties of anions and cations by affecting the chain length, number of chains of the anion and cations, and electronegativity strength. The changes in microstructure increased the physical adsorption capacity of inhibitive coal samples during low-temperature oxidation, which changed the characteristic temperature points. In stages of water evaporation and desorption mass loss (stage 2) and the thermal decomposition (stage 3), the apparent activation energy of coal samples increased. The kinetic characteristics of the obstructed coal sample were predicted using the Flynn–Wall–Ozawa method. The development ability was delayed and the risk level was reduced of CSC in stages 2 and 3. Therefore, ILs should be utilised at relatively low-temperatures (<230.0 °C) to control CSC.

- **Keywords:** Coal spontaneous combustion; Ionic liquid; Chemical inhibitor; Thermokinetic character; Reactive group

**Hitesh Panchal, Sanil S. Hishan, Robbi Rahim, Kishor Kumar Sadasivuni. *Solar still with evacuated tubes and calcium stones to enhance the yield: An experimental investigation*. Pages 150-155.**

Present research study shows the evacuated tubes coupled with solar still to enhance the yield. Basin area of 1-meter square taken for the experiments and 14 evacuated tubes have been used at a lower side of the still. Calcium stones as sensible heat storage material (SHSM) have also been utilized to enhance the yield in present work. Three modes of experiments have been performed namely conventional solar still (CSS), solar still with evacuated tubes (SSET) and solar still with evacuated tubes and calcium stones (SSETCS) during January to June 2019 at Patan District, Gujarat. Groundwater was taken as feed water in present experiments. It was examined that the average yield was enhanced by 113.52 % and 104.68 % by use of SSET and SSETCS. The payback time

(PBT) also determined in current work, and it was 237 for SSETCS. At last, it was concluded that the calcium stones are good SHSM to reduce water quantity and accumulate the heat during the daytime.


- **Keywords:** Solar still; Evacuated tubes; Calcium stones; Payback period


**Yuanjun Liu, Liang Guo, Qianru Liao, Yihe Ran, Fawen Hu, Mengchun Gao, Zonglian She, Yangguo Zhao, Chunji Jin, Yiping Liu, Guangce Wang. *Polyhydroxyalkanoate (PHA) production with acid or alkali pretreated sludge acidogenic liquid as carbon source: Substrate metabolism and monomer composition*. Pages 156-164.**


The organic acid rich acidogenic liquid produced from waste sludge anaerobic fermentation was used as a potential feedstock for polyhydroxyalkanoates (PHA) production, which is a cost-effective and environmentally sustainable PHA production system. To analyze the effect of substrate on monomer composition of PHA, different acidogenic liquid generated from waste sludge fermentation in varied initial pH were used as external carbon source. The maximal PHA content accounted for 60.3 % of the dry cell with initial fermentation pH 10.0 sludge acidogenic liquid and the recovered polymer composition was 98.3 % polyhydroxybutyrate (PHB) and 1.7 % polyhydroxyvalerate (PHV) by mass. The utilization efficiency of soluble chemical oxygen demand (SCOD), protein, NH4+-N and volatile fatty acids (VFAs) was 95.4 %, 90.5 %, 98.0 %, 99.3 %, respectively. The tyrosine-like protein, tryptophan-like protein, fulvic acid-like organics and soluble microbial by-products were primary used for PHA production, while the humic acid-like organics used little. Furthermore, mass balance analysis was introduced to further illustrate the technology reliability.



- **Keywords:** Polyhydroxyalkanoates (PHA) production; Waste sludge; Carbon source; Acidogenic liquid; Volatile fatty acids (VFAs)


**Cai-Ping Wang, Zu-Jin Bai, Yang Xiao, Jun Deng, Chi-Min Shu. *Effects of FeS2 on the process of coal spontaneous combustion at low temperatures*. Pages 165-173.**


