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P.J. Thomas, R.D. Jones. *Extending the J-value framework for safety analysis to include the environmental costs of a large accident*. Pages 297-317.

A severe accident on an industrial plant has the potential to cause, in addition to human harm, general damage and hence expense, associated with ground contamination, evacuation of people and business disruption, for example. The total cost of damages, given the name "environmental costs" in this paper, may be comparable with or larger than the cost of direct health consequences, as assessed objectively by the *J*-value approach. While the low probability of the accident may mean that the expectation of monetary loss is small, the paper develops a utility-based approach to determine how much should be spent on protection systems to protect against both environmental costs and human harm. The behaviour of the fair decision maker in an organisation facing possible environmental costs is represented by an Atkinson Utility function, which is dependent on the organisation's assets and on the elasticity of marginal utility or, equivalently, the coefficient of relative risk aversion, "risk-aversion" for short. A Second Judgment Value, J_2, may be derived from the spend on the protection system after subtracting the amount sanctioned to prevent direct human harm. This net, environmental expenditure is divided by the most that it is reasonable to spend to avert environmental costs at the highest, rational risk-aversion. The denominator in this ratio is found by first calculating the maximum, sensible spend at a risk-aversion of zero, and then multiplying this figure by a Risk Multiplier to give the maximum, fair amount to avert environmental costs. The Risk Multiplier incorporates a risk-aversion that is as large as it can be without rendering the organisation's safety decisions indiscriminate and hence random. An overall, Total Judgment Value, the J_T–value, may also be calculated, which takes into account the reduction in both human harm and environmental cost brought about by the protection system. The new J_T–value will show similar behaviour to the original *J*-value, in that J_T–values up to unity will indicate reasonable value for money, while J_T–values greater than unity will indicate a *prima facie* overspend on protection that will need to be justified by further argument. While the analysis is phrased in terms of environmental costs, the treatment is sufficiently general for all costs, including onsite damages, loss of capability etc. to be included. The new, J_T–value method provides for a full and objective evaluation of the worth of any industrial protection system. A worked example is given.

- **Keywords:** Risk aversion; Elasticity of marginal utility; Utility theory; J-value; J_T-value; J_2-value; Point of indiscriminate decision; Risk Multiplier; Disproportion; Gross disproportion

Essam A.H. Zubaidy, Dana M. Abouelnasr. *Fuel recovery from waste oily sludge using solvent extraction*. Pages 318-326.

Solvent extraction was used to recover oil from waste sludge generated from the storage of crude petroleum. Different solvent-to-sludge mass ratios were used for two solvents, methyl ethyl ketone (MEK) and LPG condensate (LPGC). Several parameters were compared, such as oil recovery as a percent of the original sludge mass, and reduction in carbon residue, ash content, and asphaltene content. A 4:1 solvent-to-sludge ratio was found to be optimum for both solvents. The MEK extraction recovered 39% by mass of the sludge as recovered oil. The LPGC recovered 32%. The amount of asphaltenes in the fuel oil was related to the concentration of fuel oil in the solvent phase during the extraction, suggesting that asphaltenes are extracted mainly by the fuel oil components, not the solvent. The physical properties and metal content of the recovered oil were measured. The recovered oil was distilled to provide diesel fuel. This diesel fuel contained high levels of sulfur and carbon residue, as well as a high diesel index, indicating the fuel requires further treatment prior to use as a fuel.

Keywords: Oil recovery; Oil sludge; Solvent extraction; Methyl ethyl ketone; LPG condensate

Lin Cui, Jinsong Zhao, Ruiqi Zhang. *The integration of HAZOP expert system and piping and instrumentation diagrams*. Pages 327-334.

The main purpose of hazard and operability (HAZOP) analysis is to identify the potential hazards in the process design which nowadays is generally developed through a computer aided design (CAD) package. Due to the time and effort consuming nature of HAZOP, it is not done in every engineering firm for every design project. To make HAZOP an integral part of process design, an integration framework is proposed in this paper to seamlessly integrate the commercial process design package Smart Plant P&ID (SPPID, Intergraph) with one of the HAZOP expert systems (named as LDGHAZOP) developed by authors. This integration makes it possible to perform HAZOP analysis easily at anytime of the whole lifecycle of a chemical plant as long as the process design is available, which might help the improvement of design quality. One industrial case study is used to illustrate the ability of the integrated system.

