US NSF – China NSF Workshop on Sustainable Manufacturing
Wuhan, China
March 13-15, 2014

Smart Manufacturing through Innovative Knowledge Extraction Methodologies in the "Big Data" Era

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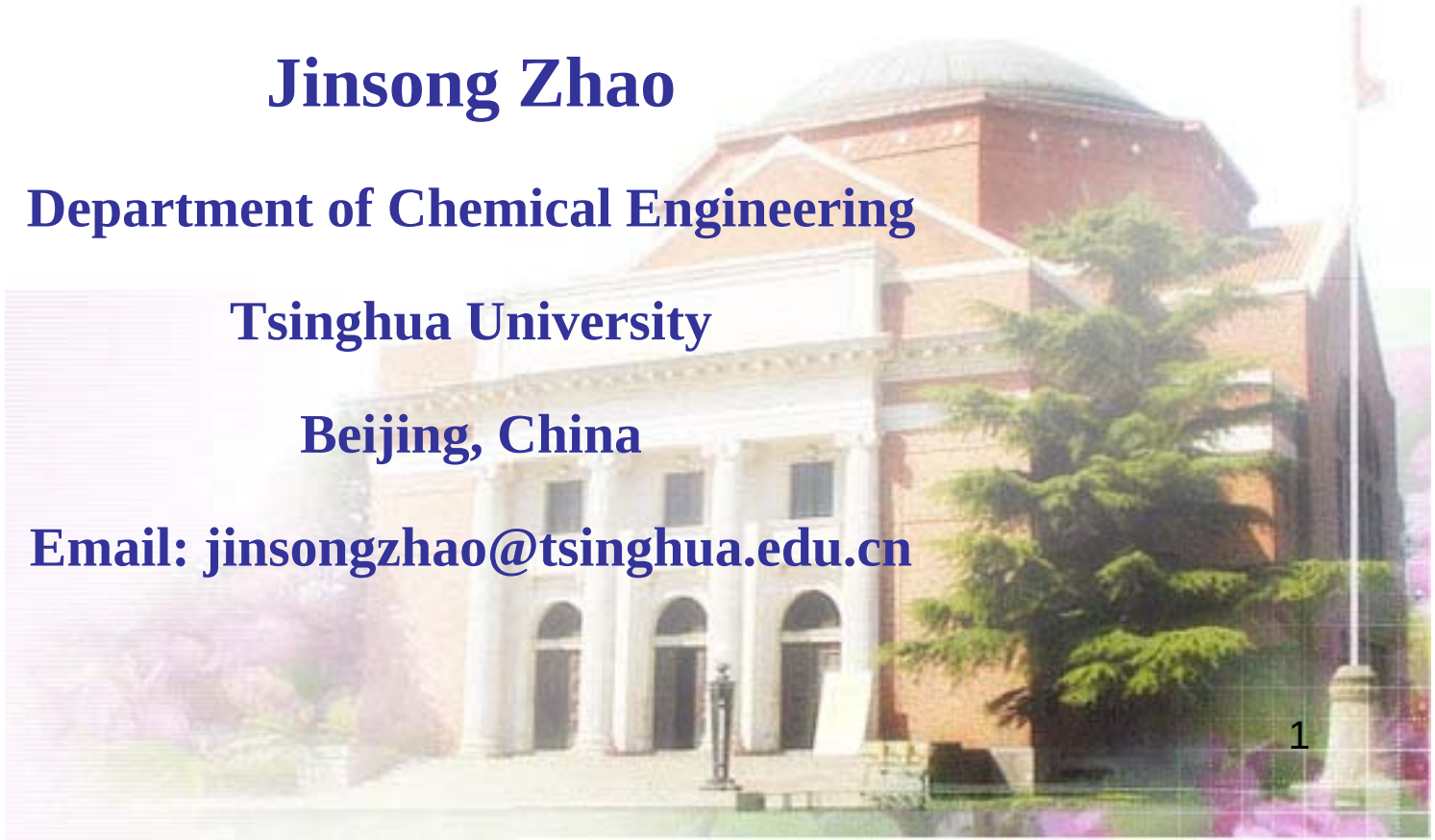


Outline

- Sustainable Manufacturing Challenges
  - From Safety Point of View
- Basic Requirements for Smart Manufacturing
- Progress Made at Tsinghua toward SM
- Future Research Directions