Spontaneous combustion of coal has become an important disaster that threatens the safety of coal mines. FeS2 is the main component of pyrite, which is suspected to be a major contributor to coal spontaneous combustion (CSC). So, it has important significance to FeS2 on the characteristics of coal oxidation for prevention and treatment. This study used coal samples mixed with different proportions of FeS2 (2.0 mass%, 4.0 mass%, and 6.0 mass% mass percentage) were tested to investigate the characteristics of spontaneous combustion, as compared with the fresh sample. The CO and CO2 production rates, critical temperature, and dry cracking temperature during oxidation were analyzed. The temperature-programmed experiments was conducted to simulate low-temperature oxidation processes realistically. In-situ infrared spectroscopy was used to appraise the evolution of low-temperature (< 200.0°C) oxidation of aromatic hydrocarbons, aliphatic hydrocarbons, and oxygen-containing functional groups on the surfaces of the samples. Experimental results showed that FeS2 exhibited a strong influence as the temperature exceeded the dry cracking temperature. Adding 2.0 mass% and 4.0 mass% FeS2 showed a promoting effect on low-temperature oxidation; however, FeS2 became an inhibitor which reached 6.0 mass%. Furthermore, adding 2.0 mass% FeS2 showed the strongest promoting effect. From a microscale perspective, the promoting effect of FeS2 on coal oxidation was due to thermal release from FeS2 oxidation, enhancing the reaction between aliphatic hydrocarbons, such as methyl groups and methylene, and oxygen. Due to the reaction of FeS2, the acidic environment was conducive to the hydrolyzation of lipid structures into highly active alcohol or phenol structures, which in turn promoted the oxidation of the coal sample. These results are

crucial for understanding the mechanism underlying the influence of FeS2 on CSC and mine safety protocols.


- **Keywords:** Pyrite; Coal spontaneous combustion; Low-temperature oxidation; In-situ infrared spectroscopy; Promoting effect


### Liang Ge, Yimin Shao, Yinjun Wang, Guangxun Zhang, Zujing Zhang, Lin Liu. *Experimental research on inerting characteristics of carbon dioxide used for fire extinguishment in a large sealed space*. Pages 174-190.


To accurately guide the quantitative injection of carbon dioxide for extinguishing the fire or diluting the accumulated toxic gases, 26 sensing devices used for detecting the multiple environmental parameters were firstly laid inside and outside of 210 m3 large sealed space, then each signal output from the sensing devices was transmitted successively to the A/D conversion module and the server with signal acquisition and analysis software, so the experimental research on inerting characteristics of carbon dioxide in different physical forms in this sealed space were carried out by using the mobile liquid storage and injection equipment, including fire source extinction, and accumulation and distribution of gas components, as well as cooling. Results show that: (1) For wood and gasoline, the critical oxygen concentration of combustion 16.98 % and the corresponding carbon dioxide concentration 28.6 % were determined comprehensively; (2) The concentration layering law in the stabilized gas was proved to be inconsistent with theoretical correspondence between specific gravity and height; (3) For direct liquid injection and gas perfusion at 2.2 MPa, the average temperature difference were 13.8 °C and 0.3 °C respectively, so the temperature drop characteristic of liquid injection was proved, and its optimal cooling distance from the nozzle is further determined from 5.6 m to 11.2 m.



- **Keywords:** Inerting characteristics; Carbon dioxide; Large sealed space; Fire extinguishment; Liquid injection; Liquid gasification


### Jinghan Zhao, Peihua Yan, Benjamin Snow, Rafael M. Santos, Yi Wai Chiang. *Micro-structured copper and nickel metal foams for wastewater disinfection: proof-of-concept and scale-up*. Pages 191-202.


It is necessary to disinfect treated wastewater prior to discharge to reduce exposure risks to humans and the environment. The currently practiced wastewater disinfection technologies are challenged by toxic by-products, chemicals and energy demand, a range of effectiveness limitations, among other concerns. An effective, eco-friendly, and energy-efficient alternative disinfection technique is desirable to modernize and enhance wastewater treatment operations. Copper and nickel micro-structured metal foams, and a conventional copper mesh, were evaluated as disinfecting surfaces for treating secondary-treated wastewater contaminated with coliform bacteria. The micro-structured copper foam was adopted for scale-up study, due to its stable and satisfactory bactericidal performance obtained over a wide range of bacterial concentrations and metal-to-liquid ratios. Three scales of experiments, using two types of reactor designs, were performed using municipal wastewater to determine the optimal scale-up factors: small lab-scale batch reactor, intermediate lab-scale batch reactor, and pilot-scale continuous tubular reactor experiments. The performance was evaluated with the aim of minimizing metal material requirement with respect to bactericidal efficiency and leaching risks at all scales. Copper foam, at or above optimal conditions, consistently inactivated over 95 % of total coliforms, fecal coliforms and E.coli in wastewater at various scales, and leachate copper concentrations were determined to be below Canadian guideline values for outfall. This study successfully implemented the "structure" strategy of process intensification, and opens up the possibility to apply micro-structured copper foam in a range of other water disinfection systems, from pre-treatment to point-of-use, and should thus become a topic of further research.

