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S.M. Miri Lavasani, Z. Yang, J. Finlay, J. Wang. *Fuzzy risk assessment of oil and gas offshore wells*. Pages 277-294.

Risk evaluation of offshore wells is a challenging task, given that much of the available data is highly uncertain and vague, and many of the mechanisms are complex and difficult to understand. Consequently, a systematic approach is required to handle both quantitative and qualitative data as well as means to update existing information when new knowledge and data become available. Each Basic Risk Item (BRI) in a hierarchical framework is expressed as a fuzzy number, which is a combination of the likelihood of a failure event and the associated failure consequence. Analytical Hierarchy Process (AHP) is used to estimate weights required for grouping non-commensurate risk sources. Evidential Reasoning (ER) is employed to incorporate new data for updating existing risk estimates. It is envisaged that the proposed approach could serve as a basis for benchmarking acceptable risks in offshore wells. **Highlights:** ► A systematic approach for handling a variety of safety data. ► Updating existing information for risk assessment when new knowledge and data become available. ► Provision of a basis for benchmarking acceptable risks in offshore wells.

- **Keywords:** Analytical hierarchy process; Basic risk item; Evidential reasoning; Fuzzy aggregative risk assessment; Offshore safety; Offshore well

Mohammad Dadashzadeh, Faisal Khan, Kelly Hawboldt, Rouzbeh Abbassi. *Emission factor estimation for oil and gas facilities*. Pages 295-299.

Fugitive emission rate quantification in an oil and gas facility is an important step of risk management. There are several studies conducted by the United States Environmental Protection Agency (USEPA) and American Petroleum Institute (API) proposing methods of estimating emission rates and factors. Four major approaches of estimating these emissions, in the order of their accuracy, are: average emission factor approach, screening ranges emission factor approach, USEPA correlation equation approach, and unit-specific correlation equation approach. The focus of this study is to optimize the USEPA correlation equations to estimate the emission rate of different units in an oil and gas facility. In the developed methodology, the data available from USEPA (1995) is used to develop new sets of equations. A comparison between USEPA correlation equations and the proposed equations is performed to define the optimum sets of equations. It is observed that for pumps, flanges, open-ended lines, and others, the proposed developed

equations provide a better estimation of emission rate, whereas for other sources, USEPA equations supply the better estimate of emission rate. **Highlights:** ► Introducing a new set of equations to estimate leak rate in oil and gas facilities. ► A quantitative comparison of the proposed equations and the one proposed by USEPA. ► A set of recommendations to define when to use which leak rate equations.

- **Keywords:** Oil and gas industry; Emission factor; Linear regression; Non-linear regression

Jianfeng Li, Bin Zhang, Wenmao Liu, Zhaoyang Tan. *Research on OREMS-based large-scale emergency evacuation using vehicles*. Pages 300-309.

In densely populated urban areas, in the event of the toxic gases leak, how to accurately determine the risky zone and take effective measures to evacuate inhabitants quickly out of dangerous areas and minimize the unexpected losses is a tropical topic in China. First, the ALOHA code defined any interested accidents scenarios. For any different exposure times and concentrations, the distances down wind direction could be determined, which eventually generated the dead zone, wounded zone, injured zone and evacuation zone. Then, it presented the procedure of an emergency evacuation routes selection, the choice of the principle of refuges and shelters for evacuated inhabitants, as well as evacuation traffic organizations, vehicle assignments, real-time communications and other traffic evacuation strategies. Finally, the OREMS code was proposed to study the sudden leak accident and design emergency response policies (ERP). A sudden gaseous leakage incident in Tianjin Olympic stadium was chosen as an example to verify the raw ERP including the evacuation road network design, the evacuation time for vehicles, vehicle running conditions and the possible road congestions. Results showed that when the radium of the emergency evacuation scope is about 3 km, the time for evacuation of 50% vehicles is proper. **Highlights:** ► Combining the gas leakage simulation with the traffic simulation to study emergency response policies. ► OREMS code as an evacuation simulation tool to design the evacuation path using the existing refuge allocation plan. ► ALOHA code was used to define an accidental scenario and affected area. ► The bottleneck during evacuation can be found and take actions to improve the evacuation efficiency.

- **Keywords:** Large-scale emergency evacuation; ALOHA; OREMS; Toxic gas leakage

Yanjun Chang, Faisal Khan, Salim Ahmed. *A risk-based approach to design warning system for processing facilities*. Pages 310-316.