Sustainable Manufacturing Challenges

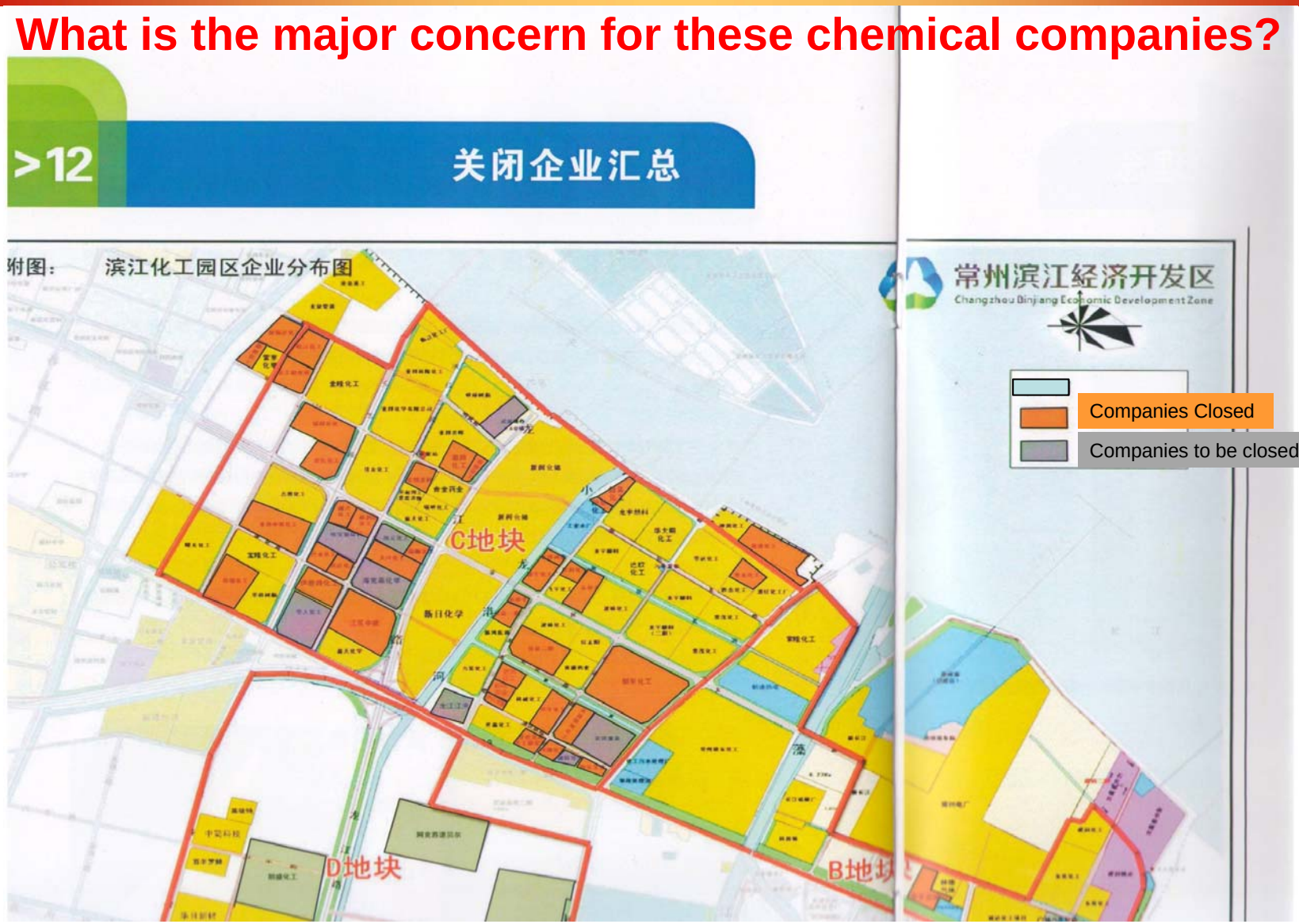
- The chemical process industry (CPI) in China has been the pillar industry
- By the end of 2013, China boasted 28,000 petrochemical businesses
  - Gross industrial output value US $2.1 trillion
- The CPI has presented a significant safety risk to human lives and the environment as well as sustainability

Sustainable Manufacturing Challenges

- Qingdao crude oil pipeline leakage and explosion accident
  - Nov. 22nd, 2013
  - 62 deaths
  - 136 injuries
  - Direct loss RMB 750M
- Pipeline permanently abandoned
- Downstream manufacturers impacted

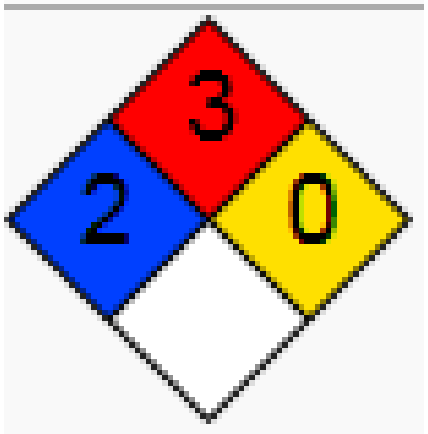
Sustainable Manufacturing Challenges

What is the major concern for these chemical companies?



Sustainable Manufacturing Challenges

- **Paraxylene (PX)**
  - **Used primarily as a feedstock for the manufacture of PTA, an important chemical in the production of fibre and plastic bottles**
  - **CAS No. 106-42-3**
  - **Material safety data**
    - **Flammable liquid**
    - **No evidence of carcinogenicity**

