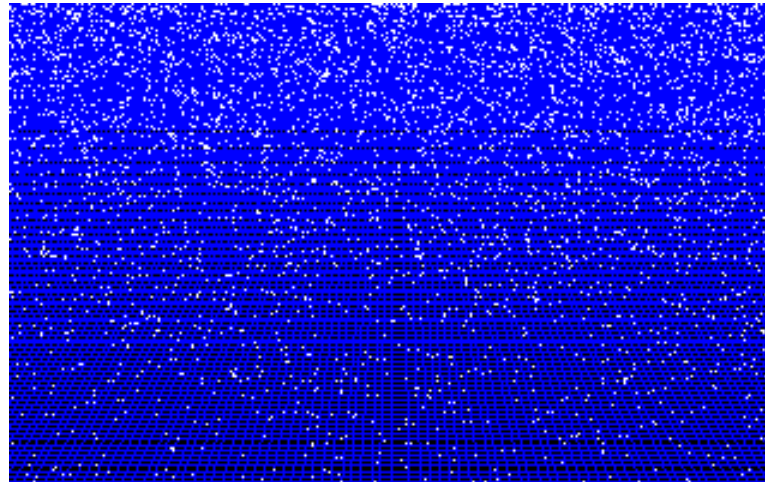


# Energy Science

## *FEW Cursus*



**Jo van den Brand**

**May 11, 2010**

# *Contents*

- **Maatschappelijke discussie**
  - **Economics of nuclear power**
  - **Safety, public opinion, outlook**



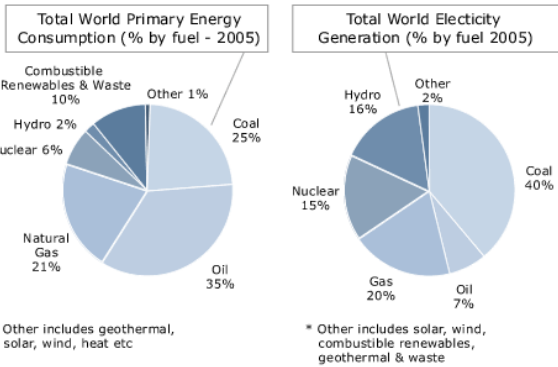


# Mining accidents



## Fatalities and injuries for mining in USA

Year	Average Annual Deaths	Average Annual Injuries
1936-1940	1,546	81,342
1941-1945	1,592	82,825
1946-1950	1,054	63,367
1951-1955	690	38,510
1956-1960	550	28,805
1961-1965	449	23,204
1966-1970	426	22,435
1971-1975	322	33,963
1976-1980	254	41,220
1981-1985	174	24,290
1986-1990	122	27,524
1991-1995	99	24,201
1996-2000	86	17,500
2001-2005	62	12,952
2006-2007	69	11,800



deadliest year in U.S. coal mining history was 1907, with 3,242 deaths

PR China	2482Mt	Russia	233Mt
USA	990Mt	Indonesia	169Mt
India	427Mt	Poland	95Mt
Australia	309Mt	Kazakhstan	92Mt
South Africa	244Mt	Colombia	64Mt

Benxihu (Honkeiko) Colliery (本溪湖煤礦), located at Benxi, Liaoning, China. On April 26, 1942, a gas and coal-dust explosion in the mine killed 1,549, 34% of the miners working that day.





# Coal mining accidents: USA and China

COAL FATALITIES BY STATE  
(CALENDAR YEAR)

STATE	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	TOTAL
ALABAMA	2	3	2	4	2	1	1	14		2	1	1	2	35
ALASKA														0
ARIZONA			1									1	1	3
ARKANSAS								1						1
CALIFORNIA														0
COLORADO		1							1	1	2		1	6
CONNECTICUT														0
DELAWARE														0
FLORIDA														0
GEORGIA														0
HAWAII														0
IDAHO														0
ILLINOIS	1					3		1	2	1		1	2	11
INDIANA	1	3			1	1	1	2	1	1		1		12
IOWA														0
KANSAS														0
KENTUCKY	5	2	16	8	6	9	9	5	13	9	12	5	12	111
LOUISIANA														0
MAINE														0
MARYLAND		2	1	1						1				5
MASSACHUSETTS														0
MICHIGAN														0
MINNESOTA														0
MISSISSIPPI														0
MISSOURI														0
MONTANA			1											1
NEBRASKA														0
NEVADA														0
NEW HAMPSHIRE														0
NEW JERSEY														0
NEW MEXICO			1					1						2
NEW YORK														0
NORTH CAROLINA														0
NORTH DAKOTA												1		1
OHIO				1				2		2	1			6
OKLAHOMA		1		1										2
OREGON														0
PENN (ANTH)	1		1	1	1		3	1	2	2			1	13
PENN (BITUM)	4	1		3		1					1	4	2	16
PUERTO RICO														0
RHODE ISLAND														0
SOUTH CAROLINA														0
SOUTH DAKOTA														0
TENNESSEE					1							1		2
TEXAS	1	1						1		1				4
UTAH		10	1		2		1		4			3	2	24
VERMONT														0
VIRGINIA	2		1		3	3	4	2	4	5	5	5	2	36
WASHINGTON														0
WEST VIRGINIA	8	9	23	3	12	10	6	13	9	9	7	7	12	128
WISCONSIN														0
WYOMING	1			1		2	1		2	1			1	9
TOTAL	26	34	47	23	28	30	27	42	38	35	29	30	38	427