- **Keywords:** Wastewater disinfection; Bactericidal performance; Process scale-up; Micro-structured metal foam; Coliform bacteria; Process intensification

**Yutao Zhang, Guozhao Ji, Dexiao Ma, Chuanshuai Chen, Yinxiang Wang, Weijian Wang, Aimin Li. *Exergy and energy analysis of pyrolysis of plastic wastes in rotary kiln with heat carrier*. Pages 203-211.**

Energy and exergy analysis is a practical thermodynamic method to assess the potentiality of waste-to-energy technologies. In this study, plastic wastes were pyrolyzed in a rotary kiln to recover energy products including gas, oil and char. The effects of heat carrier loading in the kiln and plastic waste types on the pyrolysis process, including carbon distribution, properties of liquid oil/gas, energy and exergy of products, were investigated. Heat carrier loading could enhance the energy and exergy efficiency of the pyrolysis process. The exergy and energy efficiencies of the plastic mixture pyrolysis are in the range of 60.9 %–67.3 % and 59.4–66.0 %, respectively. The energy consumption ratio of polyethylene pyrolysis with 15 % heat carrier loading and plastic mixture pyrolysis with 20 % heat carrier loading showed that the pyrolysis could achieve self-heating by combusting some recycled gas and char products. This work provided an reliable assessment of potentiality of pyrolysis with heat carrier for converting plastic wastes into fuels.

- **Keywords:** Plastic wastes; Pyrolysis with heat carrier; Rotary kiln; Exergy; Energy

**Perumal Asaithambi, Rajendran Govindarajan, Mamuye Busier Yesuf, P. Selvakumar, Esayas Alemayehu. *Enhanced treatment of landfill leachate wastewater using sono(US)-ozone(O3)–electrocoagulation(EC) process: role of process parameters on color, COD and electrical energy consumption*. Pages 212-218.**

The combination of advanced oxidation processes (AOPs) and electrochemical process is gaining growing popularity for use in wastewater treatment. The present work explores for the first time, treatment of leachate wastewater from landfill waste using a combination of sonication (US), ozonation (O3) and electrocoagulation (EC) process expressed by % color removal, % Chemical Oxygen Demand (COD) removal and its associated electrical energy consumption. The results revealed that, the combined process (US/O3/EC) is highly successful in the treatment of leachate wastewater from landfill in terms of % color removal (100 %) and % COD removal (97.50 %) with low electrical energy consumption (8kWhr/m3) than the other hybrid and single process such as O3/EC, US/EC, US/O3 and EC, O3, US. The influence of different process parameters such as electrolyte concentration (1.50–7.50 g/L), current density (1.25–7.50 A/dm2), initial effluent pH (2–11), COD concentration (2000–6000 ppm), O3 production (0.75–3.75 g/hr) and sonication power (20–100 Watts) were studied on the efficiency of pollutant removal evaluated by reduction of % color and % COD and electrical energy consumption using hybrid US/O3/EC process. Overall, the analysis clearly showed that the approaches to integrated treatment technologies could synergistically remove the pollutant from the wastewater.

- **Keywords:** Landfill leachate; Process parameters; O3/US/ECprocess; % color and % COD removal; Electrical energy consumption

**Atta Ur Rehman, Sang-Min Lee, Jung-Hoon Kim. *Use of municipal solid waste incineration ash in 3D printable concrete*. Pages 219-228.**

Concrete 3D printing is an application of 3D printing technology for the construction of concrete structural and non-structural elements. It is a rapid method of construction

without the use of formwork, with minimum labor involvement and reduced material wastage. Curved walls and complex structures can be constructed by modifying the print path and controlling the rheological properties of concrete. The fusion of this technology with waste materials is necessary to reduce the problems associated with the recycling of wastes and to minimize CO2 emissions associated with the production of cement. In this study, two different municipal solid waste (MSW) incineration ashes (fly ash and bottom ash) were used to develop a concrete having rheological and hardened requirements of concrete used in 3D printing. Waste incinerator ashes were added as a substitute of ordinary Portland cement in concrete mix proportions. Flow table test and Gilmore needle test were used to measure the flow and setting time of concrete, respectively. Yield stress was measured by shear vane test. The buildability of ash containing printable concrete was simulated by comparing the vertical stresses due to the printing of concrete layers with the increase in the strength of the first stacked layer. Workability, open time, and buildability of the mix proportions were related to yield stress. The effect of adding waste incinerator ash upon the compressive strength was measured. The bond strength between layers at different printing time gaps was evaluated using bi-surface direct shear test. Experimental results showed that setting time promoting effect and initial yield stress enhancement by incinerated fly ash allows for a rapid construction speed with concrete 3D printing. This study concludes that incinerated fly ash can be successfully recycled in 3D printable concrete due to its favorable effects on rheology which are favorable for printing concrete.