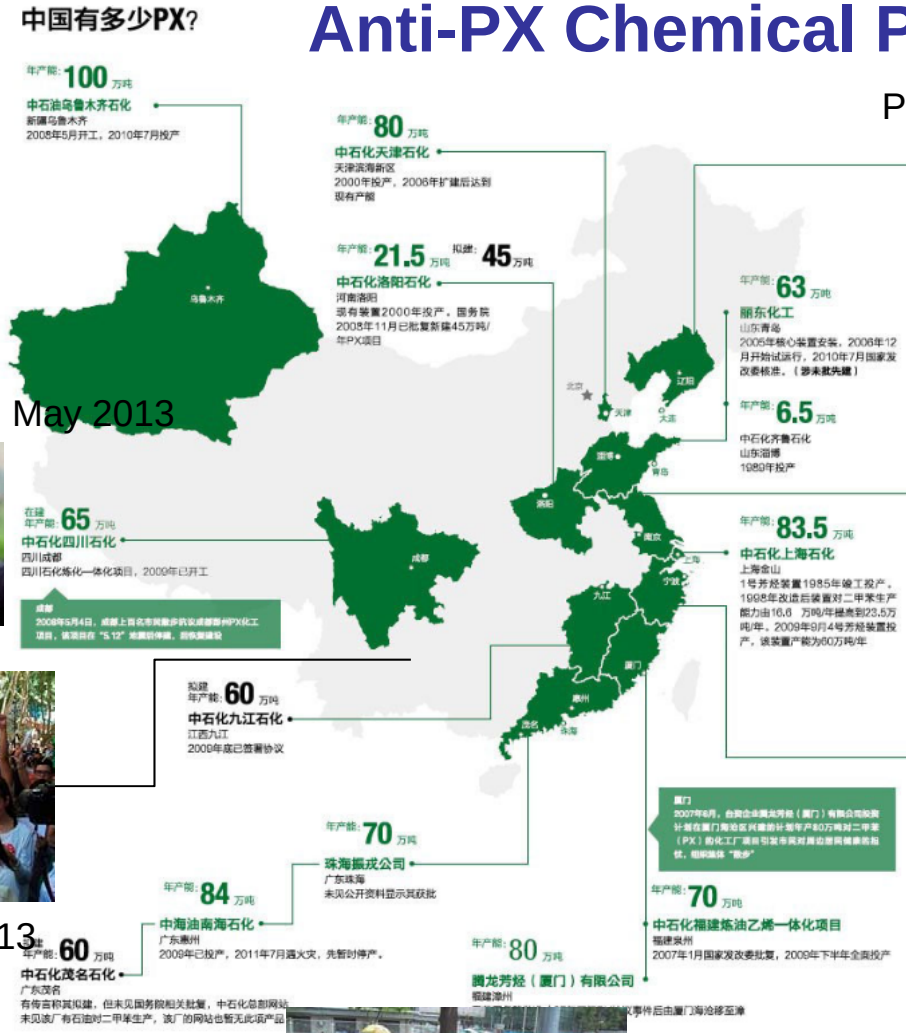







Sustainable Manufacturing Challenges

Anti-PX Chemical Plant Protests



Public Demonstration in Dalian in Sep. 2011

Pengzhou, Sichuan, May 2013

Kunming, May 2013

Public Demonstration in Oct. 2012 in Ningbo

July 2007, Public Demonstration in Xiamen

Sustainable Manufacturing Challenges

- No new PX plants have been built in China during last five years
- In 2013, 900 Million tons of PX were imported from other countries such as Korea and Japan
  - Price:10,000 RMB /ton PX
  - Total cost: 90 billion RMB=15 billion USD
- Is this a type of sustainable development?

Sustainable Manufacturing Challenges

- What do we need to do?
  - Hundreds of Laws, regulations have been enacted
  - The annual number of accidents have been decreased
  - Disasters like the Qingdao oil pipeline explosion accident still may happen
  - Public protests against new petrochemical construction projects may happen again
  - More chemical companies may be closed due to environmental and safety issues

Sustainable Manufacturing Challenges

- Study on process safety has been recognized as a key to prevent major chemical accidents
- Process safety management (PSM) standards have been promulgated in many countries
- PSM systems have been established in many international companies
- Major chemical accidents still happen worldwide

Sustainable Manufacturing Challenges

- BP Texas City Refinery Explosion Accident
  - March 25, 2005
  - 15 killed
  - 170 injured
- BP Deepwater horizon platform explosion accident
  - 11 killed
  - 17 injured
  - 700,000 tons of oil released to sea

Sustainable Manufacturing Challenges

- Why?
- Lack of risk awareness
  - Not all risks identified
  - Not all identified risks properly assessed
  - Not all properly assessed risks reduced

Sustainable Manufacturing Challenges

One answer:

Smart Manufacturing

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What is Smart Manufacturing?

- The definition of **Smart** from Webster
  - **Very good at learning** or thinking about things
  - Showing intelligence or **good judgment**

Are Chemical Manufacturers Learning?

- → **No.**
- → **Old adage**
  - ↘ **"There are no new accidents- only repeats of those we failed to learn from"**
- → **Organizational learning disability**

Hopkins Andrew (2008). Failure to learn. The BP Texas City Refinery Disaster. CCH Australia Limited.

Jinsong Zhao*, Johanna Suikkanen, Maureen Wood. Lessons Learned for Process Safety Management in China. **Journal of Loss Prevention in the Process Industries**(In Press)

Poor Learning Example

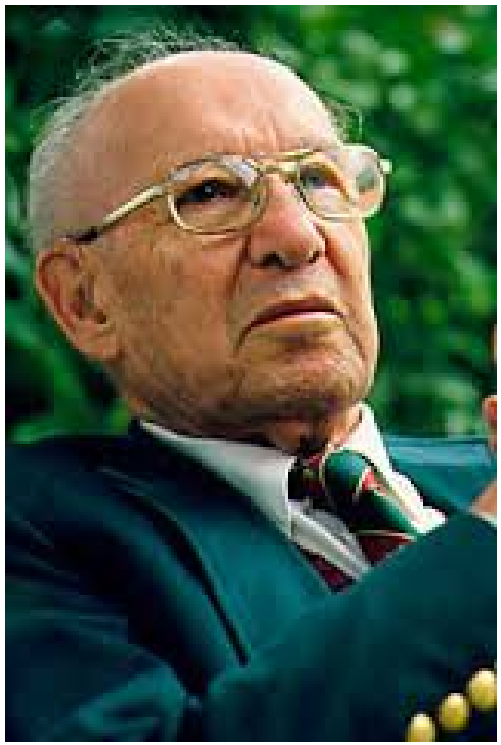
- BP Texas City Refinery explosion accident
  - March 23rd,2005
  - 15 people died
  - 170 injured
- Potential weaknesses in process safety had been highlighted in numerous reports from prior accidents that had occurred previously on the site
- According to the Baker Panel, BP had not learned those lessons
- If BP can't get it right, how should it be expected that those with less resources than a major oil company can do so?

Project Health Safety Security Environment Review Knowledge Management

Challenge: How to extract tacit knowledge from big data in PHSSER documents and experts

What is Good Judgement?

- About decision making
- Peter Drucker
  - "Every decision is a risk-taking judgement"
- Are the chemical manufacturers aware of their risks?



Poor Risk Awareness Example

- Qingdao crude oil pipeline explosion
  - Nov. 22nd, 2013
  - 62 deaths
  - 136 injuries
  - Direct loss RMB 752M
- A lot of people blamed that the emergency response was too slow
  - Why nearly residents not evacuated?
- Sinopec and the local government were not aware of the potential risk at all
  - Its severity
  - Its Likelihood

Basic Requirements for Smart Manufacturing

- Good learning manufacturer
  - Organizations don’t have knowledge
- Good risk-aware manufacturer

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Progress Made at Tsinghua toward SM

- A learning system
  - Intelligent HAZOP software platform HAZOPSuite®
- A risk awareness system
  - Intelligent Alarm Management software platform iTAM®

HAZOPSuite : A Learning System

- HAZOP is the most widely used risk identification methodology in the chemical Industry
  - Done by a team of 5~8 experts
- Time consuming
  - One week to 3 months to complete
- Potential to overlook some risks

