

Expected fatalities for one wedge of CCS mitigation

Actuarial risk assessment of carbon capture & storage at the global scale in 2050

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Main results

A few hundred fatalities per year should be expected if CCS is used to store 1 Gt C yr⁻¹ in 2050.

The large majority of the fatalities are from mining more coal, next would be shipping casualties.

If storage sites perform at risk levels socially tolerated today in analogue installations, fatalities per year could be less than one.

Analysis

The largest part of the risk is knowable, occupational and tolerated.

CCS benefit is much larger than its cost in terms of fatalities:
Abating 1 Gt C yr⁻¹ would mitigate by a few % the increase in water stress and extreme events, which cost more than 10⁵ lives each year.

Besides energy saving, all mitigation options carry non-zero risk. The largest hydroelectric dam failure caused >26.000 immediate fatalities (China, 1975).

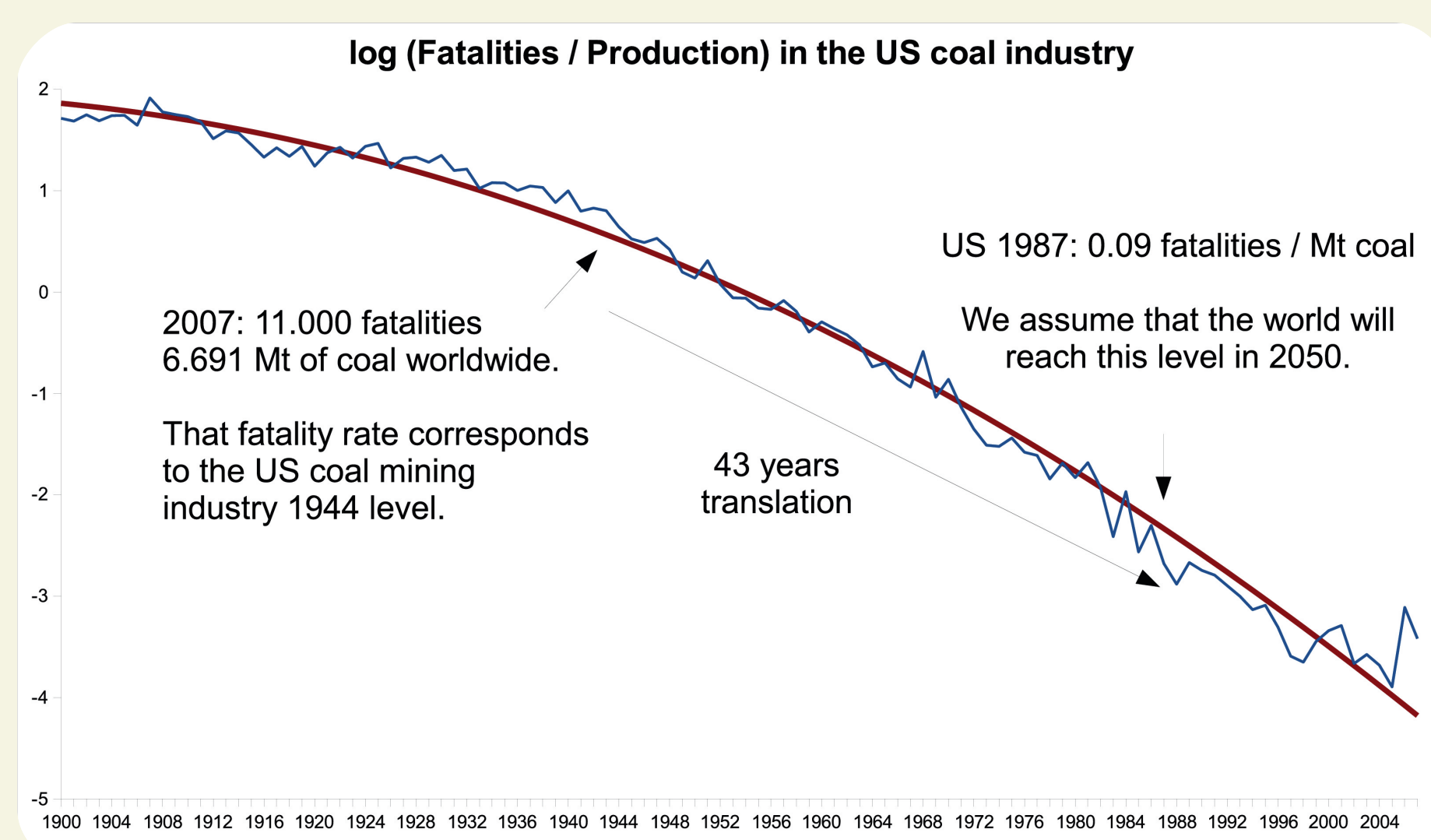
Discussion

Actuarial approaches do not account for the public's view and higher order impacts (Singleton et al. 2009). Based on limited statistics on analogue accidents, expected values are uncorrected for reporting biases and globally extrapolated to 2050.

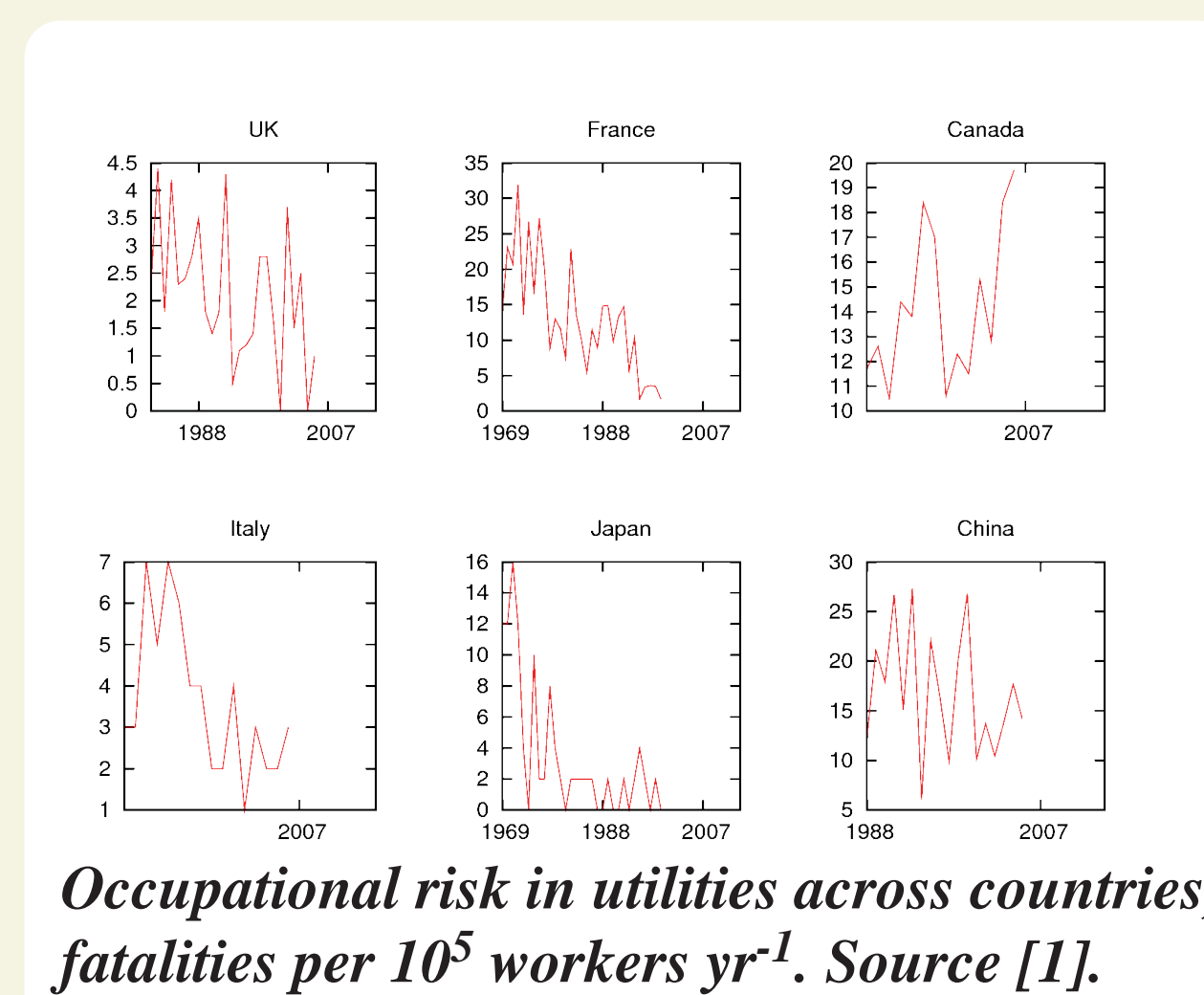
Yet this point of view complements radically most other published engineering or social risk analysis:

