出國報告 (出國類別:其他-研討會)

參加第 14 屆國際化學程序工業損害預防及安全促進研討會

服務機關：國立高雄第一科技大學

姓名職稱: 陳政任、蔡曉雲

出國地區: 義大利

出國時間: 102 年 5 月 11 日至 20 日

報告日期: 102 年 8 月 11 日

摘要

本次發表論文主要在描述台灣環境保護署在過去的二十年執行毒性化學物質管理法的演進，另外，毒災應變體系的建置與運作，包括台灣毒管法的建立、毒化學物質的管理，使用以及操作，從搖籃到墳墓的策略方式進行毒化物管制。

1999 年台灣中部 921 大地震之後，新的災害防救法產生，自此毒管法有重大修改和新法規實施，進一步監管所有的毒化物，並要求毒化物運作業者需進行毒化物的風險管理和提出減災措施。

台灣環境保護署陸續成立毒性化學物質災害的監控中心、毒性化學物質災害的應變諮詢中心和七個毒災應變隊，平時執行至少 25 人值勤，並提供 24 小時專用人力及應變器材支援協助，另外包括環境監測設備，個人防護設備，應變設備，洩漏的修補和化學品移槽處理等。從歷年毒化物的事故統計數據來看，加強監管毒化物和增強應變能力，可大大降低事故的發生和潛在危害。

參加國際會議除分享相關領域之新知外，在會中能與國外專題演講的專家學者互相討論與交換研究的觀點，有助於未來研究的方向。其壁報論文為針對主題面對面進行討論與學習最快速有效的方式，在國際研討會中，一方面可宣揚我國在此領域的努力，另外一方面可了解國際的最新發展與應用，並可刺激本校未來研究的方向。

目次

壹、目的

國際化學程序工業損害預防及安全促進研討會逐年受到重視，且已成為國際性先進而重要之年度盛事，會期以口頭論文及壁報論文為主，期間每日上午一開始常有專題演講。邀請專家、學校教授，針對國際日漸注意災害防制等相關學術研討。

本次與會主要在瞭解先進國家毒化物事故應變體系運作情形，蒐集法規沿革、外洩技術、個人防護器材、偵檢儀器、後果分析、風險評估與應變軟硬體整合應用等相關資料，並汲取實務經驗作為我國應變相關作業參考。

本次於義大利佛羅倫斯（Florence）舉辦之第十四屆「國際化學程序工業損害預防及安全促進研討會」（相關參考網址為：http://www.aidic.it/lp2013/）。藉由參與該國際性研討會的機會，將可接觸第一手來自於歐洲境內與國際供應商、開發機構、應變單位與各級政府的專業與業管人員，並直接收集相關最新且有用的資訊。

貳、過程

一、行程與工作記要

<table>
<tr><th>日期</th><th>工作記要</th></tr>
<tr><td>102 年 5 月 11 日</td><td>搭機前往義大利：
5/11PM23:20 台灣桃園國際機場-
阿姆斯特丹史基普機場-5/12AM11:45
佛羅倫斯機場</td></tr>
<tr><td>102 年 5 月 12 日</td><td>☐ 研討會報到、領取議程資料</td></tr>
<tr><td>102 年 5 月 13 日</td><td rowspan="2">參加第十四屆｢國際化學程序工業損害
預防及安全促進研討會
及壁報論文發表</td></tr>
<tr><td>102 年 5 月 15 日</td></tr>
<tr><td>102 年 5 月 16 日</td><td>搭火車至維洛納(verona)城市
義大利 CRISTANINI 公司</td></tr>
<tr><td>102 年 5 月 16 日</td><td>參訪除污設備專業公司(義大利
CRISTANINI)核生化去毒除污設備
之實際應用</td></tr>
<tr><td>102 年 5 月 17 日</td><td>彙整會議及除污設備 SaniJet 除污噴灑
動力設備的相關資料</td></tr>
<tr><td>102 年 5 月 18 日</td><td>搭火車回佛羅倫斯(Florence)城市</td></tr>
<tr><td>102 年 5 月 19 日</td><td>回程</td></tr>
</table>

二、年會日期、地點、

14th International Symposium on Loss Prevention and Safety Promotion in the Process Industries 第十四屆「國際化學程序工業損害預防及安全促進研討會」, 今年(2013)於義大利佛羅倫斯（Florence）Firenze Fiera Villa 舉行，自 5 月 12 至 15 日共為期 4 天。

三、年會內容

年會議程相當豐富，包括專題演講，口頭論文發表及壁報論文展示。在儀器展示會部份，參展之儀器商，試藥供應商，科技協會，外洩模擬軟體公司及專業出版社，共計 20 個，年會期間吸引眾多人潮駐足參觀，提供了吸收新知及充分溝通，詢問的良好機會。整個研討會共有 139 篇口頭論文、27 篇海報論文發表，可說是安全領域最盛大的研討會，分為五個主題：

- 主題一、風險管理及法規議題
  1. 危害辨識
  2. 風險評估與評析
  3. 後果分析模式
  4. 選址和土地使用規劃
  5. 法規議題（REACH、ATEX、SEVESO、GHS 與 PED 等）
     (1) 技術議題
     (2) 對於中小型企業之影響
     (3) 開發中國家之法規現況
  6. 運輸風險
  7. 安全保全風險
  8. 天然危害的風險
  9. 新發展的評估方法
  10. 風險溝通
  11. 危機管理及應變整備

■ 主題二、人為因素及管理系統

1. 控制重大危害中的人為因素
2. 人體工程學（包含控制室的設計與人員配置組成）
3. 專業才能和執行能力
4. 安全文化
5. 製程安全績效（指標及考核）
6. 製程安全教育及訓練
7. 組織變革
8. 委外外包和承攬商活動
9. 健康、安全、環境與保全管理系統
10. 合約製造
11. 評估完整性

■ 主題三、事故教訓記取學習和知識轉移

1. 從事故教訓中記取與學習
2. 辨識事故災因
3. 落實經驗教訓的策進方案
4. 知識轉移
5. 教學方法及工具
6. 從其他工業取得的經驗
7. 溝通協調與教育