- **Keywords:** Concrete 3D printing; Waste recycling; Waste incineration ashes; Fly ash; Bottom ash; Workability; Open time; Buildability

**Van-Huy Nguyen, Quoc Ba Tran, Xuan Cuong Nguyen, Le Thanh Hai, Thi Thanh Tam Ho, Mohammadreza Shokouhimehr, Dai-Viet N. Vo, Su Shiung Lam, Hai Phong Nguyen, Cong Tin Hoang, Quang Viet Ly, Wanxi Peng, Soo Young Kim, Tra Van Tung, Quyet Van Le. *Submerged photocatalytic membrane reactor with suspended and immobilized N-doped TiO2 under visible irradiation for diclofenac removal from wastewater*. Pages 229-237.**

immobilized N–TiO2 under visible irradiation for diclofenac (DCF) removal from wastewater. The effects of initial N–TiO2 concentrations for the SPMR with suspended N–TiO2 were determined for batch processes. Hydrogen peroxide was also coupled with the photocatalytic process. In continuous conditions, a reverse osmosis (RO) membrane was combined with the SPMR for enhancing effluent quality. DCF removal by the SPMR with suspended and immobilized N–TiO2 at a low N–TiO2 dosage (0.5g/L) was not much different between the two systems, but increased with higher N–TiO2 dosages for the reactor with suspended N–TiO2. Coupling H2O2 with the photocatalytic process under visible irradiation enhanced the DCF removal efficiency. In continuous conditions, DCF concentrations in the photoreactor increased during the reaction time, while those in the effluent (RO permeate) were steady for both systems and both processes. The permeate flux in the reactor with suspended N–TiO2 declined faster than in the reactor with the immobilized N–TiO2. Coupling H2O2 with the photocatalytic process yielded more resistant permeate flux rates. The cake layer formed on the microfiltration membrane of the SPMR with suspended N–TiO2 under visible irradiation was denser than others after completing the process.

- **Keywords:** SPMR; Suspended N-TiO2; Immobilized N-TiO2; Vis/N-TiO2; Vis/N–TiO2/H2O2

**Neha Shukla, Nikhil Dhawan. *Rapid microwave processing of discarded tubular lights for extraction of rare earth values*. Pages 238-249.**

In this study, recycling of spent tubular lights comprising about 40 % rare earth (Y, La, Ce, Eu, Tb) elements are explored. In this study, two different processing routes comprising leaching followed by microwave treatment, and vice versa are investigated. Leaching of Eu-Y values followed by microwave treatment of leach residue with sodium hydroxide was found promising for rare earth extraction. Different routes comprising one step, two-step, and acid baking in the microwave were compared based on the recovery of rare earth values. Two-step process consisting of acid leaching followed by NaOH microwave treatment of leach residue was found best concerning overall extraction and separation of Y-Eu and La-Ce-Tb oxides. The material balance shows that 50 g mixed oxide of Y, Eu, and ~8 g of La, Ce, Eu, Tb, Y mixed oxide with purity over 97 % can be recovered from 100 units of discarded tubular lights. Finally, it is concluded that microwave processing can be employed for the recovery of rare earth values from abundantly available discarded tubular lights.

- **Keywords:** Tubular lights; Recycling; Microwave; Leaching; Cerium; Terbium

**Xiao-Qiao Zhao, Hao Wang, Wen-Qian Wu, Jun Zhang, Wang-Hua Chen, Zi-Chao Guo, Li-Ping Chen. *Kinetic-parameters-free method of determining autocatalytic decomposition from experimental adiabatic data*. Pages 250-259.**

The decomposition of many hazardous materials goes through autocatalytic mechanisms. Due to the unpredictably sudden heat evolution companied with the decomposition of these materials, it is of great importance to identify autocatalytic decompositions and treat them with caution. In this work, a kinetic-parameters-free criterion is proposed to determine the autocatalytic decomposition using adiabatic calorimeters. This criterion states that the decompositions are autocatalytic if the values of RTp2Tf−Tp obtained by adiabatic experiments in different conditions are variable; otherwise they follow n-order behavior. Mathematical simulations at different values of φ, α0 and Ton have been conducted for n-order and autocatalytic decompositions to validate the criterion. To further validate the criterion, this method is applied to four representative substances: DCP, 20 % DTBP in toluene, BO and CHP. Overall, the validity of this criterion has been verified by simulation and experiment results.