Regarding objectively expected fatalities, the risk of leakage is the least important.

Mining 5 Gt of coal: 250 to 500 fatalities



CO₂ capture at 1.500 sites: 1 to 8 fatalities



+5 to +10 workers per site

3 to 14 fatalities per 100.000 workers in utilities (see figure left), 4 to 17 in the chemical industry [2]

Industrial use of CO₂ is 100-115 Mt/yr [3], and there are 12 recorded deaths from CO₂ chemical use 1926-1997 [4], that is 1,7 deaths yr⁻¹ Gt⁻¹ CO₂

1. ILO, 1969-2006
2. Raghavan and Swaminathan, 1996
3. Aresta and Tommasi, 1997; IPCC, 2005
4. Khan and Abbasi, 1999

Shipping 2.000 Gt miles: 23 to 57 fatalities

We assume that 10% of CO₂ is shipped rather than pipelined, as many CO₂ emitters like power plants and heavy industries are located in portuary zones.

The statistical fatality rate in shipping is about:

11,4 fatality Tt⁻¹ mile⁻¹ yr⁻¹ in oil tanking over 1978-2001 [1]

28,6 fatality Tt⁻¹ mile⁻¹ yr⁻¹ in all goods trade over 1989-2004 [2]

1. Intertanko/LMIS/IMO, 2009

2. UNCTAD/IMO, 1989-2004

150.000 km of pipelines: 1 to 15 fatalities

	Natural gas transmission	Hazardous liquids	CO ₂
Period	1986-2008	1986-2008	1990-2008
Fatalities	65	50	0
Network size (1000 km)	522	255	6,2
Fat/Mkm/yr	5,4	8,5	0

Statistics of pipeline fatal incidents in the USA. Source: US DoT PHMSA (2009)

US: 5,4 - 8,5 fat. Mkm⁻¹ yr⁻¹ (see table)

Europe: 11,1 fat. Mkm⁻¹ yr⁻¹ (Oil pipelines, 1971-2006, Concawe, 2008)

The zero fatalities on 0,1178 Mkm yr of CO₂ pipeline network imply a rate below 25,43 fatality Mkm⁻¹ yr⁻¹.

(assuming a Poisson process, 95% confidence level, e^{-0.1178*25.43} = 0.05)

Some societies may tolerate a risk rate as high as 10⁻⁴ fatality km⁻¹ yr⁻¹ [1].