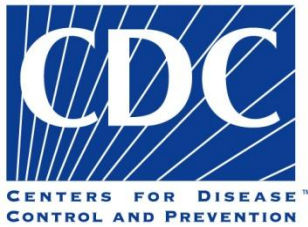
## 中国劳工通讯 China Labour Bulletin

Year	Total number of coal mine accidents	Total number of deaths
2000	2,863	5,798
2001	3,082	5,670
2002	4,344	6,995
2003	4,143	6,434
2004	3,639	6,027
2005	3,341	5,986

In 2004: China official statistics: 6,027 deaths  
USA reported 28 deaths in the same year

Coal production in China is twice that of the USA, while the number of coal miners is around 50 times that of the USA

Thus, deaths in coal mines in China are  
4 times as common per worker  
108 times as common per unit output  
as in the USA.

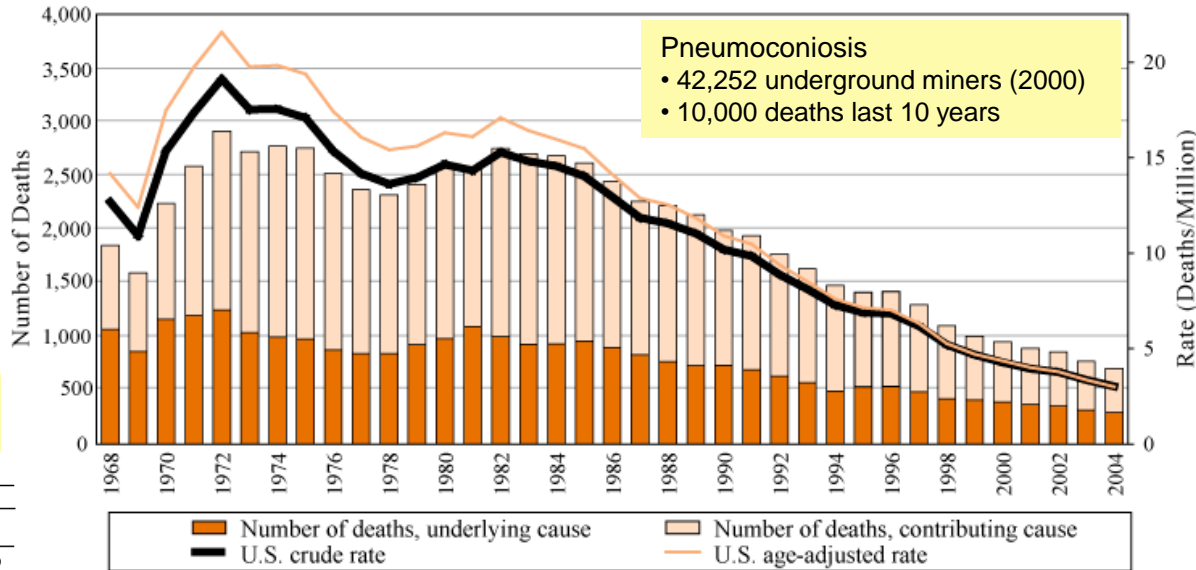


# Work-Related Lung Disease (WoRLD) Surveillance System

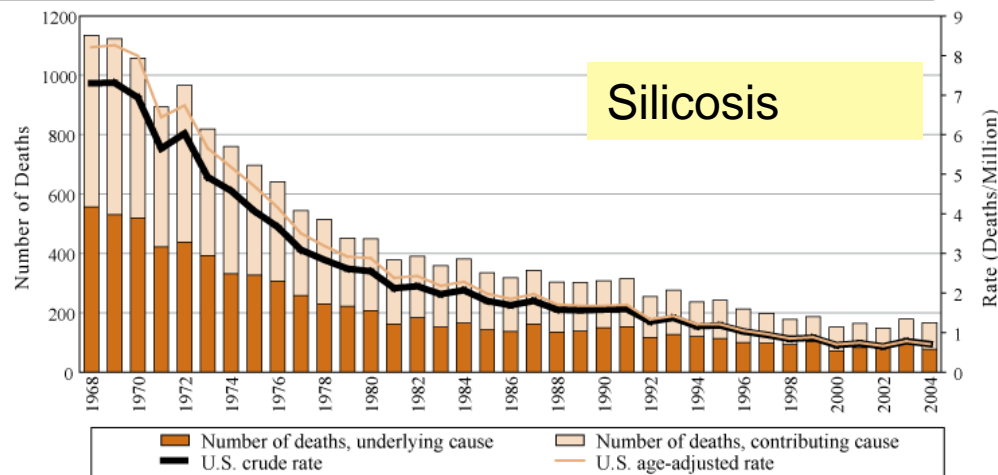
<http://www.cdc.gov/>

US residents, age 15 and over, 1968 - 2004

Federal Black Lung Program:



Year	Social Security Administration (SSA)		Department of Labor (DOL)		All	
	Beneficiaries	Amount (dollars)	Beneficiaries	Amount (dollars)	Beneficiaries	Amount (dollars)
1980	399,477	1,032,000,000	139,073	813,205,000	538,550	1,845,205,000
1981	376,505	1,081,300,000	163,401	805,627,000	539,906	1,886,927,000
1982	354,569	1,076,000,000	173,972	784,085,000	528,541	1,860,085,000
1983	333,358	1,055,800,000	166,043	858,854,000	499,401	1,914,654,000
1984	313,822	1,038,000,000	163,166	873,932,000	476,988	1,911,932,000
1985	294,846	1,025,000,000	160,441	905,517,000	455,287	1,930,517,000
1986	275,783	971,000,000	156,892	629,075,000	432,675	1,600,075,000
1987	258,988	940,000,000	153,769	655,290,000	412,757	1,595,290,000
1988	241,626	904,000,000	150,123	656,689,000	391,749	1,560,689,000
1989	225,764	882,000,000	145,289	650,123,000	371,053	1,532,123,000
