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Esteban J. Bernechea, Juan Antonio Vílchez, Josep Arnaldos. *A model for estimating the impact of the domino effect on accident frequencies in quantitative risk assessments of storage facilities.* Pages 423–437.

It is well known that the domino effect can have a major impact on accidents in storage facilities, as it can increase the consequences of an initial event considerably. However, quantitative risk assessments (QRAs) do not usually take the domino effect into account in a detailed, systematic way, mostly because of its complexity and the difficulties involved in its incorporation. We have developed a simple method to include the domino effect in QRAs of storage facilities, by estimating the frequency with which new accidents will occur due to this phenomenon. The method has been programmed and implemented in two case studies. The results show that it can indeed be used to include the possibility of domino effect occurrence in a QRA. Furthermore, depending on the design of a facility, the domino effect can have a significant effect on the associated risk.

- **Keywords:** Domino effect; Quantitative risk assessment; Storage facilities

Mimi H. Hassim, Markku Hurme, David W. Edwards, Nik N.N.A. Aziz, Fariha L.M. Rahim. *Simple graphical method for inherent occupational health assessment.* Pages 438–451.

The concept of inherently safer design was introduced to design a fundamentally safer process so that hazards can be avoided or minimized rather than controlled or managed. The ideology has later been extended to the environmental, but not health criteria due to its complicated underlying principles. Even though health risk methods are already established, majority are for existing plants assessment. Early consideration of health aspect starting from process design stage however, has received much less attention. This paper introduces a simple graphical method to evaluate the inherent occupational health hazards of chemical processes during the R&D stage. A survey was conducted to identify the important health parameters for the graphical method development, involving nine world inherent safety and health experts. Based on their input, process mode, material volatility, operating pressure and chemical health hazard (toxicity and adverse effect) are the significant factors affecting inherent health hazards of chemical processes. The choice of parameters was bounded by the information availability at this stage. The method was applied on six routes to methyl methacrylate and ten routes to acetic acid. The parameters were plotted for each subprocess of the alternative routes. The 'healthiest' route was selected based on thorough hazards assessment across all the subprocesses. The first case study reveals the tertiary butyl alcohol as the 'healthiest' one as it poses relatively lower, or at least comparable hazards to the other routes due to exposure and health impacts. Meanwhile the acetic acid case study indicates ethanol

oxide and ethyl oxide based routes as the inherently healthier as they operate at lower operating pressure besides posing comparable hazards level for the other three parameters, compared to the other routes. The case studies show that the inherent occupational health of a chemical process can already be evaluated easily in the R&D stage with the simple graphical method proposed.

- **Keywords:** Occupational health; Graphical method; Process design; R&D; Hazard assessment

Farid Kadri, Eric Châtelet, Guangpu Chen. *Method for quantitative assessment of the domino effect in industrial sites.* Pages 452–462.

Accidents caused by the domino effect are the most destructive accidents related to industrial sites. The most typical primary incidents for a domino effect sequence are explosions (57%), followed by fires (43%) (Abdolhamidzadeh et al., 2010). These former can generate three escalation vectors (heat load, overpressure, and fragments), and may affect the surrounding equipments and/or facilities. If the affected targets are damaged, they may also explode and generate other threats to other surrounding facilities and so on. These chains of accidents may lead to catastrophic consequences and may affect not only the industrial sites, but also people, environment and economy. This paper presents a methodology for quantitative assessment of domino effects caused by fire and explosion on storage areas. The individual and societal risks are also estimated.

- **Keywords:** Domino effect; Cascading events; Risk assessment; Explosions; Fires

Y.F. Khalil, S.M. Opalka, B.L. Laube. *Experimental and theoretical investigations for mitigating $NaAlH_4$reactivity risks during postulated accident scenarios involving exposure to air or water.* Pages 463–475.

Experimental and theoretical studies were conducted to investigate the pyrophoricity and water-reactivity risks associated with employing sodium alanate ($NaAlH_4$) complex metal hydride in on-board vehicular hydrogen (H_2) storage systems. The ignition and explosivity of $NaAlH_4$ upon exposure to oxidizers in air or water were attributed to the spontaneous formation of stable hydroperoxyl intermediates on the $NaAlH_4$surface and/or H_2 production, as well as the large driving force for $NaAlH_4$ conversion to favorable hydroxide products predicted by atomic and thermodynamic modeling. The major products from $NaAlH_4$ exposure to air: $NaAl(OH)_4$, gibbsite and bayerite $Al(OH)_3$, and Na_2CO_3 observed by XRD, were identified to be formed by surface-controlled reactions. The reactivity risks were significantly minimized, without compromising de-/re-hydrogenation cyclability, by compacting $NaAlH_4$ powder into wafers to reduce the available surface area. These core findings are of significance to risk mitigation and H_2 safety code and standard development for the safe use of $NaAlH_4$ for on-board H_2 storage in light-duty vehicles.

