

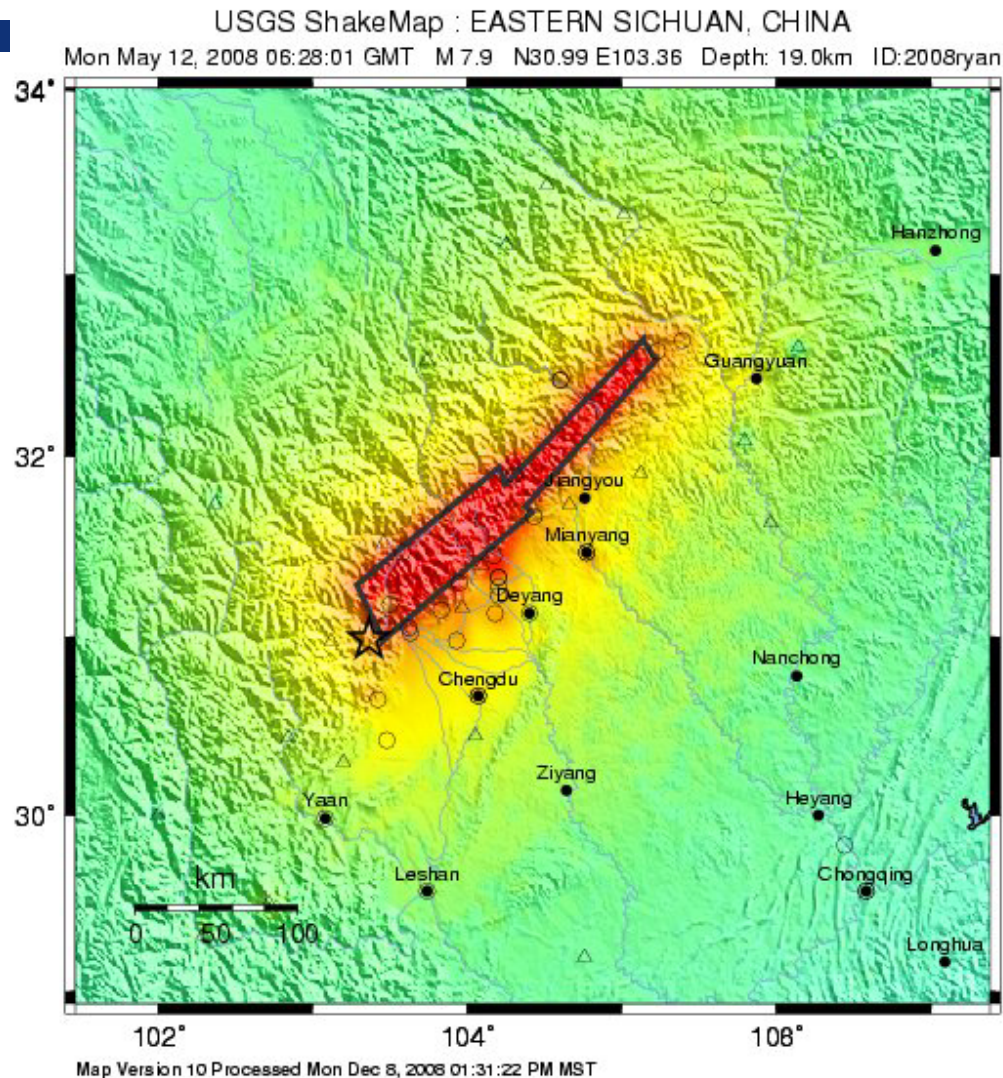
The 12 May 2008 Wenchuan earthquake: Impact on industry

E. Krausmann¹, A. M. Cruz¹, B. Affeltranger²

¹ EC, Joint Research Centre, Institute for the Protection and Security of the Citizen, Major Accident Hazards Bureau, Ispra, Italy

² INERIS, Accident Risks Division, Verneuil-en-Halatte, France

- Main shock: $M_w=7.9$
- Depth 19 km
- Fault rupture > 200 km
- Ground motion duration: 100s
- Max. PGA: 0.96g
- Numerous aftershocks ($M > 6$)
- Vertical PGA > horizontal PGA in some cases