- **Keywords:** HAZOP; P&ID; Process design; Expert system

Alireza Bahadori, Hari B. Vuthaluru. *Simple Arrhenius-type function accurately predicts dissolved oxygen saturation concentrations in aquatic systems*. Pages 335-340.

A sufficient supply of dissolved oxygen (DO) is vital for life in higher organisms. In aquatic systems, oxygen regulates respiratory metabolism, mediates biogeochemical cycles, and is an integral component of water quality. In this work, a simple predictive tool for dissolved oxygen saturation concentrations in aquatic systems as a function of chloride concentration and temperature using a novel Arrhenius-type asymptotic exponential function has been formulated. The proposed method predicts the amount of dissolved oxygen saturation concentrations for temperatures up to 50 °C and chloride concentrations up to 25 g/l. Estimations are found to be in excellent agreement with the reliable data in the literature with average absolute deviation being 3%. The tool developed in this study can be of immense practical value for the engineers and scientists to have a quick check on the oxygen saturation concentrations in aquatic systems at various conditions without opting for any experimental measurements. In

particular, environmental science experts would find the proposed approach to be user-friendly with transparent calculations involving no complex expressions.

- **Keywords:** Dissolved oxygen; Chloride concentration; Aqueous solubility; Aquatic system

F. Cammarota, A. Di Benedetto, P. Russo, E. Salzano. *Experimental analysis of gas explosions at non-atmospheric initial conditions in cylindrical vessel*. Pages 341-349.

Accidental gas explosions in industrial equipment are seldom initiated at atmospheric conditions. Furthermore, fuel–air mixtures are generally turbulent due to rotating parts or flows. Despite these considerations, few studies have been devoted to the analysis of explosion properties at conditions of temperature and pressure different from ambient and in the presence of turbulence; therefore, experiments are still needed, even at lab-scale, e.g. for the design of mitigation system as venting devices. In this work, experimental explosion tests have been performed in 5 l, cylindrical tank reactor with stoichiometric methane–air mixtures at initial pressure and temperature up to 600 kPa and 400 K, centrally ignited or top ignited, and with the effect of initial turbulence level by varying the velocity of the mechanical stirrer.

- **Keywords:** Gas explosion; K_G; Turbulent combustion; Pressure effects

Manickam Matheswaran, T. Raju. *Destruction of methylene blue by mediated electrolysis using two-phase system*. Pages 350-355.

The destruction and colour removal of methylene blue were carried out by mediated electrochemical oxidation using cerium(IV) mediator in nitric acid medium using two-phase system and was applied for oxidation of organic compound. Organic compounds and mediator were taken in the organic and aqueous phases respectively. The influence of organic solvent type, cerium(III) concentration, dye concentration, stirring speed and temperature were investigated in order to find the optimum conditions of the system to check the removal of COD and colour in the organic phase. The decolourisation followed the pseudo-first order reaction for electrochemically oxidized cerium(IV). The maximum colour removal efficiency of 95% was achieved within 45 min in dichloromethane solvent system. The COD removal efficiency and colour removal rate were increased with increase in temperature and stirring speed.

- **Keywords:** Electrochemical oxidation; Methylene blue; Two-phase system; Cerium(IV); Mediator

Kai-Tai Lu, Yung-Chuan Chu, Ting-Chi Chen, Kwan-Hua Hu. *Investigation of the decomposition reaction and dust explosion characteristics of crystalline dicumyl peroxide*. Pages 356-365.

The dicumyl peroxide (DCP) is widely used as a polymerization initiator, catalyst and vulcanizing agent in the chemical industry. A number of accidents have been caused by its thermal instability in storage or manufacturing process. Thus, its hazard characteristics have to be clearly identified. First of all, the differential scanning calorimeter (DSC) is used to measure the heat of decomposition reaction, which can contribute to understanding the reaction characteristics of DCP. The accelerating rate calorimeter (ARC) is used to measure the rates of temperature and pressure rises of decomposition reaction, and then the kinetics parameters are estimated. Furthermore, the MIKE 3 apparatus and the 20-l-Apparatus are used to measure and analyze the dust explosion characteristics of DCP at room temperature and atmospheric pressure. Finally, Semenov's thermal explosion theory is applied to investigate the critical runaway

condition and the stability criterion of decomposition reaction, and to build the relationship of critical temperature, convective heat transfer coefficient, heat transfer surface area and ambient temperature. These results contribute to improving the safety in the reaction, transportation and storage processes of DCP.