■ 主題四、製程安全工程

1. 安全評核系統
2. 永續性
3. 本質安全
4. 安全設計
5. 火災及爆炸消減
6. 工廠平面配置與骨牌效應
7. 生物科技
8. 實驗及試驗級工廠
9. 核能安全
10. 柔性工程（Resilience engineering）
11. 新興技術（emerging technology）

■ 主題五、物質危害

1. 嶄新發展與新興技術的危害
2. 物質的危害性質
3. 奈米材料（nano-materials）
4. 化學反應分類（REACH 與 GHS）
5. 危害性質預測模式（Quantitative structure-activity/property relationship，QSPR）

本次與會共發表口頭論文一篇與海報論文一篇，口頭論文是 Parameters for Attenuation and Suppression of Detonation Wave with Inert Particles(附件一)，這是出國人陳政任透過國科會台俄合作計畫所產出的研究，本論文提出利用惰性固體粒子來消減爆轟波的模式，並與實驗結果相比獲得相當好的結果。口頭報告後獲得許多與會者的提問，皆對此一創新的模式感到興趣。本次發表的海報論文 Risk Management and Regulatory Control of Toxic Chemicals in Taiwan (附件二、三)主要在描述台灣環境保護署在過去的二十年執行毒性化學物質管理法的演進，另外，毒災應變體系的建置與運作，包括台灣毒管法的建立、毒化學物質的管理，使用以及操作，從搖籃到墳墓的策略方式進行毒化物管制。這是結合環保署長官與出國人過去十餘年在毒災應變與毒化物管理工作的心得，也受到與會人士的興趣。

參加國際性研討會，另可認識相當多的重要文獻的作者，例如於粉塵爆炸的條件與實際技術「Some Myths and Realities about Dust Explosions」是由 Dr. Paul R. Amyotte 主講，Amyotte 博士是期刊 Journal of Loss Prevention in the Process Industries 的主編，在製程安全領域頗受尊重，其演講說明到發生粉塵爆炸的必要條件，必需同時滿足以下五個元素：（i）燃料（ii）氧化劑（iii）引火源，（iv）的燃料和氧化劑的混合，以及（v）限制下的混合物，雖然它看起來簡單，但若刪除五個元素的任一個元素，即可防止或減輕粉塵爆炸。

四、參訪內容

利用地利之便，本此研討會後並順道參訪除污設備專業公司(義大利 CRISTANINI)核生化去毒除污設備之實際應用。CRISTANINI 針對核生化的特性以超過 30 年的研究與開發經驗，生產製造經國際認可，能徹底除污消除核生化威脅的產品，其中 SaniJet 除污噴灑系統，加上 BX24 除污劑有效消除多種化學武器戰劑(GD 及 VX 等)，兼具簡單、高效率、快速等優點。

過去的化武除污劑多為以毒攻毒的方式，利用一強氧化劑來分解化武戰劑成為毒性較低之分子，例如超級漂白劑，其成份為 93%次氯酸鈣+7%氫氧化鈉，透過氧化與水解作用可破壞 HD (Mustard)、VX (Nerve Agent)等化武戰劑，但本身具腐蝕性。另一常見的 DS-2 除毒劑，其成份為 70%二乙烯三胺、28%乙二醇甲醚、2%氫氧化鈉，可破壞 HD (Mustard)、VX (Nerve Agent)等，但使用時需著呼吸防護具，且乙二醇甲醚毒性高已被列管為毒性化學物質，故國外早已建議停用。CRISTANINI 的 BX24 除污劑可說是新一代的除毒劑，為含氯的長鏈分子，具有漂白劑的分解特性，不僅可分解化武戰劑，也可分解一些工業有毒物質，但毒性因蒸氣壓低而更低，可直接用於人員或器材，目前歐洲國家已廣泛採用。本次參訪有機會直接瞭解並測試其解毒劑與噴灑設備，已建議環保署希望未來能有機會引入台灣。

參、 心得與建議

此次參加第 14 屆國際化學程序工業損害預防及安全促進研討會，並以壁報論文乙篇展示，其題目描述台灣環境保護署在過去的二十年執行毒性化學物質管理法的演進，另外，毒災應變體系的建置與運作，包括台灣毒管法的建立、毒化學物質的管理，使用以及操作，從搖籃到墳墓的策略方式進行毒化物管制。

另外觀看其他國家之壁報論文，發現品質及內容上相當有水準，而且在研討過程中尤其熱烈，與會會員對於各項主題均有相當大的興趣，與作者之溝通密切，獲益匪淺。

藉由此次與國外持續技術交流並落實在國內技術移轉與茁壯成長之機制，將在多年來已建置的環境事故緊急應變領域專業技術上，由應變專業訓練、應變設施與設備、業界/民間/地方政府整合應變計畫體系、先進國家 HAZMAT 小組先進設備與整備，以國際管理、預防、整備、應變及復原等先進技術、設備、訓練與整合應用等重要資訊，特別是針對現場人員與設備除污先進設備及技術的現地瞭解與技術交流，未來均將持續增進國內在先進毒化災應變訓練、設備資材、專業技術、應用科技，以及業界整合聯防體系之推動與茁壯。建議未來毒災應變體系可持續參與此類研討會，持續提升技術交流。

肆、 附錄-照片

	
14th International Symposium on Loss Prevention and Safety Promotion in the Process Industries 研討會入口處	Poster_ Risk Management and Regulatory Control of Toxic Chemicals 壁報論文展示

	
義大利 CRISTANINI 的總經理合影	義大利 CRISTANINI 除污裝備

伍、 附件一

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Parameters for Attenuation and Suppression of Detonation Wave with Inert Particles