V. Venkatasubramanian, J. Zhao, S. Viswanathan. ***Computers & Chem. Eng.****, vol.24, 2291-2302, 2000*

HAZOPSuite : A Learning System

→ Inconsistency

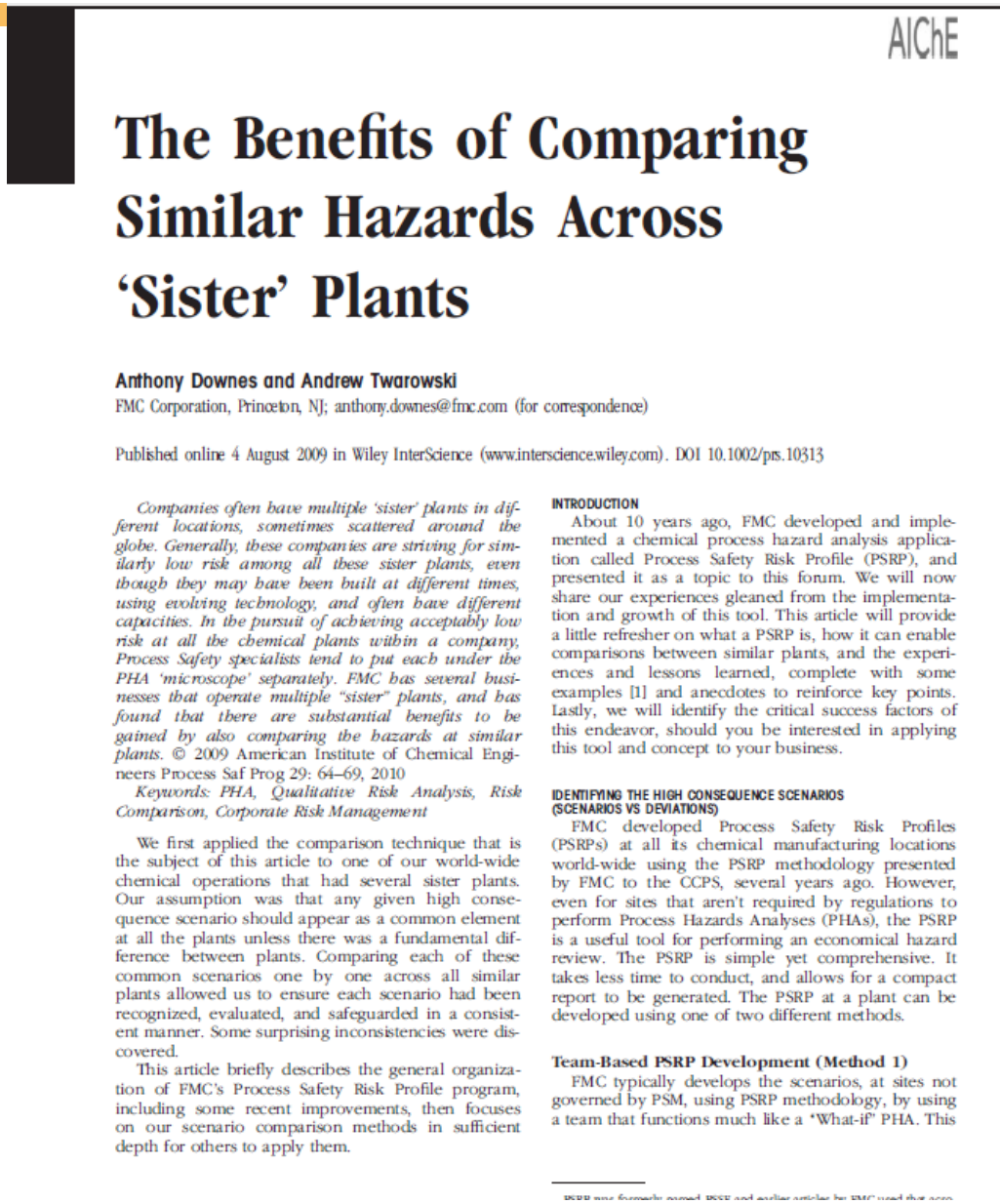
HAZOP results of a chemical process from two HAZOP teams

Comparison items	Foreign HAZOP experts	HAZOP team from DuShanZi of PetroChina
Number of Recommendations	258	400
Adopted	160	328
Rejected	98	72
Time	10 days	17 days
Number of identical recommendations	142	

FMC Corporation

- HAZOP analysis done by independent HAZOP teams
- High risk scenarios missed or misrated by ‘sister’ plants
- How to help the HAZOP team identify all risk scenarios?

→ Process Safety Progress, 29(1), 2010



AIChE

The Benefits of Comparing Similar Hazards Across ‘Sister’ Plants

Anthony Downes and Andrew Twarowski
FMC Corporation, Princeton, NJ; anthony.downes@fmc.com (for correspondence)

Published online 4 August 2009 in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/prs.10313

Companies often have multiple ‘sister’ plants in different locations, sometimes scattered around the globe. Generally, these companies are striving for similarly low risk among all these sister plants, even though they may have been built at different times, using evolving technology, and often have different capacities. In the pursuit of achieving acceptably low risk at all the chemical plants within a company, Process Safety specialists tend to put each under the PHA ‘microscope’ separately. FMC has several businesses that operate multiple “sister” plants, and has found that there are substantial benefits to be gained by also comparing the hazards at similar plants. © 2009 American Institute of Chemical Engineers Process Saf Prog 29: 64–69, 2010

Keywords: PHA, Qualitative Risk Analysis, Risk Comparison, Corporate Risk Management

We first applied the comparison technique that is the subject of this article to one of our world-wide chemical operations that had several sister plants. Our assumption was that any given high consequence scenario should appear as a common element at all the plants unless there was a fundamental difference between plants. Comparing each of these common scenarios one by one across all similar plants allowed us to ensure each scenario had been recognized, evaluated, and safeguarded in a consistent manner. Some surprising inconsistencies were discovered.

This article briefly describes the general organization of FMC’s Process Safety Risk Profile program, including some recent improvements, then focuses on our scenario comparison methods in sufficient depth for others to apply them.

INTRODUCTION

About 10 years ago, FMC developed and implemented a chemical process hazard analysis application called Process Safety Risk Profile (PSRP), and presented it as a topic to this forum. We will now share our experiences gleaned from the implementation and growth of this tool. This article will provide a little refresher on what a PSRP is, how it can enable comparisons between similar plants, and the experiences and lessons learned, complete with some examples [1] and anecdotes to reinforce key points. Lastly, we will identify the critical success factors of this endeavor, should you be interested in applying this tool and concept to your business.