- **Keywords:** Autocatalytic decompositions; Adiabatic calorimetry; Mathematical simulations; Kinetic-parameters-free method

**Arun Kumar, Surabhi Shrivastava, Nishith Verma, Chung-Chuan Hsueh, Chang-Tang Chang, Bor-Yann Chen. *Electrolyte-free electro-oxidation of aqueous glyphosate: CuPc-ACF electrode and optimization of operating parameters*. Pages 260-271.**

A novel approach is proposed in this study for degrading aqueous glyphosate (GLYP) efficiently via electro-oxidation (EO) using a novel copper phthalocyanine (CuPc)-dispersed activated carbon fiber (ACF) electrode. Green synthesis of the CuPc-ACF electrode was achieved by electro-sorption process through oxidation-reduction of the Cu species, using cyclic voltammetry, also for the first time. The prepared electrode was directly applied to degrade the aqueous recalcitrant pollutant without supplementation of an electrolyte and external source of oxidant. Operating parameters of the EO system were optimized via response surface methodology (RSM) based on central composite design using performance index of the area under the curve (AUC). A complete degradation of a synthetic GLYP solution at high concentration (1000 mg L−1) was indicated at the optimized pH and biased potential of 11 and 2.5 V (vs Ag/AgCl), respectively. Kinetic assessment of the experimental data revealed a threshold voltage between 1.5 and 2.0 V required to trigger an effective and irreversible degradation of the aminomethyl phosphonic acid (AMPA) intermediate. The kinetics for degradation of GLYP

was proposed via two pathways: a consecutive first-order reversible or an irreversible reaction forming the AMPA intermediate and a parallel reaction forming final transformed products. The study indicated a green route for the synthesis of the CuPc-ACF electrode for complete degradation of GLYP using EO as a green technology.


- **Keywords:** Glyphosate degradation; Copper phthalocyanine; Electro-Oxidation; Response surface methodology; Reaction kinetics


**Lucas Pandolphi Zini, Marielen Longhi, Eliena Jonko, Marcelo Giovanela. *Treatment of automotive industry wastewater by electrocoagulation using commercial aluminum electrodes*. Pages 272-284.**


Industrial liquid wastes may cause serious damage to nature and human health. Taking into account the protection of water resources and, especially, compliance to current legislation and international standards, several technologies for wastewater treatment have been studied. In general, the physico-chemical treatment is well-established and is applied by most industries. Electrocoagulation (EC) is a wastewater treatment method that has been evaluated as a procedure that may replace conventional treatment and significantly reduce the amount of sludge produced. Within this context, this work aimed to apply EC to the treatment of an industrial liquid waste from an automotive company to assess the efficiency of the technique. The industrial wastewater was collected, treated, and analyzed with regard to some discharge standards, including phosphorus, oils and greases, pH, turbidity, and metals (Al, Cr, Fe, Mn, and Zn). Moreover, the wear of aluminum electrodes used in the process, the electricity consumption, and compliance with the discharge standards were also evaluated. In general, either the removal efficiency or the reduction of discharge parameters was proportional to time and electric current density, but only one set of applied parameters met all limits. Electric current efficiencies exceeded 150 %, indicating that the wear of electrodes surpassed the estimate provided by Faraday's law. In addition, the electricity consumption increased proportionally to the time and electric current density with a loss of energy as heat.



- **Keywords:** Electrocoagulation; Aluminum electrodes; Wastewater treatment; Physico-chemical parameters


**César Ramírez-Márquez, Esbeydi Villicaña-García, Brenda Cansino-Loeza, Juan Gabriel Segovia-Hernández, José María Ponce-Ortega. *Inherent occupational health hazards in the production of solar grade silicon*. Pages 285-294.**


Solar energy has become one of the most developed renewable energy sources in recent years. As with any energy source or product, there are health risks associated with the manufacturing of solar cells. And even though the photovoltaic industry uses far lesser amounts of toxic and flammable substances than many other industries, the use of hazardous chemicals can present occupational and environmental hazards. One of the most important aspects in the selection of new processes lies in the protection of workers' health. Health risks can be reduced if a process is chosen properly and in preliminary phases. Since we have found that it is necessary to carry out an evaluation of the health risks to workers in the production of polycrystalline silicon for the manufacturing of photovoltaic cells, in this work we will use the Process Route Healthiness Index to quantify the health risk that each silicon production process represents (the higher the index, the higher the hazards). The polycrystalline silicon production processes evaluated with the healthiness index are: Siemens Process, Intensified Fluidized Bed Reactor Union Carbide Process, and Hybrid Process. Our results show that the Siemens Process is the healthiest process, but with the Process Route Healthiness Index values are closer to the Hybrid Process. Apart from this, a guide to the

assessment of inherent occupational health hazards in SiSG production processes was also developed, which provides results alike those to the PHRI methodology.