Alarm flooding is a major safety issue in today's processing facilities. Important recommendations are available for alarm management; however, they are often violated in practice, especially in the alarm systems implemented through the distributed control system. An effective process alarm prioritization and management system is desired for a safe and effective operation of a process facility. In present work, authors address two main issues related to an alarm system – the reliability and the prioritization of the alarms. The main objective is to deal with the alarm-flooding problem in process facilities. A multi alert voting system based on sensor redundancy approach is proposed to improve the reliability. A quantitative risk-based alarm management approach is proposed to address the flooding issue. In the risk-based approach, an integrated model consisting of the probability (P), the impact (I) of the potential hazards, and the process safety time is proposed to prioritize these raised alarms. The proposed approach is further explained by a reactor system with pressure and temperature variable monitoring and controls, where the hazards associated with two alerts caused by over high pressure and over high temperature are analyzed and integrated with response time for alarms generation and prioritization. **Highlights:** ► A new quantitative risk-based alarm management methodology. ► Alarm prioritization by integrating reliability, impact of the

potential hazards, and the available time to act. ► Application of the proposed methodology to a reactor system is demonstrated.

- **Keywords:** Alarm warning; Alarm management; Process safety; Risk assessment

R. Ball. *Oscillatory thermal instability and the Bhopal disaster*. Pages 317-322.

A stability analysis is presented of the hydrolysis of methyl isocyanate (MIC) using a homogeneous flow reactor paradigm. The results simulate initiation of the thermal runaway that occurred inside the storage tank of MIC at the Bhopal Union Carbide plant in December 1984. The stability properties of the model indicate that the thermal runaway may have been initiated at a large amplitude, hard thermal oscillation at a subcritical Hopf bifurcation. This type of thermal misbehavior cannot be predicted using conventional thermal diagrams and classical ignition theory, and may be typical of liquid thermoreactive systems. **Highlights:** ► Investigation of the thermal runaway that led to the Bhopal disaster. ► Thermal runaway is initiated at the onset of a hard thermal oscillation at a subcritical Hopf bifurcation. ► This non-classical oscillatory thermal misbehavior may be generic in reactive organic liquids. ► Results may also inform better management of organic peroxide based explosives.

- **Keywords:** Methyl isocyanate; Liquid explosives; Thermal runaway; Oscillatory instability; Bhopal disaster

Yasuhiro Sugimoto, Daisuke Tashima, Yoki Asano. *A simple method to harness DC (direct current) electrical energy generated by bacterial activity*. Pages 323-326.

We developed a new system for collecting electrons generated by bacterial activity to supply DC (direct current) electrical energy. This system used eight titanium sub-electrodes (surface area of each sub-electrode: 189 cm2) connected to one central main titanium electrode (surface area of electrode: 1571 cm2). The distance between each sub-electrode and the main electrode was 30 cm. In an initial experiment, we collected electrons during composting cattle excreta, which was mixed with a commercially available microbial compost activator/starter. We analysed the relationships between the composting temperature and electrical current and voltage. Electrons were effectively collected and used successfully to obtain DC electrical energy. Generation of a stable voltage of approximately 0.5 V was clearly observed. This voltage was not related to compost temperature; however, the generated electrical current increased and decreased with compost temperature. The method was then used in a second experiment to collect electrons generated by bacterial activity in an agricultural field (area: 48 m2). Electrons in the field were effectively collected, and we measured a stable voltage of approximately 1.1 V and a stable current of approximately 0.7 mA. The system has the advantages of being simple, easily maintained, inexpensive, and applicable to large-scale agricultural fields.

- **Keywords:** Bacterial activity; Electron; Electrical energy

Kai Chen, Hengyi Lei, Yuejuan Li, Hualiang Li, Xinghong Zhang, Chuang Yao. *Physical and chemical characteristics of waste activated sludge treated with electric field*. Pages 327-333.