IDENTIFYING THE HIGH CONSEQUENCE SCENARIOS (SCENARIOS VS DEVIATIONS)

FMC developed Process Safety Risk Profiles (PSRPs) at all its chemical manufacturing locations world-wide using the PSRP methodology presented by FMC to the CCPS, several years ago. However, even for sites that aren’t required by regulations to perform Process Hazards Analyses (PHAs), the PSRP is a useful tool for performing an economical hazard review. The PSRP is simple yet comprehensive. It takes less time to conduct, and allows for a compact report to be generated. The PSRP at a plant can be developed using one of two different methods.

Team-Based PSRP Development (Method 1)

FMC typically develops the scenarios, at sites not governed by PSM, using PSRP methodology, by using a team that functions much like a “What-if” PHA. This

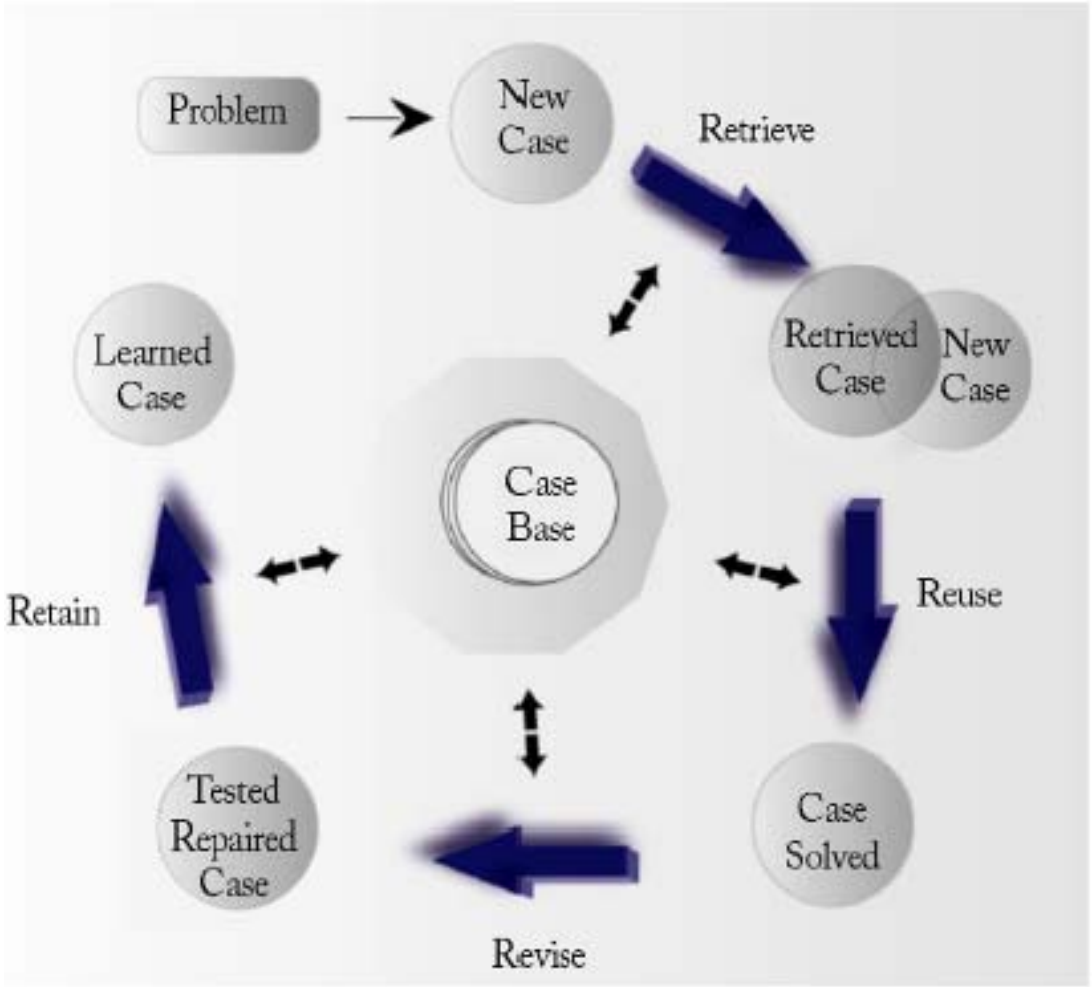
Big Data of HAZOP Analysis Reports

- 100+ pages long per HAZOP report
- 50+ chemical processes in a typical refinery
- 20+ refineries in a oil corporation
- 100 x 50 x 20 = 100,000 pages HAZOP reports in different places
- Every three to five years, HAZOP has to be redone
- How to utilize the knowledge embedded in these reports to improve the HAZOP analysis quality in the future?