- **Keywords:** Metal hydrides; Sodium alanate; Risk mitigation; Powder compaction; Pyrophoricity; Water reactivity; On-board reversible

Paul G. Holborn, Paul N. Battersby, James M. Ingram, Anthony F. Averill, Philip F. Nolan. *Modelling the mitigation of a hydrogen deflagration in a nuclear waste silo ullage with water fog.* Pages 476–482.

During the decommissioning of certain legacy nuclear waste storage plants it is possible that significant releases of hydrogen gas could occur. Such an event could result in the formation of a flammable mixture within the silo ullage and, hence, the potential risk of ignition and deflagration occurring, threatening the structural integrity of the silo. Very fine water mist fogs have been suggested as a possible method of mitigating the

overpressure rise, should a hydrogen–air deflagration occur. In the work presented here, the FLACS CFD code has been used to predict the potential explosion overpressure reduction that might be achieved using water fog mitigation for a range of scenarios where a hydrogen–air mixture, of a pre-specified concentration (containing 800 L of hydrogen), uniformly fills a volume located in a model silo ullage space, and is ignited giving rise to a vented deflagration. The simulation results suggest that water fog could significantly reduce the peak explosion overpressure, in a silo ullage, for lower concentration hydrogen–air mixtures up to 20%, but would require very high fog densities to be achieved to mitigate 30% hydrogen–air mixtures.

- **Keywords:** Hydrogen; Explosion; Mitigation; Water fog; CFD modelling

Jun Dong, He Sheng, Chunyu Wen, Mei Hong, Huizhong Jiang. *Effects of phosphorous on the stabilization of solid waste in anaerobic landfill.* Pages 483–488.

Anaerobic bioreactor attracted more attention in recent years because of its environmental and financial benefits. Nutrients and moisture could exert profound influences on the degradation of the pollutants and stabilization of solid waste in anaerobic landfill. The objective of this work was to investigate the effects of the activated sludge and phosphorous addition on the stabilization of solid waste. The experimental results indicated that phosphorous is the limiting nutrients in the landfill leachate; phosphorous and activated sludge simultaneously could stimulate the growth of the bacteria, enhance the attenuation of pollutants in landfill leachate and accelerate the stabilization of solid waste; the final removal efficiency of COD and NH_4^+-N in R-C (phosphorous and activated sludge added simultaneously) was up to 95.13% and 73.4%, respectively. Therefore, phosphorous addition is an effective way to enhance the stabilization of solid waste in anaerobic landfill.

- **Keywords:** Phosphorous; Anaerobic landfill; Solid waste; Sewage sludge

Abolfazl Biabani-Ravandi, Mehran Rezaei, Zohreh Fattah. *Study of Fe–Co mixed metal oxide nanoparticles in the catalytic low-temperature CO oxidation.* Pages 489–494.

Iron–cobalt mixed metal oxide nanoparticles (Co/Fe molar ratio: 1/5) have been prepared by a simple co-precipitation method and employed as catalyst in low-temperature CO oxidation. The prepared catalysts were characterized by thermal gravimetric and differential thermal gravimetric analyses (TGA/DTG), X-ray diffraction (XRD), temperature programmed reduction (TPR), N_2 adsorption (BET) and transmission electron microscopy (TEM) techniques. The results revealed that inexpensive iron–cobalt mixed metal oxide nanoparticles have a high potential as catalyst in low temperature CO oxidation. The results showed that increasing in calcination temperature increased the crystallite and particle size and decreased the specific surface area, which caused a decrease in catalytic activity of prepared catalysts. In addition, the pretreatment conditions affect the catalytic activity and catalyst pretreated under oxidative atmosphere showed the higher activity than those pretreated under reductive and inert atmospheres.

- **Keywords:** CO oxidation; Iron; Cobalt; Nanoparticles; Calcination; Pretreatment atmosphere

N. Antuñano, D. Herrero, P.L. Arias, J.F. Cambra. *Electrowinning studies for metallic zinc production from double leached Waelz oxide.* Pages 495–502.