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The method of gas detonation wave attenuation and suppression by chemically inert particles injection before the leading shock front is considered. Parameters and cell size of a steady detonation wave are calculated. The minimum mass fraction and total mass of particles and the characteristic size of the cloud, which are necessary for detonation wave suppression, are calculated. Methane-, Cyclohexane-, Hydrogen- and Silane-air mixtures with particles of W, WC, Al_2O_3, SiO_2 and KCl are considered. Results of calculations quite good correspond to available experimental data. The process of suppression is more effective, if particles have high heat capacity and heat of melting. Among the particles under consideration Al_2O_3 and SiO_2 particles are better for detonation suppression.
Detonation limits for different chemical compositions of methane-air mixtures and mass fractions of SiO_2 particles are calculated. An increase of particles concentration leads to increase of the lower and decrease of the upper detonation limit. If a mass fraction of condensed phase is high enough, detonation wave propagation is impossible.
A steady detonation wave reflection from a rigid wall ($D \rightarrow D$ reflection) in cyclohexane- and silane-air mixtures with SiO_2 particles is considered. It is shown, that particles can drastically reduce pressure and temperature behind the reflected wave and therefore prevent crucial destruction of equipment.
The efficiency of detonation wave suppression at different relations between fuel and oxidizer is calculated. Methane- and cyclohexane-air mixtures with Al_2O_3 particles are considered. It is shown, that for every particles concentration the value of cell size has a minimum, which corresponds to a fuel-rich chemical composition. It means that for this relation between fuel and oxidizer the efficiency of detonation wave suppression by particles injection has a maximum.

1. Introduction

Chemically inert solid particles can be used for effective control of gaseous detonation. Theoretical and experimental investigation of detonation wave (DW) suppression in gaseous mixtures by injection of chemically inert particles ahead the wave front are very important for safety industry and very far to be completed.
An algorithm for calculation parameters and cell size of detonation wave in a mixture of a gas with chemically inert microparticles was presented in article of Fomin and Chen (2009). Results of calculations are used for analysis of the method of multifront detonation wave (DW) suppression by particles injection before the leading shock front. The ratio between the channel diameter and the detonation cell size was used to estimate the limit of detonation. The minimum total mass of the particles and the characteristic size of the cloud, which are necessary for detonation suppression, were calculated. It was shown, that such suppression is more effective, if the particles have high heat capacity, low melting point and high heat of melting.
But the model of Fomin and Chen (2009) was not compared with available experimental results. The validity of the model for a wide range of chemical compositions of gaseous mixtures and kinds of particles

was not verified. Additionally, the following questions still need to be considered. Is it possible to reduce an impact of DW on the wall by the particles injection and therefore prevent crucial destruction of equipment, caused by detonation? How additions of the particles influence on pressure and temperature behind a reflected wave? How chemical composition of gas influences on DW parameters at different mass fraction of condensed phase? At which chemical compositions relative cell size is bigger and therefore the efficiency of DW suppression by particles injection is higher? How concentration limits of detonation wave depend on mass fraction of a condensed phase? Such problems will be considered here for a wide range of chemical compositions of gaseous mixtures and kinds of particles. Fomin and Chen model (2009) (with some modifications, see below) will be used.

2. Parameters and relative cell size of DW in gas-particles mixture

The typical results of calculations of DW parameters in gas-particles mixture is shown in Figure 1. A steady one dimensional DW in methane/O_2/N_2 mixture with WC, KCl, and Al_2O_3 microparticles is considered; α is the unitless mass fraction of condensed phase, u_D, P and T are DW velocity, pressure and temperature in Chapman-Jouguet (C.–J.) plane respectively, T_{sw} and P_{sw} are temperature and pressure behind the shock front, P_0 and T_0 are initial pressure and temperature.

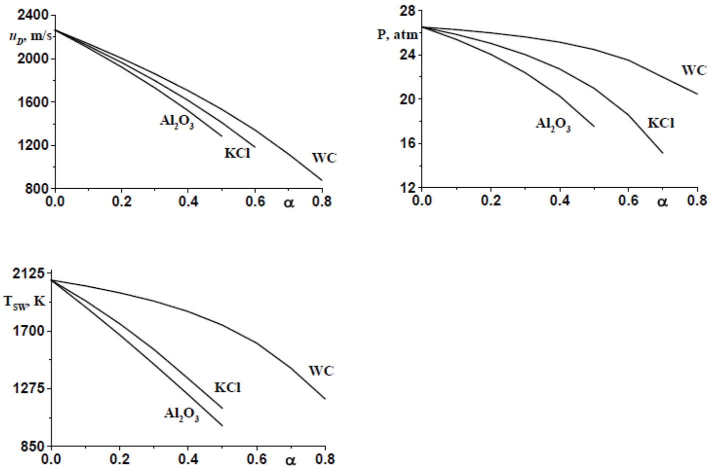

Figure 1: DW parameters in $CH_4 + 2O_2 + N_2$ mixture with Al_2O_3 , KCl and WC microparticles; P_0 = 1 atm, T_0 = 273 K

Energy losses due to heating of particles are determined by corresponding increase in enthalpy of condensed phase. The increase in enthalpy of Al_2O_3 is greater than that for KCl and WC, heated to the same temperature. As a result, as is seen from Figure 1, DW parameters in mixture with WC and KCl (i.e., the wave velocity, pressure, and temperature behind the leading shock front and in C.-J. plane) are higher than the corresponding parameters of mixture, containing Al_2O_3 particles. Similar results have been obtained for cyclohexane-, hydrogen- and silane-air mixtures.

3. Minimum total mass of a cloud; comparison with experimental data

Note the minimal total mass of particles that should be injected into the tube to suppress DW and the corresponding longitudinal size of the cloud as *M* and *H*. In Fomin and Chen (2009) model it was assumed that $F = L = a$, where L, F and a are the longitudinal size of the cloud after compression, the distance between the leading shock front and C.-J. plane and the transverse size of detonation cell respectively. In the frames of the present work it is assumed that $F \approx 3a$ and, owing to transition processes, caused by detonation wave penetration into the cloud, $L \approx 3F$. Such changes increase the accuracy of M and H calculations as compare with corresponding formulas of Fomin and Chen (2009) model. The value M, calculated in the frames of the algorithm, presented here, is shown in Figure 2; η is the unitless molar fraction of the fuel in the gas, d is a tube diameter (d = 16.4 mm). Calculations: SiO_2 microparticles; experimental results (Laffitte and Bouchet, 1959): potassium bitartrate 10–20 μm particles. Black triangles and squares correspond to experiments and calculations respectively. As can be seen, the calculated value M quite good corresponds to the available experimental results.