Ontology based Case Based Reasoning Technology

Four phases in CBR

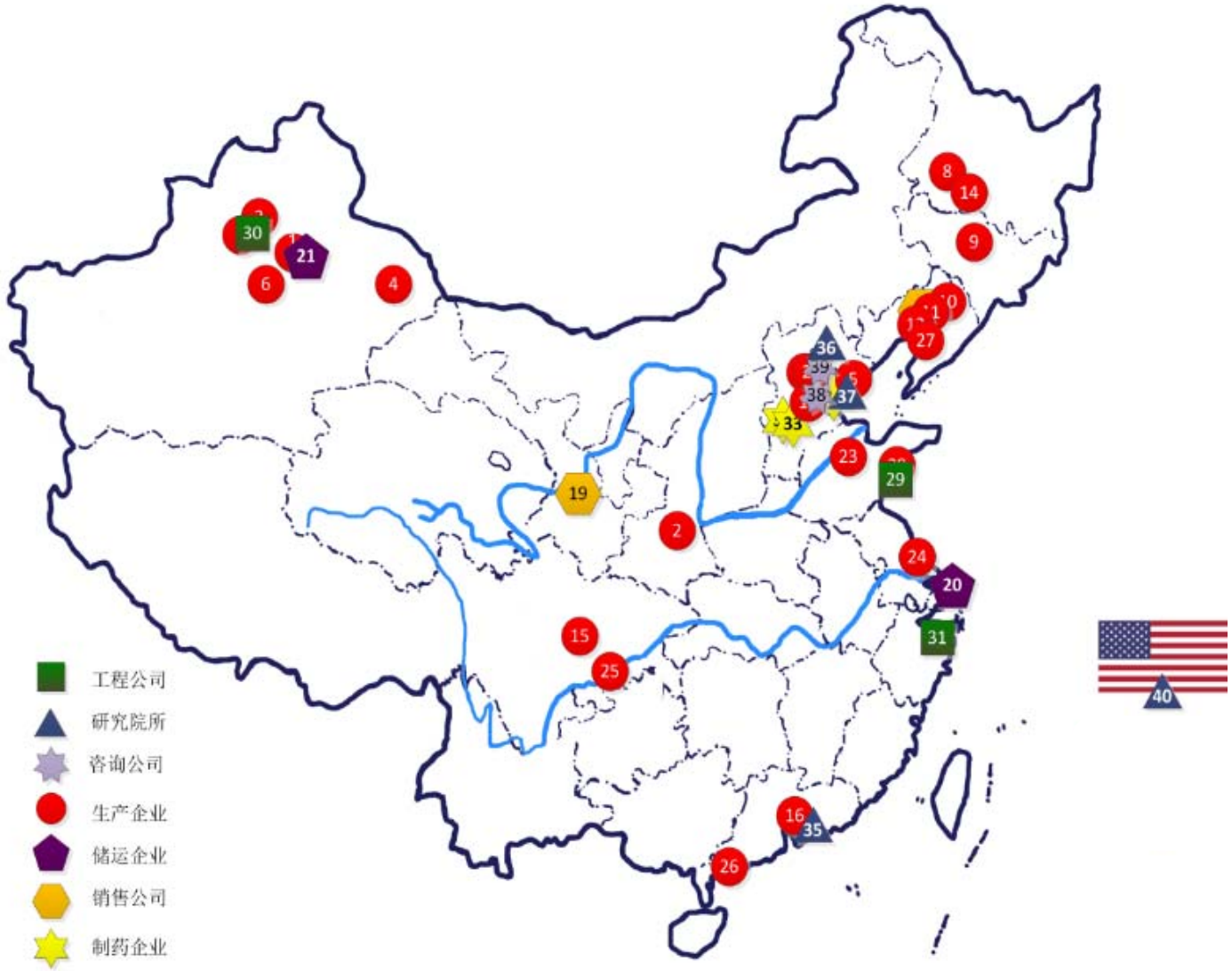
- **Retrieve**
- **Reuse**
- **Revise**
- **Retain**



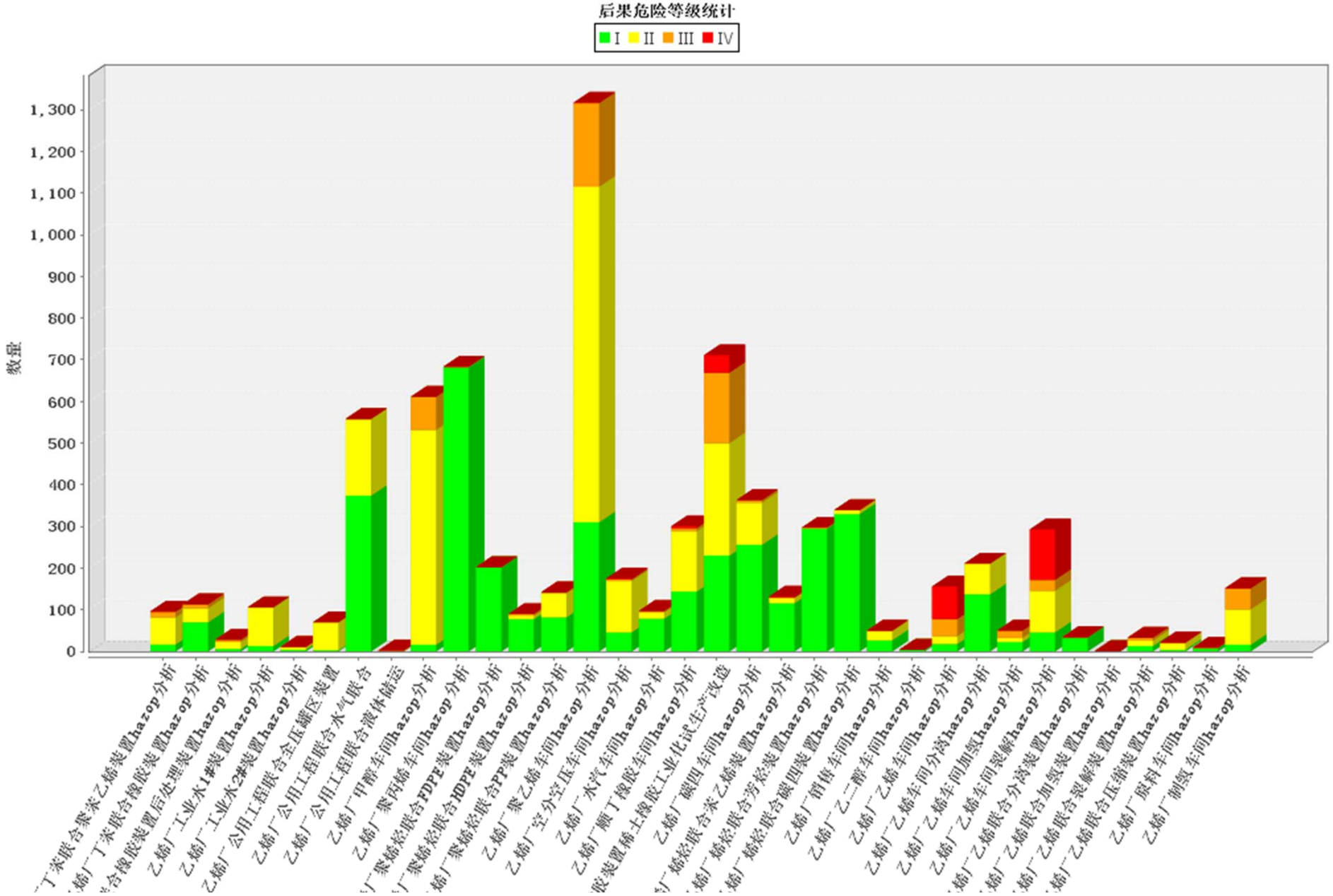
Self learning

Jinsong Zhao, Lin Cui, Lihua Zhao, Tong Qiu, Bingzhen Chen. ***Computers & Chemical Engineering****, 33(1):371-378，2009*