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

- Total area affected 500,000 km²
- Casualties: 70,000 dead, many injured
- Building damage: > 5,000,000 buildings collapsed, 21 million suffered damage (from USGS, 2009)
- Extensive damage to lifelines
- Economic losses ca. 140 billion US\$ (from P. Shi, 2008)
- Near-epicentre intensity XI on CSIS (design intensity VII)

- **Chemical industry in natural-hazard zones:** major accident potential with secondary consequences on the surroundings
→ **NATECH accidents**

NATECH

Natural-hazard triggered **tech**nological accident

Where “technological accident” is understood as

+ Damage to and hazardous-materials release from fixed chemical plants

+ Damage to and release from oil and gas pipelines

- Sichuan Province: many chemical facilities → how did they perform under the earthquake loads?

- Little public information

→ **Natech Field visit: 18 facilities**

in Deyang, Shifang, Mianzhu,
Mianyang, Anxian, Dujiangyan

Collect data on:

- + Damage to buildings & equipment
- + Safety measures
- + Hazardous-materials releases





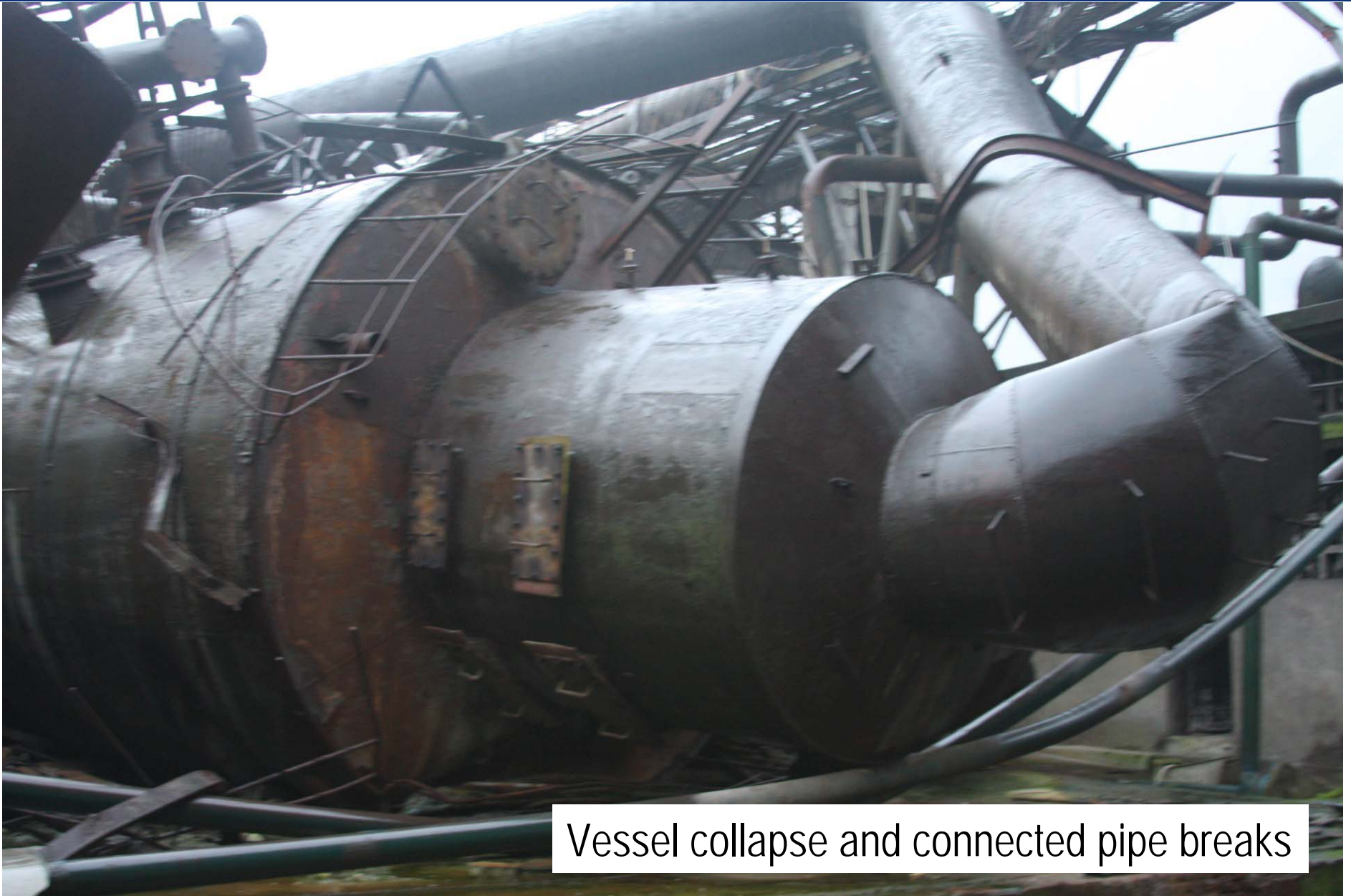
Building and pipe damage



Collapsed dryer



Damage to production building



Vessel collapse and connected pipe breaks



Pipe connection failure



Damage to masonry chimney

- **Structural damage to and collapse** of warehouses, offices and manufacturing buildings was the **main cause of worker death** (> 275 fatalities in 2 heavily damaged plants alone) ➡ problem of concrete structures
- Old facilities built with **no or little seismic design** were more heavily affected
- **Pipe and equipment damage** or breaking caused much of the loss at facilities. This was due to direct earthquake loading, support failure or debris impact.
- **Tanks and vessels** were damaged by debris impact, foundation failure or directly by the earthquake forces, e.g. toppling ➡ problem of no anchoring or restraining (**liquid sloshing?**).
- In some sites we observed **soil liquefaction-induced damage**.