1990	210,678	863,400,000	139,854	626,521,000	350,532	1,489,921,000
1991	196,419	844,400,000	134,205	942,428,000	330,624	1,786,828,000
1992	182,396	822,500,000	128,761	973,636,000	311,157	1,796,136,000
1993	168,365	794,300,000	123,213	984,666,000	291,578	1,778,966,000
1994	155,122	751,900,000	117,569	994,655,000	272,691	1,746,555,000
1995	143,011	696,700,000	111,769	995,722,000	254,780	1,692,422,000
1996	131,143	654,600,000	105,923	992,128,000	237,066	1,646,728,000
1997	119,233	614,888,000	100,352	1,004,672,000	219,585	1,619,560,000
1998	109,271	576,389,000	94,488	999,822,000	203,759	1,576,211,000
1999	98,977	541,200,000	88,716	1,005,246,000	187,693	1,546,446,000
2000	91,596	522,147,000	82,910	422,656,000	174,506	944,803,000
2001	79,518	487,420,000	70,530	396,928,000	150,048	884,348,000
2002	73,593	453,862,000	65,747	384,234,000	139,340	838,096,000
2003	65,638	416,971,000	61,162	370,389,000	126,800	787,360,000
2004	58,598	379,829,000	56,719	346,864,000	115,317	726,693,000
2005	51,972	345,476,000	52,531	329,863,000	104,503	675,339,000



Federal Black Lung Program:

- 4000 new cases of black lung every year in the USA (4% of workers annually)
- 10 000 new cases every year reported in China (0.2% of workers).

# ***Black lung disease in China***

## **Black lung disease claims 140,000 lives in China**

The black lung disease has claimed 140,000 lives in the Chinese mainland since the occupational disease report system was founded in 1950s, revealed vice Health Minister Jiang Zuojun at a televised conference for prevention and treatment of occupational diseases held in Beijing March 17, 2005.