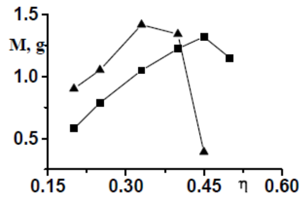

Figure 2: The minimum mass of particles, leading to detonation suppression. Mixture $\eta CH_4 + (1 - \eta)O_2$, P_0 = 1 atm, T_0 = 298 K

4. Detonation wave reflection from a rigid wall in gas-particles mixtures

A problem of DW reflection from a rigid wall in gas/chemically inert particles mixtures is considered (Figure 3a). A steady one-dimensional DW with constant C.-J. parameters behind the leading front impacts a rigid wall. As a result, reflected wave occurs. The gaseous phase behind the reflected wave front is in a state of chemical equilibrium. Such kind of reflection in gaseous mixtures called D → D reflection. The same term for DW reflection in gas/particles mixtures is used here.

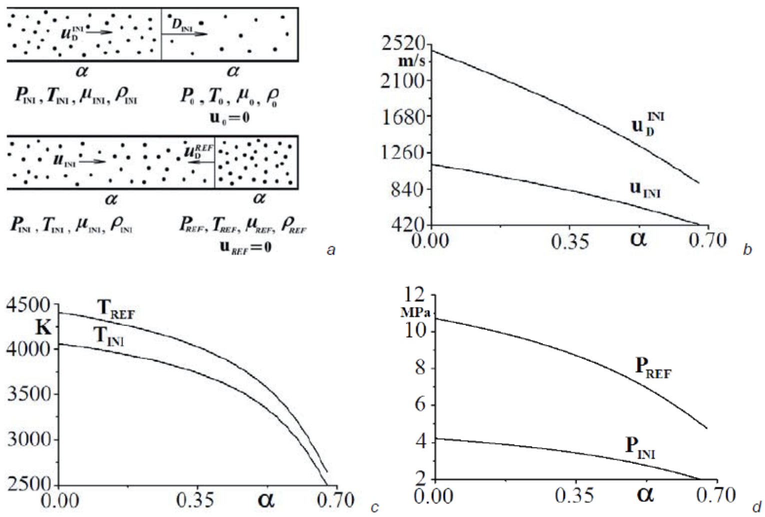

Figure 3: D → D reflection of DW in $0.1C_6H_{12} + 0.9O_2$ mixture with Al_2O_3 microparticles

Mass fraction of particles and parameters of initial detonation wave (velocity u_D^{INI}, temperature T_{INI}, pressure P_{INI}, mixture velocity u_{INI}, density ρ_{INI} and molar mass μ_{INI} of gas) assumed to be known. Parameters of reflected wave (velocity u_D^{REF}, pressure P_{REF}, temperature T_{REF}, mixture velocity u_{REF}, density ρ_{REF} and molar mass μ_{REF} of gas) should be calculated. The following system of algebraic equations is used: conservation equations of (a) mass, (b) momentum and (c) energy, (d) equation of state, (c) equation of chemical equilibrium and (d) traditional condition, that behind the reflected wave velocity of a mixture equals to zero. Thus, the number of equations equals to the number of variables.
Results of calculations of D → D reflection in mixture $0.1C_6H_{12} + 0.9O_2$ with Al_2O_3 microparticles are presented in Figure 3(b-d), α is the unitless mass fraction of condensed phase. As can be seen, particles can essentially reduce parameters of reflected wave and therefore prevent crucial destruction of equipment, caused by detonation. For example, as can be seen from Figure 3c, if mass fraction of particles increases from 0 to 0.675, a temperature behind reflected wave decreases in 1.67 times. Attenuation of pressure in this case is even more effective: its value decreases in 2.25 times (Figure 3d).

5. The influence of gas composition on DW suppression by particles injection

The efficiency of detonation wave suppression in gas-particles mixtures with different stoichiometry and mass fractions of condensed phase can be analyzed. The results of calculation of DW parameters in cyclohexane/oxygen and CH_4/oxygen mixtures with Al_2O_3 and SiO_2 microparticles and different stoichiometric relation between fuel and oxidizer are presented in Figures 4-6; η is the unitless molar fraction of the fuel in the gas, α is the unitless mass fraction of condensed phase, a_P is the transverse cell size in gas without particles, P_0 = 1 атм, T_0 = 298 K. As can be seen from Figures 5 and 6, at fixed concentration of the particles the value a/a_P has the minimum. Such minimal value corresponds to the lowest efficiency of detonation wave suppression (because the minimum value of the relative cell size corresponds to the maximum values of M and α_*). For example, if α = 0.5, then a/a_P has the minimum value at η = 0.1625 (stoichiometric mixture corresponds to η = 0.1). It means that for this stoichiometry the efficiency of detonation wave suppression by particles injection is minimal too. An increase of the value a/a_P in fuel-lean and fuel-rich mixtures means that the efficiency of detonation suppression by particles injection increases too. But for fuel-rich mixtures such effect is not so essential.

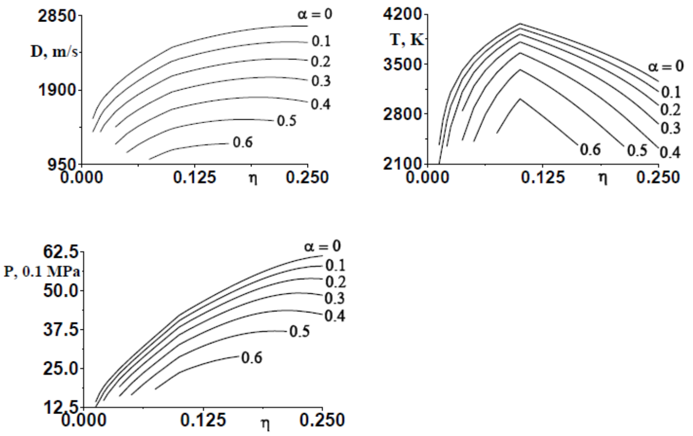

Figure 4: C.-J. parameters of DW at different stoichiometry and mass fraction of microparticles. Mixture: $\eta C_6H_{12} + (1 - \eta)O_2$ with Al_2O_3 microparticles