Research highlights: ▶The DSC thermogram of decomposition reaction of 98% crystalline DCP reveals an endothermic peak around 40 °C due to the melting point and an exothermic peak around 168 °C due to the decomposition of DCP. The released heat is equal to 744.85 J/g. The activation energy E and pre-exponential factor A are 124.58 kJ/mol and 1.19E15 min^{-1}, respectively. ▶The 98% crystalline DCP has a MIE between 1 and 3 mJ, which indicates that it is very sensitive to static discharge. Its maximum K_{St} value is 211 bar m/s at room temperature and atmospheric pressure. The explosion class is *St*-2, which indicates that its explosibility is strong. ▶Two critical temperature points of T_c is obtained from the diagram of heat generation rate and theoretical critical heat removal rate vs. temperature. One is the critical extinction temperature $T_{C,E}$ = 442.13 K and the other is the critical ignition temperature $T_{C,I}$ = 373.63 K.

- **Keywords:** Dicumyl peroxide; Hazard characteristics; Decomposition reaction; Dust explosion; Critical temperature

R.S. Singh, B.N. Rai, S.N. Upadhyay. *Removal of toluene vapour from air stream using a biofilter packed with polyurethane foam*. Pages 366-371.

Biodegradation of toluene vapour was investigated for 168 days in a polyurethane packed biofilter inoculated with a mixed microbial population. Biofilter consisted of five square cross-section modular units each of size 0.16 m × 0.16 m × 0.20 m and filled with the polyurethane foam cubes up to a height of 0.15 m. Inlet concentration of toluene was varied from 0.04 to 2.5 g m^{-3} and the volumetric flow rate of toluene loaded air from 0.06 to 0.90 m^3 h^{-1}. Depending upon initial loading rates, removal efficiency ranging from 68.2 to 99.9% and elimination capacity ranging from 10.85 to 90.48 g h^{-1} m^{-3} were observed during steady state operations. More than 90% removal efficiency was observed up to an inlet loading rate of 76.3 g h^{-1} m^{-3}. High carbon recovery (>90%) indicated effective biodegradation in the bed. Low variation of pH (7.2–8.8) and pressure drop (45.8–76.3 Pa) was observed. The stability of the biomass was evident from the fast response of the biofilter to shutdown and restartup.

Research highlights

▶Biofilter packed with polyurethane was used successfully to degrade toluene. ▶RE ranging from 68.2 to 99.9% was observed. ▶EC ranging from 10.85 to 90.48 g h^{-1} m^{-3} was observed. ▶High carbon recovery (>90%) indicated effective biodegradation in the bed. ▶Low variation of pH (7.2–8.8) and pressure drop (45.8–76.3 Pa) were observed. ▶The biofilter responded quickly for after change in operating conditions.

- **Keywords:** Biofiltration; Biofilter media; Removal efficiency; Elimination capacity; Polyurethane foam; VOCs; Toluene

Linice Vasconcelos Cavalcante Bonaparte, Antonio Tavernard Pereira Neto, Luis Gonzaga Sales Vasconcelos, Romildo Pereira Brito, José Jaílson Nicácio Alves. *Remediation procedure used for contaminated soil and underground water : a case study from the chemical industry*. Pages 372-379.

This is a case study of contamination by a non-aqueous phase liquid (NAPL) that leaked from a chemical plant. The remediation procedure adopted for the initial phase of the plume migration was a plastic diaphragm wall coupled with a series of water extraction

wells designed to avoid environmental impact on the surrounding ecosystems. Monitoring has shown that the containment is successful, and additional measures that contribute to accelerating remediation have been adopted. The authors wished to investigate how remediation might be further enhanced. The use of in situ aeration coupled with a system of soil vapor extraction (AS/SVE) has been chosen, since the remediation of sites with characteristics similar to those in this study, if based exclusively on dissolved-phase control, would take several decades to be completed. The transport of contaminant plumes has been simulated by using an analytical model to evaluate the effectiveness of the natural attenuation of the contaminant. The results of the simulation have confirmed the limited effectiveness of the natural attenuation of the contaminant, as well as the effective increase of remediation that would occur if the AS/SVE system is applied. A sensitivity analysis that included several combinations of increments of parameters that correspond to the decay rate of the source and the dissolved plume has simulated what might happen if the AS/SVE system is implemented.

- **Keywords:** Contamination; Groundwater; Soil; Remediation