Users of HAZOPSuite



Smart Decision: Where to invest your safety budget?



iTAM: A Risk-Aware System

- 30%~40% accidents occurred during startups
  - Alarm systems are disable or overlooked during startups
  - Jilin petrochemical plant explosion accident
    - Nov. 3rd, 2005
    - 8 death, 60 injuries
    - 10,000 people evacuated

iTAM: A Risk-Aware System

Technician: Deepwater Horizon warning system disabled

By David S. Hilzenrath
Washington Post Staff Writer
Friday, July 23, 2010; 7:33 PM

KENNER, LA. -- Long before an eruption of gas turned the Deepwater Horizon oil rig into a fireball, an alarm system designed to alert the crew and prevent combustible gases from reaching potential sources of ignition had been deliberately disabled, the former chief electronics technician on the rig testified Friday.

THIS STORY

- Tropical storm Bonnie 2010: Oil spill work on hold as system approaches
- » Technician: Deepwater Horizon warning system disabled
- Chinese do what they can with what's on hand

VIDEO

Engineer: Deepwater Horizon alarm 'inhibited'

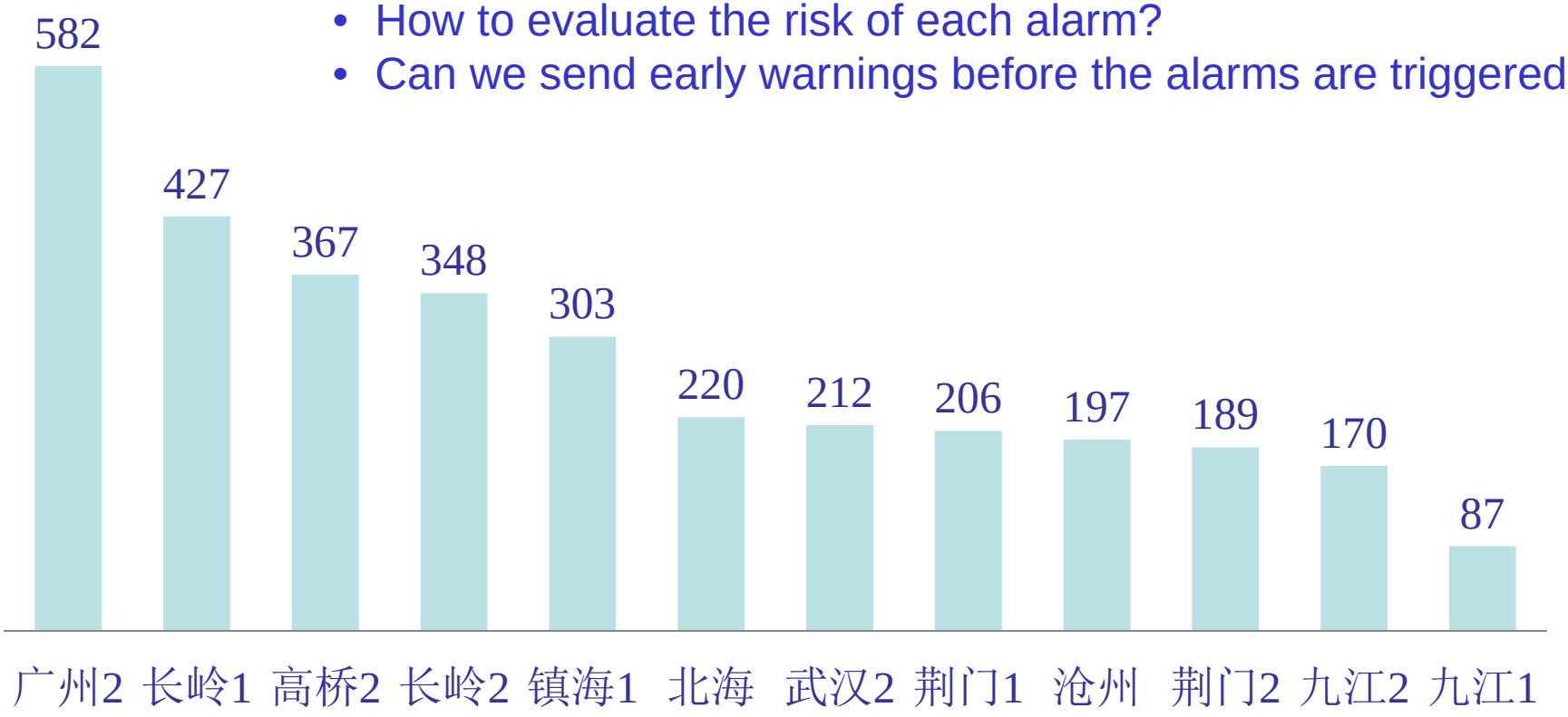
The chief engineer on the Deepwater Horizon tells a government panel that warning systems on the drilling rig were inhibited because the crew did not want to be disturbed in the middle of the night.

» LAUNCH VIDEO PLAYER

Michael Williams, an ex-Marine who survived the April 20 inferno by jumping from the burning rig, told a federal panel probing the disaster that the alarm system was one of an array of critical systems that had been functioning unreliably in the run-up to the blowout.

iTAM: A Risk-Aware System

- Why different FCC units behave so differently?
- Can the operator effectively handle so many alarms?
- How to diagnose the root causes of the alarms?
- How to evaluate the risk of each alarm?
- Can we send early warnings before the alarms are triggered?