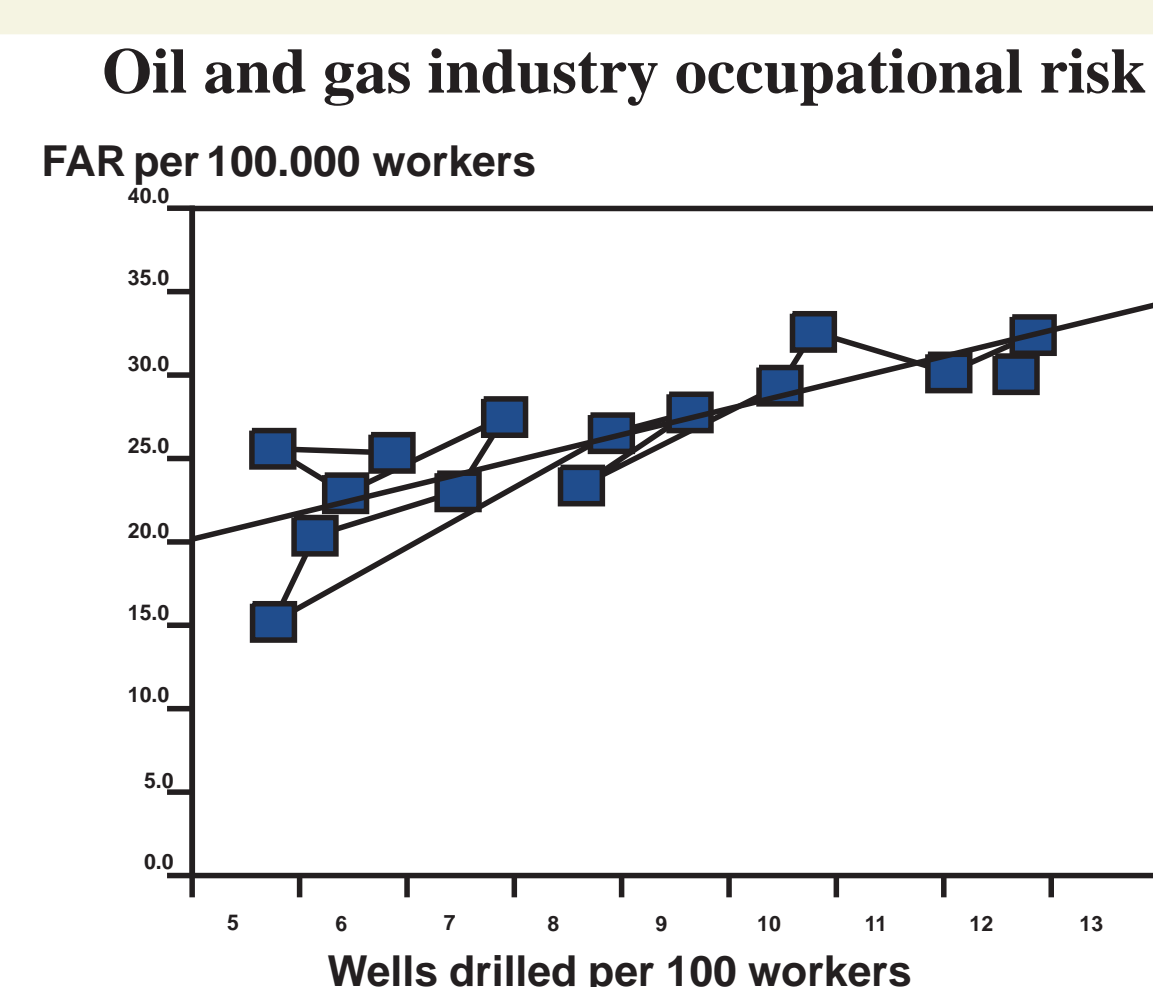
1. Jo and Crowl, 2008

6.000 injection wells: 10 to 23 fatalities

Based on 1993-2007 statistics, we estimated that in the US oil and gas industry, per 100.000 workers:

Fatalities = 13,2 + 147 Wells / Workers

Assuming 10 workers/well, we report the 95% confidence interval.



Storage at 1.500 sites: 0 - 1 fatality

Analogy with steam injection shows low blowout rates and consequences from operational, idle/shut-in and abandoned wells: one fatality 1991-2005 for 4.053 injection wells, no public injuries [1].

The ALARP principle applies: all reasonable measures in the ALARP zone will be taken to reduce the risk until the cost of further reduction is disproportionate with the benefit. Accepted risk levels for analogue projects range from 10⁻⁶ to 10⁻⁴ fatality per year [2].

1. Jordan and Benson, 2008

2. Schjølberg and Øst Dahl, 2008