- **Keywords:** Solar grade silicon; Inherent occupational health hazards; Siemens process; Intensified FBR Union carbide process; Hybrid process


**Yih-Wen Wang, Chieh-Yu Huang. *Thermal explosion energy evaluated by thermokinetic analysis for series- and parallel-circuit NMC lithium battery modules*. Pages 295-307.**


The self-heating effect and pressure-blasting potential of a C/LiNixMnyCo1-x-yO2 (NMC) lithium battery were evaluated using adiabatic calorimetry. Such batteries are widely used in electric vehicles. Various states of charge (SoCs) of NMC battery modules connected in series and parallel circuits were examined to investigate the exothermic characteristics and thermal explosion energy under an open-circuit voltage (OCV) state. The heat generation and thermal explosion in various NMC battery modules were compared. The runaway reaction inside the cell and pressure dissipating out of the battery casing were assessed. Thermal runaway and explosion occur in a chargeable battery at an OCV state when the battery module fails or heats to an elevated temperature. Various SoCs of NMC modules were tested to measure the variances in temperature and pressure under adiabatic conditions. Electrochemical and chemical reaction kinetics and calorimetric test data from thermal runaways of various NMC modules were evaluated to create a battery thermal explosion energy model including enthalpy change and work.



- **Keywords:** Self-heating effect; Pressure-blasting potential; NMC battery module; Reaction kinetics; Thermal explosion energy model


**Mohamed F. Attallah, Hanan M. Abdelbary, Entessar A. Elsofany, Yasser T. Mohamed, Mohamed M. Abo-Aly. *Radiation safety and environmental impact assessment of sludge TENORM waste produced from petroleum industry in Egyp*t. Pages 308-316.**


The characterization and radiological study of sludge technically enhanced naturally occurring radioactive materials (TENORM) waste samples collected from the production of oil and gas at Gabal EL Zeit eastern desert in Egypt were carried out using different analytical and radiological spectrometry. The sludge TENORM waste sample was fractionated to 3 different particle sizes (< 1mm, < 1.6mm, < 2mm) as well as bulk sample. Sludge TENORM waste (bulk and different sizes) samples were characterized by Fourier transform infrared (FTIR), energy dispersive x-ray, (EDX) and x-ray diffraction (XRD). The mean activities of bulk and different sizes for U-238, Ra-226, Pb-210, Ra-224, K-40 and U-235 were high levels of natural background radiation. Radiation hazard indices were calculated to assess the risk of these samples on workers and the environment. Some of the representative radiation indices such as radium equilibrium Raeq, absorbed dose rate Dabs, annual effective dose rate Dann, external and internal hazard index Hex, Hin, annual gonadal dose equivalent AGDE, activity utilization index AUI, excess lifetime cancer risk factor ELCR, representative gamma index $I_{\gamma}r$, and alpha index $I\alpha$ were derived and compared with the world average values. The results demonstrated that there is a harmful radiation effect posed to the public or factory workers.



- **Keywords:** Radioactive materials; Natural gas; Radium; Lifetime cancer risk; Health impact


**Kyriaki Kiskira, Stefano Papirio, Yoan Pechaud, Silvio Matassa, Eric D. van Hullebusch, Giovanni Esposito. *Evaluation of Fe(II)-driven***

***autotrophic denitrification in packed-bed reactors at different nitrate loading rates*. Pages 317-324.**

Nowadays, nitrate represents one of the major contaminants of the hydrosphere, mainly affecting the quality of groundwater intended to the production of drinking water. This study proposes the use of Fe(II)-driven autotrophic denitrification as a high-potential, innovative bioprocess to couple microbially-catalyzed nitrate reduction to Fe(II) oxidation. Two identical up-flow packed bed reactors (PBRs), i.e. PBR1 and PBR2, with granular activated carbon as biofilm carrier were seeded with a Thiobacillus-mixed culture and operated for 153 days at different feed nitrate concentrations and hydraulic retention times (HRTs). The results show enhanced nitrate removal rates and efficiencies at increasing nitrate loading rates. In particular, nitrate removal and Fe(II) oxidation up to 85 and 95 %, respectively, were achieved in PBR1 at nitrate loading rates as high as 12.5mg NO3−/L/h. Besides not undermining the denitrification efficiency, increasing the nitrate loading rate from 8.1 to 12.5mg NO3−/L/h led to specific nitrate removal rates as high as 14.3mg NO3−/g VS/h. In PBR2, Fe(II)-driven denitrification was investigated at a constant nitrate loading rate by concomitantly decreasing the feed nitrate concentration and HRT. Despite the less severe operational conditions, the use of lower nitrate loading rates resulted in a lower nitrate removal efficiency than that obtained in PBR1.