Waelz oxide is a zinc and lead concentrate pyrometallurgically derived from electric arc furnace dust. There are clear incentives to leaching and purify this oxide to produce liquors that can be electrowinned to obtain recycled metallic zinc. This study is focused on this electrolytic zinc production from previously obtained sulphuric liquor. This liquor was obtained from double leached Waelz oxide (DLWO) throughout a hydrometallurgical process. The electrolytic liquor, after the corresponding leaching and purification stages, contains around 49 kg/m^3. This liquor was fed to an electrowinning process where platinum or lead anodes and aluminium cathodes were used. After optimizing the different electrowinning critical parameters, and working at these optimal conditions, almost 88 secondary zinc kg were precipitated per each initial DLWO tonne in one-through process. The zinc purity was higher than 99.5%. After some mass balance calculations, it can be concluded that, optimizing the process configuration through internal recycling, around 210 Zn kg/DLWO t with purity near to 100% could be achieved.

- **Keywords:** Electrowinning; Hydrometallurgy; Zinc; Waelz oxide

Hui Yang, Shuri Li. *Emergy analysis of cassava vinasse treatment.* Pages 503–507.

Vinasse has great pollution to the environment. A number of technologies have been explored for reducing the pollution of vinasse. Sustainability has become an important factor when discussing wastewater treatment techniques. Emergy analysis was used to evaluate the treatment of cassava vinasse in this paper. Cr (emergy consumption ratio) as a new emergy index was proposed to measure the impact of waste treatment to the society. Centrifugal solid–liquid separation, UASB (up-flow anaerobic sludge bed), and SBR (sequencing batch reactor activated sludge process) are used in the treatment process. The emergy indices for cassava vinasse treatment system were as follows: EYR (emergy yield ratio) was 6.20, ELR (environmental loading ratio) was 5.81, ESI (emergy sustainability index) was 1.07, and Cr was 4.60E+12 sej/m^3. The emergy of coal electricity accounts for 46% of all purchased inputs. It is necessary to improve the treatment technology to reduce the electricity used.

- **Keywords:** Emergy analysis; Vinasse; Sustainability

A. Azapagic, Z. Chalabi, T. Fletcher, C. Grundy, M. Jones, G. Leonardi, O. Osammor, V. Sharifi, J. Swithenbank, A. Tiwary, S. Vardoulakis. *An integrated approach to assessing the environmental and health impacts of pollution in the urban environment: Methodology and a case study.* Pages 508-520.

This paper presents a new decision-support methodology and software tool for sustainable management of urban pollution. A number of different methods and tools are integrated within the same platform, including GIS, LCA, fate and transport modelling, health impact assessment and multi-criteria decision analysis. The application of the framework is illustrated on a case study which investigates the environmental and health impacts of pollution arising from different industrial, domestic and transport sources in a city. The example city chosen for the study is Sheffield, UK, and the main pollutants considered are NOx, SO_2 and PM10. The results suggest that the absence of the current large industrial sources in the city would lead to a 90% reduction of the SO_2 and 70% of the NO_2 ground concentrations, consequently preventing 27 deaths and 18 respiratory hospital admissions per annum for a population of 500,000. Based on the total annual

mortality and hospital admissions in Sheffield for the year of the assessment, this means that 0.53% of premature deaths and 0.49% of respiratory hospital admissions would be prevented by the estimated reduction in air pollution.

- **Keywords:** Integrated sustainability assessment; Urban pollution; LCA; Air dispersion modelling; Health impacts

Qi Yang, Jun Yi, Kun Luo, Xiaoli Jing, Xiaoming Li, Yang Liu, Guangming Zeng. *Improving disintegration and acidification of waste activated sludge by combined alkaline and microwave pretreatment.* Pages 521-526.

The individual alkaline or microwave pretreatment has been proved to be effective in disintegration and acidification of waste activated sludge (WAS). In this study, the effects of combined alkaline and microwave pretreatment at different pH and specific energy input (Es) on WAS disintegration were investigated using response surface methodology (RSM). Combined pretreatment achieved disintegration degree (DD) of 65.87% at Es of 38,400 kJ/kg TS and pH 11.0. The ANOVA further demonstrated that pH showed more significant effect on DD than Es. Anaerobic batch experiment results showed that combined pretreatment not only significantly improved volatile fatty acids (VFAs) accumulation but also shortened the time for the highest VFAs accumulation. The maximal VFAs accumulation (1500 mg COD/L) obtained at Es of 28,800 kJ/kg TS and fermentation time of 72 h, which was about two times that of the treatment without microwave (850 mg COD/L) at 96 h. The analysis of VFAs composition showed that the VFAs mainly consisted of acetic and iso-valeric acids, accounting for 57.3–70.1% of total VFAs.

- **Keywords:** Acidification; Alkaline-microwave pretreatment; Disintegration; Response surface methodology; Waste activated sludge