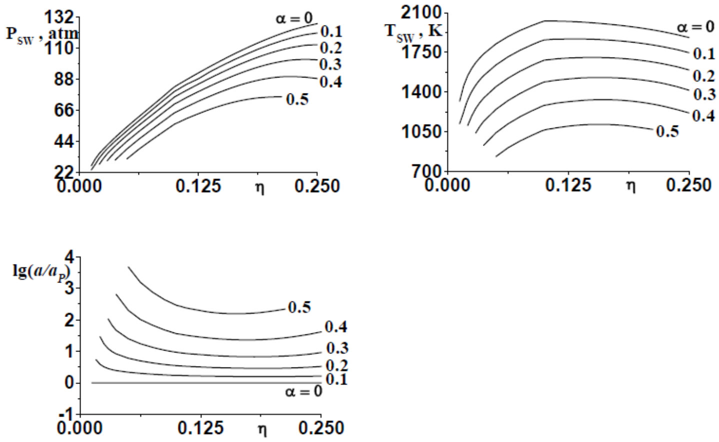

Figure 5: Von Neumann spike parameters and relative detonation cell size at different stoichiometry and mass fraction of condensed phase. Mixture ηC_6H_{12} + $(1 - \eta)O_2$ with Al_2O_3 microparticles

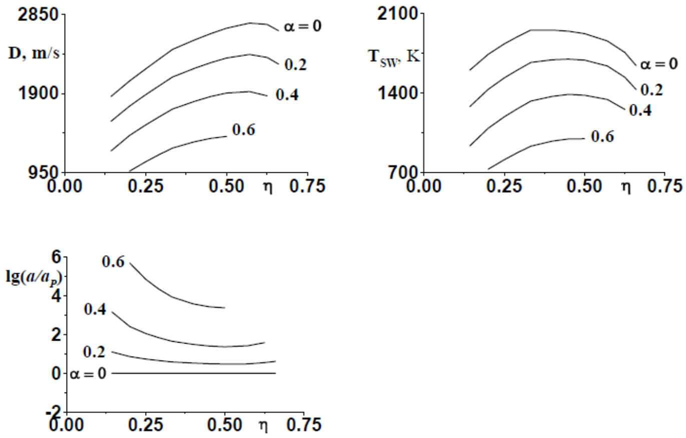

Figure 6: DW parameters and relative cell size at different stoichiometry and mass fraction of condensed phase. Mixture ηCH_4 + $(1 - \eta)O_2$ with SiO_2 microparticles

6. Detonability limits of DW in gas-particles mixtures

The algorithm for calculation the detonability limits in gaseous mixtures (see, for example, Vasil'ev, 2012) can be used for calculation the existence region of detonation waves in the gas-particles mixtures too. For

this purpose, equation $a = \pi d$ and detonation cell size as a function of chemical composition of a mixture and mass fraction of a condensed phase should be used (Fedorov et al., 2012).
Methane/oxygen gaseous mixture with SiO_2 microparticles will be considered. The algorithm for calculation detonation wave parameters and relative cell size, presented here, will be used, P_0 = 1 атм, T_0 = 298 K, d = 16.4 mm. The relative cell size as a function of the chemical composition of the mixture and mass fraction of the condensed phase is shown in Figure 6, η is the unitless molar fraction of the fuel in the gas. Detonation cell size in pure methane-oxygen gaseous mixture can be found in Vasil'ev et al. (2000) article. Equation $a = \pi d$, Figure 6 and Vasil'ev et al. (2000) article allow us to calculate the detonation limits in the heterogeneous mixture under consideration (Figure 7). Results of calculations qualitatively correspond to the available experimental data (Wolanski et al., 1988).

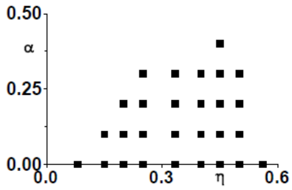

Figure 7: The existence region of detonation wave. Mixture $\eta CH_4 + (1 - \eta)O_2$ with different mass fractions of SiO_2 microparticles. Black squares correspond to the existence region of detonation wave

7. Conclusions

C.-J. parameters, cell size, limits and D → D reflection of DW in mixtures of combustible gas with chemically inert microparticles are calculated. The method of attenuation and suppression of multi-front DW in gas by particles injection is analyzed. The algorithm for estimation the minimal total mass of particles and characteristic size of the cloud, which are necessary for successful quenching of DW is presented. Results of calculations quite good correspond to the available experimental data.
It is shown, that the efficiency of detonation suppression is more effective for fuel-lean mixtures. D → D reflection of DW is considered. According to calculations, particles can essentially reduce pressure and temperature behind the reflected wave.

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伍、 附件二


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Risk Management and Regulatory Control of Toxic Chemicals in Taiwan

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Toxic Chemicals Control Act in Taiwan

The Environmental Protection Administration (EPA) of Executive Yuan, ROC Taiwan, is in charge of the implementation of **Toxic Chemical Substances Control Act (TCSCA)** since its promulgation in 1986. Under the Act, the Taiwan EPA has currently declared **302** toxic chemicals under state control. The number is increased at a rate of about 10 chemicals per year.

Toxic Chemical Substance Control Act Between 2001 and 2007

The initiation of on-scene response aids

The Fu-kuo incident with runaway reaction and toxic release in May 2001. 1 Fatality and 109 injuries.

EPA appreciated the importance of the on-scene response and setup on-scene response centers in northern, central, and southern Taiwan. In five years' time from 2002 to 2006, more than 500 on-scene response services were provided. The 3 centers expanded into 7 Emergency Response Teams(ERTs) in 2007 operated by:

- Industrial Technology Research institute (TRI) for Information Center and Control Center,
- Chung Yuan Christian University for 3 Northern Teams
- National Yunlin University of Science and Technology (NYUST) for 2 Central teams
- National Kaohsiung First University of Science and Technology (NKFUST) for 2 Southern Teams

The Setup of Emergency Response Team

The primary objectives of the seven ERTs are as follows:

- Provide round-the-clock on-scene emergency response aids to a toxic chemical incident within one hour after the incident's occurrence. The aid includes technical advice, coordination of the response, PPE for the responders, kits for stopping leaks or spills, advice on clean up, etc.
- Provide on-scene air pollution monitoring. The monitoring equipment includes a portable GC-MS, a dual function open-path and closed-cell FT-IR spectrometer, photo-ionisation detector (PID), flame-ionisation detector (FID), multiple gas detector, and detection tubes.
- Provide surface water, soil, solid waste analysis at the incident site. The analytical equipment includes a headspace module of portable GC-MS for water and solid waste or soil, a Smith Detection Identify IR for unknown solid, and a portable X-Ray Fluorescence (XRF) for heavy metal detection.
- Provide assistance for incident investigation.