Number of Alarms from Different FCC Units in One Day

iTAM: A Risk-Aware System

- Fault diagnosis has been studied for more than half century
  - AI technologies
    - Neural networks, expert systems
  - Statistical models
    - PCA, DPCA, MPCA, KPCA, PLS
- None plug & play technology available in the market place
  - Lack of adaptability
    - not functioning well during startups, grade transitions or after process retrofit
  - Heavily dependent on fault data samples

iTAM: A Risk-Aware System

- Dynamic alarm management
  - Bayesian Estimation
    - Dynamically estimate the alarm thresholds during startups to avoid the alarm flooding issue
- Dynamic fault diagnosis
  - Artificial immune system
    - Adaptation property
      - Only those antibodies that recognize the antigens proliferate
    - Data reduction capability
      - Proved by our experiments and literature (Dudeck, 2012)

Grzegorz Dudeck (2012). IEEE Trans. On Evolutionary Computation. 16(6): 847-860
Dai, Zhao (2011), **Industrial & Engineering Chemistry Research**, 50(8): 4534-4544
Zhao, Shu, Zhu, Dai (2014) , **Industrial & Engineering Chemistry Research (In press)**
Zhu, Shu, Zhao, Yang(2014). **Journal of Loss Prevention in the Process Industry (In press)**

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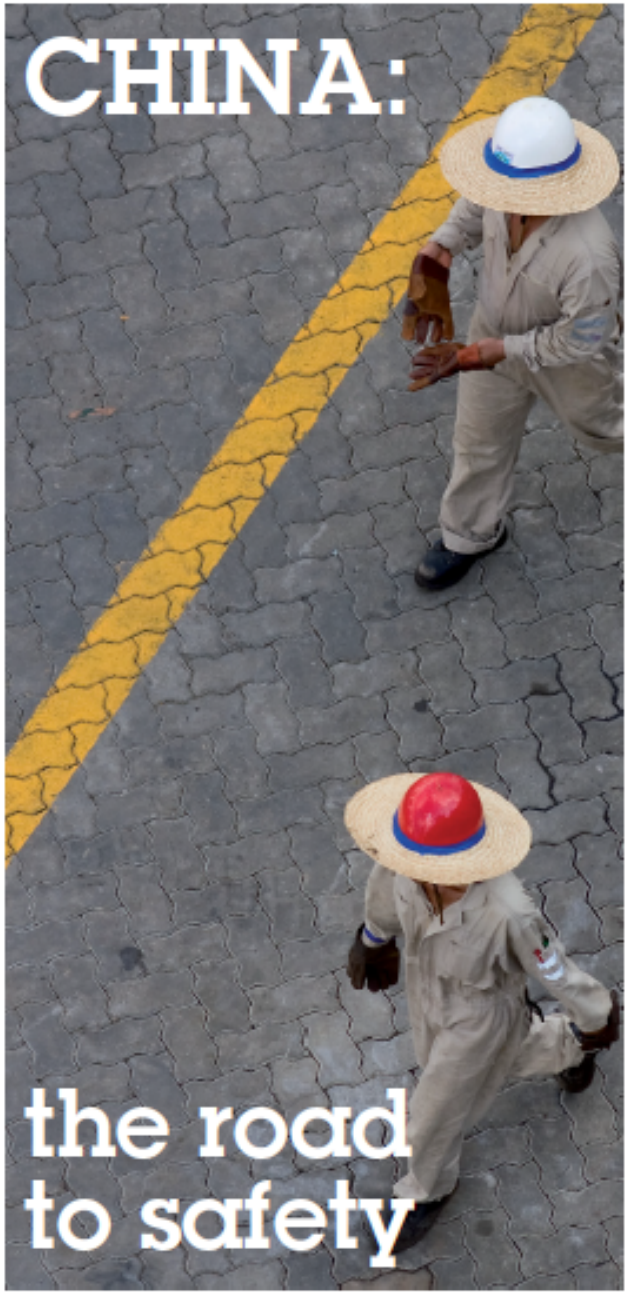
tce Featured Article February, 2012

Process safety management complexity

Process safety knowledge management (PSKM)

Challenge: How to extract knowledge?



In developing countries, process safety often takes a back seat to the all-important production growth. While China is making progress towards reversing that trend, it still has a way to go, says **Jinsong Zhao**

While efforts have been made – by the Chinese government and other stakeholders – to improve process safety, the results aren't yet satisfactory. For example, even though the total number of chemical accidents has decreased continuously for several years, the number of major chemical accidents increased by around 30% in 2010.

To prevent major chemical accidents, we need to improve process safety, instead of personal safety. This article looks at some of the process safety progress in China and suggests ways to help prevent major chemical accidents.

a process safety snapshot

In China, the chemical process industry has become a core feature of its industry in general. By the end of 2008, the country boasted 28,515 petrochemical businesses. And in 2010, the gross industrial output value was US$1,400b – or put another way, around 22% of China's GDP.

However, along with success has come a significant safety risk to human lives, property and environment. Figure 1 shows the number of environmental emergency events reported to the Ministry of Environment Protection (MEP) over several years – it's clear that the number of events is growing rapidly year on year.

Of these events, about 40% were caused by production accidents. So why have production accidents resulted in so many environmental emergencies? The scale of the chemical processes has been tripled or quadrupled over the past 20 years, and it's becoming increasingly difficult to contain the impact of the accidents within the chemical plants, of which more than 70% are located close to rivers, lakes and seas. It's not difficult to understand why chemical process accidents have resulted in such a huge impact to the environment in China.

Recent research (He *et al*) deduced a

Future Research Directions

- With the advance of information technology, the chemical industry is going through a dramatic transition from a "data poor" to a "data rich" paradigm
  - In a big oil corporation, the amount of the data gathered from its facilities reaches the order of Petabyte (1PB=1,000,000 GB)
- How to effectively extract knowledge from the "big data"?
  - Past approaches developed in a "data poor" era don't work well in the new world

Venkat Venkatasubramanian(2009). ***AIChE Journal****, 55(1):2-8*

Acknowledgements

- National Natural Science Foundation of China (NSFC)
- Ministry of Education of China
- Ministry of Science and Technology (MOST)
- UNEP
- China National Petroleum Corporation (CNPC)
- BP
- My colleagues and graduate students

Thank you very much !