This study investigates the physical and chemical characteristics of sludge treated with controlled levels of electric field. The results indicated that the potential gradient and contact time strongly influenced the physical and chemical characteristics of sludge. Based on the settling velocity measurements, a potential gradient of 6 V/cm with a

treatment time of 10 min is recommended as an optimal condition for improving sludge settling. For sludge disintegration, applying a higher potential gradient and a longer treatment time to the sludge are more efficient than applying lower levels. The results of the experiments presented here show that an electric field not only disintegrates sludge and destroys microbial cells but also removes and solubilizes organic substances. Possible mechanisms of electric field treatment are also discussed. **Highlights:** ► We investigate the physical and chemical characteristics of sludge treated with controlled levels of electric field. ► Electric field pretreatment could release organic substances by destroying sludge structure and degrading the pollutants. ► Higher supplied power could lead to increased organic matter decomposition and solubilization. ► A potential gradient of 6 V/cm with a treatment time of 10 min is an optimal condition for improving sludge settling.

- **Keywords:** Potential gradient; Settleability; Treatment time; Physical–chemical characteristics; Waste activated sludge

F. Javier Benitez, Juan García, Juan L. Acero, Francisco J. Real, Gloria Roldan. *Non-catalytic and catalytic wet air oxidation of pharmaceuticals in ultra-pure and natural waters*. Pages 334-341.

A wet air oxidation (WAO) process was applied to four selected pharmaceuticals (metoprolol, naproxen, amoxicillin, and phenacetin) individually dissolved in ultra-pure water, varying the temperature and oxygen pressure. Due to the moderate (amoxicillin) or low (metoprolol, naproxen, and phenacetin) efficiency found in the oxidation of these pollutants, a catalytic wet air oxidation (CWAO) process was then tested using a platinum catalyst supported on multi-walled carbon nanotubes (CNT). In this CWAO process, the pharmaceuticals were dissolved together in ultra-pure water and in four natural water matrices—a reservoir water, a groundwater, and two waters from different municipal wastewater treatment plants. On the basis of the measurements of their removals, a discussion is given of the influence of the main operating variables: the presence or absence of catalyst, type of catalyst (the synthesized Pt/CNT or a commercial Pt/AC), catalyst dosage (0.005–0.050 g), temperature (120–140 °C), and oxygen pressure (20–40 bar). In most experiments, the removals were in the sequence: amoxicillin > naproxen > phenacetin. In addition, total organic carbon (TOC) removal measurements were made of some of the natural waters tested. **Highlights:** ► WAO of pharmaceuticals in ultra-oure water provided low to moderate removal efficiencies. ► CWAO significantly enhanced the degradations. ► A synthesized platinum catalyst supported on multiwalled carbon nano tubes (Pt/CNT) was used. ► CWAO experiments were applied to the pharmaceuticals dissolved in four real water matrices with relevant eliminations.

- **Keywords:** Wet air oxidation; Catalytic wet air oxidation; Platinum/carbon-nanotube catalyst; Pharmaceuticals; Ultra-pure and natural waters

Ren-Cun Jin, Chun Ma, Qaisar Mahmood, Guang-Feng Yang, Ping Zheng. *Anammox in a UASB reactor treating saline wastewater*. Pages 342-348.

The feasibility of an anammox (anaerobic ammonium oxidation) UASB (upflow anaerobic sludge blanket) bioreactor to treat ammonium-rich brines was investigated in batch and continuous-flow experiments. The evidence from batch tests indicated that the anammox activity was significantly inhibited under highly saline conditions while the inhibition was reversible. Saline shock loading of 30 g NaCl l−1 caused a 67.5% decrease in specific anammox activity (SAA) compared to reference biomass (not exposed to salt). However, the acclimatized biomass displayed a SAA value just 45.1% lower than that of the reference biomass. When transferred from brine to freshwater, the salt-exposed biomass resumed its activity by 43.1%. Subsequent to appropriate acclimatization, careful manipulation nitrite concentration, nitrogen loading rate (NLR), and other operational parameters for 77 days, the results of continuous-flow experiment revealed that under

the salinity of 30 g NaCl l−1 the reactor performed well and the substrate removal capacity (nitrogen removal rate, NRR, of 448 ± 15 mgl−1 d−1) was comparable to the condition of freshwater (NRR of 464 ± 13 mgl−1 d−1). However, the anammox UASB bioreactor was prone to malfunction under transient operating conditions. **Highlights:** ► The feasibility of an anammox UASB bioreactor to treat ammonium-rich brines was investigated. ► The anammox activity was significantly inhibited by saline shock loading while the inhibition was reversible. ► Subsequent to appropriate acclimatization, the reactor performed well under the salinity of 30 g NaCl l−1.

- **Keywords:** Anammox; Salinity; UASB; Performance; Biological nitrogen removal