The Taiwan EPA founded the seven ERTs through contracted projects. Each ERT has full-time staffs of sixteen people. EPA also provided directly the following equipment to each team:

Further Stringent Management and Control of Toxic Incidents in Transportation

Although the ERTs helped greatly the control of the toxic incidents, the number of responded incidents reached a record high in 2007, among which more than 20% were transportation incidents. Regulatory efforts were initiated in 2008 and revised regulations were issued for transportation of toxic chemicals:

- Regulations Governing the Transportation Management of Toxic Chemical Substances: A real-time tracking system shall be installed in transportation vehicles.
- Regulations Governing the Establishment and Management of Dedicated Environmental Protection Units or Personnel: The carrier shall assign one Class C dedicated personnel.
- Toxic Chemical Substances Hazard Prevention and Response Plan Regulations: A transportation hazard prevention and response plan shall be submitted to the competent authority for future reference.

Analysis of number of incident from year 2006 and onward.

Conclusions

Growing industrial development has brought the growing need for the use of a wide range of toxic chemicals. Taiwan EPA implemented both regulatory measures as well on-scene response supports to minimize the potential impacts from toxic chemical incidents. The efforts have shown that the number of incidents has declined from 2009 but yet eliminated completely. Challenges remain with the proper response and prevention of incidents.

Taiwan EPA is planning to further expand the regulatory control and support in the following two issues:

- A total solution to the incident response and recovery.
- Establishment of training fields and training regulations for emergency response of toxic incidents.

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Risk Management and Regulatory Control of Toxic Chemicals in Taiwan

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In this paper, we describe the evolution of Toxic Chemical Substances Control Act (TCSCA) regulated by Taiwan Environmental Protection Administration during the past two decades. The TCSCA was originally drafted for the management of utilization and operation of toxic chemical substances from cradle to grave. Following the 921 earthquake in central Taiwan in 1999, the newly issued Disaster Prevention and Mitigation Act further required that the risk management and disaster mitigation from all listed toxic chemicals must also be regulated in TCSCA. Since then, significant modification in the Act and new regulations are added and implemented. In addition, Taiwan EPA is also established information and monitoring centres and seven emergency response teams. These facilities provide 24-hour service and have at least 25 people on duty at all times. The main tools used by these facilities are environmental monitoring equipment, personal protection equipment, and response equipment for leak patching and chemical transfer. The increased regulatory control and response capabilities have greatly reduce the occurrence and potential impact from toxic chemicals incidents as evident from the incident statistics.

1. Introduction to Toxic Chemicals Control Act in Taiwan

Taiwan is a well-populated island stocked with industries ranging from refineries, petrochemicals, specialty chemicals, pharmaceuticals, semiconductor fabrication, and electronics manufacturing, etc. All these industries rely heavily on the use or production of chemicals. Although the rapid industrial development brings prosperity to the people, it also brings adverse effects such as pollution and, more recently, the disasters from the use or production of chemicals.

The Environmental Protection Administration (EPA) of Executive Yuan, ROC Taiwan, is in charge of the implementation of Toxic Chemical Substances Control Act (TCSCA) (EPA, 2012a) since its promulgation in 1986. The Act aims to reduce the potential hazards and prevent potential pollution from the use of these chemicals. Under the Act, the Taiwan EPA has currently declared 298 toxic chemicals under state control. The number is increased at a rate of about 10 chemicals per year as shown in Figure 1. Licenses are required for the manufacturing, import, sale, and use of these toxic chemicals. The TCSCA was originally drafted for the management of utilization and operation of toxic chemical substances from cradle to grave.

Article 24 of the Act also requires that persons handling the toxic chemical substances shall immediately take emergency measures and report to the Responsible Agencies at the local government level where the accident occurred, within one hour of the occurrence of one of the following incidents:

1. Pollution of the environment surrounding the handling site as the result of chemical leaking, reactions, or other incidents; or
2. Potential pollution of the environment or endangerment of human health as the result of accidents occurring during toxic chemical substance transportation.

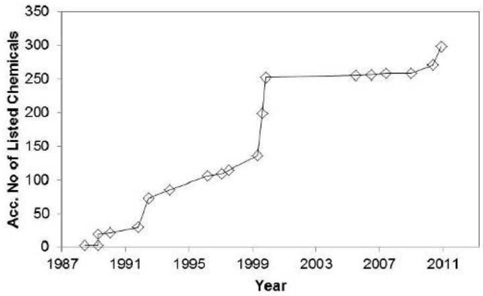

Figure 1: Number of listed toxic chemicals.

The Responsible Agency shall order persons handling toxic chemical substances to take necessary measures addressing the aforementioned incidents, and may order such persons to partially or totally terminate handling of the substances upon the occurrence of the incidents. The persons handling toxic chemical substances shall, after the incidents, be responsible for cleaning up according to relevant regulations and shall submit a written report describing the incidents and the remedial measures taken to the Responsible Agency at the local government level where the accident occurred for reference. Clearly, the Act has required the operating facilities to be responsible for the response and clean up in case of incident occurrence. The requirement, however, has posed a significant burden for small facilities that have very limited resources, experience, and capabilities. Unfortunately, small facilities represent more than 90% of the total facilities using the listed toxic chemicals.