- **Keywords:** Nitrate; Autotrophic denitrification; Ferrous iron; Loading rate; Packed-bed reactor

**Siti Nur Hatika Abu Bakar, Hassimi Abu Hasan, Abdul Wahab Mohammad, Siti Rozaimah Sheikh Abdullah, Rahmat Ngteni, Khairul Muis Mohamed Yusof. *Performance of a laboratory-scale moving bed biofilm reactor (MBBR) and its microbial diversity in palm oil mill effluent (POME) treatment*. Pages 325-335.**

The treatment performance of palm oil mill effluent (POME) using a laboratory-scale moving bed biofilm reactor (MBBR) was investigated in this study. Two types of biofilm carriers were used to fill the MBBR: black plastic media (BPM) and Hexafilter (HEX). Three media filling fractions (MFFs: 25 %, 50 % and 70 %) and retention times (RTs: 24, 48 and 72 h) were investigated to achieve the best MBBR performance in terms of the removal of chemical oxygen demand (COD) and ammonia-nitrogen (NH3-N) from POME. Increasing the RT significantly improved the removal of COD and NH3-N, whereas increasing the MFF resulted in insignificant changes. Overall, HEX performed better than BPM at 50 % MFF (72 h RT). Metagenomics analysis identified approximately 13 phyla of bacteria on the HEX compared to the BPM with only 10 phyla. Based on these findings, the laboratory-scale MBBR deserved a vote as an alternative treatment for POME under appropriate RTs and MFFs and in the presence of a suitable microbial community.

- **Keywords:** Biofilm; Moving bed biofilm reactor; Palm oil mill effluent; Media filling fraction; Microbial diversity

**N. Asikin-Mijan, N.A Rosman, G. AbdulKareem-Alsultan, M.S. Mastuli, H.V. Lee, N. Nabihah-Fauzi, I.M Lokman, Fahad A. Alharthi, Abdulaziz Ali Alghamdi, Amjad Abdullah Aisyahi, Y.H. Taufiq-Yap. *Production of renewable diesel from Jatropha curcas oil via pyrolytic-deoxygenation over various multi-wall carbon nanotube-based catalysts*. Pages 336-349.**

Jatropha curcas is a highly toxic plant that produces seed containing viscous oil with productivity (2 ton/ha), it grows in tropical and sub-tropical regions and offer greater adaptability to a wide range of climatic and soil conditions. Its oils have been noted as an important alternative to produce green diesel via deoxygenation reaction. This study,

deoxygenation of jatropha curcas oil (JCO) was carried out over NiO–Fe2O3 and NiO–ZnO catalysts that supported onto multi-walled carbon nanotube (MWCNT). It had found that high Fe and Zn dosages were ineffective in deoxygenation and greatest activity was observed on NiO(20) Fe2O3(5)/MWCNT catalyst. Structure-activity correlations revealed that low metal loading, large density of weak + medium acidic sites and strong basic sites play key role in enhancing the catalytic activities and n-(C15+C17) selectivity. Comparing carbon nanostructures and carbon micron size supported NiO-Fe2O3 revealed that green diesel obtained from NiO–Fe2O3/MWCNT catalysed deoxygenation had the highest heating value and the lowest amounts of oxygen content. Thereby, it confirmed the importance of carbon nanostructure as the catalyst support in improving the diesel quality. Considering the high reusability of NiO-Fe2O3/MWCNT (6 consecutive runs) and superior green diesel properties (flash point, cloud properties and cetane index) demonstrated the NiO–Fe2O3/MWCNT catalyst offers great option in producing excellent properties of green diesel for energy sector.