Plant ID	Year built	PGA [%g]	Damage severity
1	?	?	Minor
2	2002	?	Minor
3	1995	20-40	Minor
4	1989	20-40	Moderate
5	1994	40	Moderate
6	1958	60	Collapse
7	1950s	60	Collapse
8	1970s	60	Major
9	?	40	Minor
10	1978 (+ upgrades)	20	Minor
11	? (recent)	20	None
12	1983	20-40	Minor
13	1984	60-80	Major
14	1950s	60-80	Major
15	1999 (built to higher standard)	60	Minor
16	?	20-40	Minor
17	2003	20-40	Moderate
18	1999	40	Minor



- + Active and passive safety barriers also affected by the earthquake
- + Bracing of pipes mostly effective in preventing pipe displacement
- + Anchoring of equipment mostly effective



- Vast number of broken flanges, pipes and vessels ➡
hazmat releases must have occurred
- Ammonia releases in at least 5 facilities ➡ evacuation of
6,000 residents, pollution of a river, damage to crops
- Sulphuric acid spills
- Sulfur burning and explosion
- Phosphorus fires
- Ignition probability high after release of flammable
substance during an earthquake (ca. 76%)

- **Direct losses** due to building and equipment damage: probably around 250 million US\$ in visited facilities alone
- **Indirect costs** due to plant shutdown and business interruption (also from human losses): unknown
- 6 months after earthquake major repair and reconstruction still underway
- Some companies have moved production away from the fault zone

- Natural disasters can have major impact on industry with devastating consequences on man, the environment and/or the economy
- **Wenchuan earthquake damage to industry typical for earthquake-triggered Natechs**
- Release scenarios: toxic dispersion, fires, explosions
- High PGA areas: building damage dominant, lower PGA areas: equipment damage dominant
- Buildings with some seismic design performed better ➡ importance of implementing **seismic building codes**
- **Realistic assessment of earthquake severity** and resultant loading on structure in codes ➡ seismic codes updated



**THANK YOU
FOR YOUR ATTENTION!**

Contact: elisabeth.krausmann@jrc.ec.europa.eu