After the implementation of the Disaster Prevention and Response Act (NDPPC, 2002) in 1999, the Taiwan EPA is also in charge of disaster prevention and response of toxic chemicals. Thus, Taiwan EPA contracted the Centre for Environmental, Safety, and Health Technology (CESH) of Industrial Technology Research Institute (ITRI) for the level-one response service to the whole island, namely providing necessary response information service over the phone, fax, or internet to the incident facilities. The information provided includes the materials safety datasheets (MSDS), the emergency response guidelines, selection of personal protective equipment etc. The level-one response service has helped the local EPA office and fire brigades to handle the response properly till early 2001.

2. Toxic Chemical Substance Control Act Between 2001 and 2007

2.1 The initiation of on-scene response aids

In May 2001, a runaway reaction incident (Kao and Hu, 2002) in an acrylic plant in Hsinchu, northern Taiwan, resulted in 1 fatality and 109 injuries and raised great awareness of the proper response of toxic chemical incidents. The explosion energy was estimated to be about 1000 kg TNT, implying a possible vapour cloud explosion from the runaway reactor. Glass windows of buildings within 500 m radius were shattered. The explosion and fire also resulted in significant fire, smoke, and chemical and gas spillage. The incident required significant response aids and monitoring equipment and were provided by ITRI which happened to be located in close proximity to the plant. ITRI provided, during the response and cleanup of this incident, the following support:

- On-scene technical advice for chemical spillage and clean up.
- On-scene coordination for locating resources such as personal protection equipment (PPE) from other operating facilities.
- On-scene air monitoring of smoke and chemical vapour by Fourier Transform Infrared (FTIR) spectroscopy.

The incident could have been worse if it occurred elsewhere, without the direct and prompt help from ITRI. EPA appreciated the importance of the on-scene response and decided in late 2001 to setup level-two response centres in northern, central, and southern Taiwan for a more prompt and direct response of toxic chemicals incidents. ITRI, National Yunlin University of Science and Technology (NYUST), and National Kaohsiung First University of Science and Technology (NKFUST) were chosen for the setup of joint response centres in northern, central, and southern Taiwan, respectively. ITRI was chosen for its proven experience in emergency response while NYUST and NKFUST were chosen for their combined expertise in environmental and safety engineering.

In five years' time from 2002 to 2006, more than five hundred on-scene response services were provided. The incidents ranged from a leak of a toxic gas cylinder to a large-scale fire in a high-tech facility. The effective response service has greatly reduced the potential impact from these incidents. More details on the level-two response systems have been provided in Chen et al. (2003).

2.2 The Setup of Emergency Response Team

Although the three response centres did provide effective responses to the incidents, the growing number of incident has increased the burden and timing on the response work. In 2007, EPA proposed a Plan to Strengthen Toxic Chemical Safety Management and Incident Response which was ratified by the Executive Yuan. This involves commissioning the establishment of information and monitoring centres and seven Emergency Response Teams (ERTs) with increased staffs and equipment to reduce the response load and timing.

The responsible counties for the seven ERTs were divided according to geographic and traffic considerations. Taiwan is an island, with 70% of its land consisting of hills and mountains that spread from the north to the south, dividing the island into west and east areas. Traffic from west to east relies on three roads that cross the Central mountains. Among the seven teams, six teams are located in the west, while one team is located in the east, reflecting the fact that most industrial parks and small industries are also located in the west. The three ERTs in the northern and eastern part of Taiwan are operated by a response centre held by the Chung Yuan Christian University. The two ERTs in the central part of Taiwan are operated by a response centre in National Yunlin University of Science and Technology. The two ERTs in the southern part of Taiwan are operated by a response centre in National Kaohsiung First University of Science and Technology. In addition, there is one Information Centre and a Control Centre both operated by Industrial Technology Research Institute. Figure 2 shows the geographic location of the seven teams.

Figure 2: Geographic location of the seven ERTs. The separation line is the county borderline.

The primary objectives of the seven ERTs are as follows:

- Provide round-the-clock on-scene emergency response aid to a toxic chemical incident within one hour after the incident's occurrence. The aid includes technical advice, coordination of the response, PPE for the responders, kits for stopping leaks or spills, advice on clean up, etc.
- Provide on-scene air pollution monitoring. The monitoring equipment includes a portable GC-MS, a dual function open-path and closed-cell FT-IR spectrometer, photo-ionisation detector (PID), flame-ionisation detector (FID), multiple gas detector, and detection tubes.
- Provide surface water, soil, solid waste analysis at the incident site. The analytical equipment includes a headspace module of portable GC-MS for water and solid waste or soil, a Smith Detection Identify IR for unknown solid, and a portable X-Ray Fluorescence (XRF) for heavy metal detection.
- Provide assistance for incident investigation.

The other objectives of the ERTs include but are not limited to:

- Provide non-emergency information service to local EPA bureaus.

- Hold response training courses for persons in charge of toxic chemical management in operating facilities.
- Assist large-scale drills for the response of toxic chemicals in each county.
- Assist local EPA officers in inspecting and auditing the operating facilities.

In addition to the seven ERTs, an Information Centre is also set up to provide safety related information during emergency response and non-emergency inquiries. The Information Centre also holds all relevant information from every toxic chemical operating facility. This information helps to assess the operating facilities should an incident occur. Another Control Centre is also set up directly in the EPA headquarters to help EPA officers in acquiring photos or video clips from the incident, monitoring the progress of the incident, and assessing the impact from the incident. Both centres are operated by Industrial Technology Research Institute.

For the service to be effective and prompt, it is necessary that the ERTs are promptly notified of the incident. Article 24 of the Toxic Chemical Substances Control Act has regulated that the operating facilities must report the incident to the local EPA office within one hour after occurrence. This is usually the case when the incident is caused directly by the listed toxic chemicals. In the cases when the incident was not caused directly by the listed toxic chemicals, the reporting may be delayed.

The best practice found is to have a direct link between the Information Centre and the local fire brigades where most incidents, regardless of the causes, were reported. Upon receiving incident messages from the fire brigade, the Information Centre immediately check and confirm for the chemicals involved and provide relevant information to the ERTs and the fire brigade. On-scene emergency response of the ERTs is activated, depending on the cause of the incident and possible chemicals involved.