- **Keywords:** Carbon; Deoxygenation; Iron; Multiwall carbon nanotube; Nickel

**Rajkumar R., Rohan Karthik Raman, Sarves S., Samdavid Swaminathan. *Hydrodynamics and phenol adsorption studies in continuous counter current liquid-solid settling column*. Pages 350-358.**

Adsorption is a cost-efficient and a well-established method to treat a large volume of wastewater. Most of the adsorption studies have been carried out in batch and continuous (packed and fluidized bed column) reactors. In most of the continuous operations, a solid adsorbent is held in batch mode and the liquid phase is continuous. In a counter-current liquid-solid adsorber, both the liquid and solid phase will be continuous. In this study, synthetic wastewater containing phenol of 200 ppm is treated in a counter-current liquid-solid adsorber using activated carbon as the adsorbent. The adsorption kinetics and the effect of size and mass of adsorbent were studied in batch operation. Thermodynamic properties including Gibbs' free energy, standard enthalpy and entropy change were calculated and the feasibility of the process is confirmed. In the continuous counter-current liquid-solid settling column, the effects of liquid flow rate, particle size and solid flow rate on hydrodynamics and mass transfer have been studied. From the range of flow rates studied in this work, liquid flowrate of 10 lph and solids (of diameter 0.5 mm) flow rate of 24 g/s gave the maximum phenol removal. An empirical equation has been proposed to predict the mass transfer coefficient for the range of continuous process.

- **Keywords:** Phenol; Activated carbon; Fluidized bed adsorber; Adsorption; Counter-current; Settling column

**Chuipeng Liu, Zhirong Wang, Chi Ma, Xiangwen Wang. *Influencing factors of the chain effect of spherical gas cloud explosion*. Pages 359-369.**

Flammable gases and liquids are widely used in industry and have serious leakage hazards. When a leaking gas cloud accidentally encounters an ignition source, it results in vapor cloud explosion accidents and multiple explosions. Pressure and flow field monitoring of a primary exploding spherical gas cloud and the secondary explosion of the gas cloud were conducted using the pressure acquisition system and schlieren system, and the impact of different influencing factors on exploding were analyzed. It was found that the larger the size of the primary exploding gas cloud, the smaller the distance between the primary exploding gas cloud and the secondary explosion gas cloud, and the larger the explosion intensity of the two gas clouds. Ignition on both sides of the primary exploding gas cloud was more likely to cause a blasting effect than was central ignition. The change in sparking ignition energy had no obvious effect on explosion propagation. When multiple gas clouds were exploding, the position of the primary exploding gas cloud

had a considerable influence on the chain effect of exploding. If the primary exploding gas cloud was located in the middle of multiple gas clouds, interaction occurred between the primary exploding spherical gas cloud and the secondary explosion gas cloud because the angle formed by the secondary explosion gas cloud decreased, and the explosive intensity of the exploding gas cloud was higher. When the primary exploding gas cloud was on the side, the smaller the angle, the closer the lateral gas cloud was to the flame development path of the explosive gas cloud, which increased the likelihood of a blast and increased explosion intensity.

- **Keywords:** Chain explosion; Size effect; Ignition energy; Ignition position; Gas cloud spacing; Explosive gas cloud location

**Li Ma, Ruizhi Guo, Mingming Wu, Weifeng Wang, Lifeng Ren, Gaoming Wei. *Determination on the hazard zone of spontaneous coal combustion in the adjacent gob of different mining stages*. Pages 370-379.**

Coal seam mining, especially during roadway driving with narrow coal pillars, can cause air leakage along the gob side and increase the risk of spontaneous coal combustion. To explore the oxygen distribution and spontaneous coal combustion risk zone in an adjacent gob of a fully mechanized mining face, a temperature-programmed experiment, a secondary oxidation experiment, gas monitoring, and numerical simulation were conducted. The oxygen consumption rates of the coal sample in primary and secondary oxidation processes were compared, and the oxygen concentration at the inner coal pillar of an adjacent gob was monitored. The oxygen concentration distribution in the adjacent gob was simulated, and the spontaneous coal combustion risk zone in the adjacent gob was determined. The results show that secondary coal oxidation was stronger than primary oxidation below 90 °C, and primary coal oxidation was stronger than secondary oxidation above 90 °C. The oxygen consumption rate ratio (i.e., the oxidation size) of the coal sample during primary and secondary oxidation processes below 90 °C was fitted to obtain the relationship. During roadway driving of the 2202 working face along the gob, the air leakage intensity of the coal pillar was between 0.0335–0.0365 cm3/(s·cm2). The area 23 m from the coal pillar to the depth of the adjacent gob behind the heading face was found to be at risk of spontaneous coal combustion. During normal and end mining of the 2202 working face, the air leakage intensity of the coal pillar along the gob was between 0.005–0.024 cm3/(s·cm2). The residual coal in a narrow area, 87 m long in the adjacent gob was in an oxidizing environment. When the working face advanced slowly, the residual coal in this area was prone to oxidation and at risk of spontaneous combustion.

- **Keywords:** Narrow pillar; Spontaneous coal combustion; Adjacent gob; Oxygen concentration; Numerical simulation