Another rapid source of acquiring incident information is through the TV news. CNN-like TV news media in Taiwan are popular and compete vigorously for breaking news like a chemical incident. They usually arrived at the incident site almost the same time as the fire brigade and broadcasted the incident immediately with Satellite News Gathering (SNG) systems. Therefore, regular monitoring of the TV news is also done in the Information Centre.

The Taiwan EPA founded the seven ERTs through contracted projects. Each ERT has full-time staffs of sixteen people. EPA also provided directly the following equipment to each team:

- 20+ sets of Level A suits with self-contained breathing apparatus (SCBA).
- 1000+ sets of personal protection kits, each including a disposable Level C suit, a half-mask air-purifying respirator, a pair of chemical resistant gloves, and a chemical absorbent pad.
- 1 medium-size vans, 1 medium-size truck, and 1 large-size truck.
- 2 sets of portable four-gas detectors.
- 2 sets of direct-reading gas-detecting tubes covering all possible toxic gases or vapours
- A Photo-ionisation detector (PID) for continuous monitoring of air pollutant down to ppb level.
- A Flame-ionisation detector (FID) for the continuous monitoring of all flammable air pollutant down to sub-ppm level
- A portable FT-IR with dual open path and closed cell sampling loops for identification and monitoring of air pollutant down to ppm level at the incident site.
- A portable GC-MS system for the identification and monitoring of volatile organic chemicals at the incident site.
- A solid FTIR system for the identification of unknown waste or powder at the incident site.
- A portable X-Ray Fluorescence (XRF) for the detection of heavy metals in soil or solid waste at the incident site.

2.3 Regulatory control on toxic incidents

In addition to the ERT system that helps the operating facilities in responding to the toxic incidents, EPA also strengthen the regulatory control towards the response of toxic incidents. The new regulations issued in 2007 included:

- *Toxic Chemical Substances Accident Investigation and Disposal Report Operating Standards (EPA, 2012b)*

  The handler of toxic chemical substances shall submit a preliminary accident investigation and disposal bulletin within three days after an accident occurs, and shall submit a summary accident investigation and disposal report within 14 days after the accident to the special municipality, county, or city competent authority in the area where the accident occurred for subsequent reference, and shall send copies to the central competent authority.
- *Toxic Chemical Substance Handling Liability Insurance Regulations (EPA, 2012c)*

When the total quantities of manufactured, used, stored, or transported toxic chemical substances exceed a specific quantity, the handler shall purchase liability insurance prior to handling.

Both regulations aimed at the enforcement of the handlers to have more liability and learning in an incident.

3. Further Stringent Management and Control of Toxic Incidents in Transportation

Although the establishment of the ERTs helped greatly the control of the toxic incidents, the number of responded incidents reached a record high in 2007, among which more than 20% were transportation incidents as shown in Figure 3 The transportation incidents which consisted mainly tank truck incidents on the road not only require significant resources and efforts to respond but also put nearby communities into risk. Regulatory efforts were initiated in 2008 and revised regulations were issued for transportation of toxic chemicals.

- *Regulations Governing the Transportation Management of Toxic Chemical Substances (EPA, 2012d)*
  A real-time tracking system shall be installed in transportation vehicles when the total quantities of transported toxic chemical substances exceed a specific quantity.
- *Regulations Governing the Establishment and Management of Dedicated Environmental Protection Units or Personnel (EPA, 2012e)*
  When the total quantities of transported toxic chemical substances exceed a specific quantity, the carrier shall assign one Class C dedicated personnel, and shall provide the name of that dedicated personnel and the carrier he is employed by on the toxic chemical substance transport manifest.
- *Toxic Chemical Substances Hazard Prevention and Response Plan Regulations (EPA, 2012f)*
  Owners of toxic chemical substances who carry out on their own or commission others to transport toxic chemical substances shall submit a transportation hazard prevention and response plan to the special municipality, county or city competent authority for future reference.

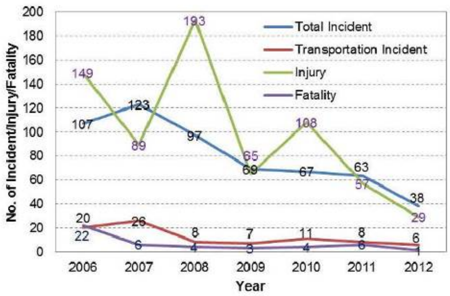

Figure 3: Analysis of number of incident from year 2006 and onward. Data for year 2012 is updated to August.

The stringent requirement on the management of toxic chemicals transportation drastically reduced the number of all transportation incidents, whether it was listed toxic chemicals or non-listed chemicals, from 26 incidents in 2007 to below 10 incidents after 2008. Overall numbers of injury and fatality from these incidents are also reduced. Training and education of truck drivers and toxic facility operators are increased as a result of the new regulations.

4. Conclusions

Growing industrial development has brought the growing need for the use of a wide range of toxic chemicals. Taiwan EPA implemented both regulatory measures as well on-scene response supports to minimize the potential impacts from toxic chemical incidents. The efforts have shown that the number of incidents has declined from 2009 but yet eliminated completely. Challenges remain with the proper response and prevention of incidents.

With the technical supports from Chung Yuan Christian University, National Yunlin University of Science and Technology, National Kaohsiung First University of Science and Technology, and the Industrial Technology Research Institute, Taiwan EPA is planning to further expand the regulatory control and support in the following two issues:

- A total solution to the incident response and recovery: Although the Toxic Chemical Substances Control Act requires the operating facilities to be responsible for the response and clean up in case of an incident, there remain small facilities with very limited staff that are unable to fulfil any response task. The well-equipped ERTs will play an increasing role in the incident response in these small facilities. The ERTs may also contract specialists to perform post-incident recovery and the cost will be compensated later through the facility or its insurer. The total solution from incident response and recovery will help to prevent any incident from endangering the environment.
- Establishment of training fields and training regulations for emergency response of toxic incidents: A comprehensive training field for toxic incident response is under construction in northern Taiwan to aid the training and education of tank truck drivers and toxic facility operators. Another two training fields are also under planning and will be built in central and southern Taiwan. All these three training fields are planned to be completed by 2015 and will be operated by the ERTs. Regulations are also planned to be issued that requiring toxic facility operators be trained in these training fields.

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