A total of 580,000 black lung cases have been reported in China so far, and there are 440,000 people suffering from black lung disease at present. The number of black lung case is increasing roughly **10,000 annually**. In addition, China reports nearly 30,000 poison cases relating to occupation and use of pesticide in production. About 1,500 people die from poison.

Jiang acknowledged the occupational disease has grown so rampant in some areas that "black lung village" and "poison village" have emerged. Many laborers have become impoverished due to the disease. Moreover inappropriate settlement of disputes over occupational diseases has led to incidents that influence social harmony and stability, including blockade of road, strike, demonstration, and group appeal to higher authority for help. Occupational disease has become a grave problem that harms public health and social stability.

To strengthen prevention and treatment of occupational diseases, the Chinese government has adopted occupational health review system for construction projects; imposed strict approval for aptitude of service departments for occupational health; rectified diagnosis and appraisal for occupational disease.

The Health Ministry has decided to launch a publicity week with feature "Safeguard laborer's health by prevention of occupational diseases", in which consultation regarding prevention and treatment of occupational disease will be offered to laborers free of charge.

*By People's Daily Online*



# Radiation exposure of coal

*Americans living near coal-fired power plants are exposed to higher radiation doses than those living near nuclear power plants that meet government regulations*

*The population effective dose equivalent from coal plants is 100 times that from nuclear plants*

The extremely high standards of the nuclear industry result in a regimen of care and containment



## **NCRP Report No. 95, *Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources***

NCRP Report No. 95 is another of the assessment series of reports. This Report recognizes that there are many consumer products available which emit ionizing radiation, in some cases as an essential element of the proper performance of the device and in other cases as incidental or extraneous to the purpose for which the product was designed. The Report evaluates the exposures from all of these types of products. Treated are electronic products such as television receivers and airport luggage inspection systems; radioactive materials such as radioluminous products, building materials, glass and ceramics; and miscellaneous exposure sources such as high voltage vacuum electronic units. Also covered are exposures resulting from disposal of radioactive surplus items and transport of radioactive materials. Recommendations for dose reduction are also provided in the Report

Science 8 December 1978: Vol. 202. no. 4372, pp. 1045 – 1050 DOI: 10.1126/science.202.4372.1045

### **Articles**

#### **Radiological Impact of Airborne Effluents of Coal and Nuclear Plants**

**J. P. McBride**<sup>1</sup>, **R. E. Moore**<sup>2</sup>, **J. P. Witherspoon**<sup>2</sup>, and **R. E. Blanco**<sup>3 1</sup> Research staff member of the Chemical Technology Division, Oak Ridge, Tennessee 37830

<sup>2</sup> Research staff members of the Health and Safety Research Division, Oak Ridge, Tennessee 37830

<sup>3</sup> Manager of Radioactive Waste Management Research and Development Programs at Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830

Radiation doses from airborne effluents of model coal-fired and nuclear power plants (1000 megawatts electric) are compared. Assuming a 1 percent ash release to the atmosphere (Environmental Protection Agency regulation) and 1 part per million of uranium and 2 parts per million of thorium in the coal (approximately the U.S. average), population doses from the coal plant are typically higher than those from pressurized-water or boiling-water reactors that meet government regulations. Higher radionuclide contents and ash releases are common and would result in increased doses from the coal plant. The study does not assess the impact of non-radiological pollutants or the total radiological impacts of a coal versus a nuclear economy.

*The amount of uranium-235 alone dispersed by coal combustion is the equivalent of dozens of nuclear reactor fuel loadings*

*The energy content of nuclear fuel released in coal combustion is greater than that of the coal consumed*

# *Unclean Fuels Kill 1.5 Million People Per Year - UN*

GENEVA - Half the world's population burns wood, coal, dung and other solid fuels to cook food and heat their homes, exposing them to dangerous smoke that kills 1.5 million people a year, the UN health agency said on Thursday.

The World Health Organisation (WHO) said women and children in Africa and Asia were especially vulnerable to indoor air pollution from open fires and poorly ventilated stoves.

Children make up 800,000 of the 1.5 million people who die each year from polluting household fuels, women account for 500,000 deaths and the remaining 200,000 are men.

"Day in day out, and for hours at a time, women and their small children breathe in amounts of smoke equivalent to consuming two packs of cigarettes per day," the WHO said.

Yet in a report entitled "Fuel For Life: Household Energy and Health," the Geneva-based agency said it could cost as little as US\$6 per family to install better-insulated and fuel efficient stoves in developing countries.

"Making cleaner fuels and improved stoves available to millions of poor people in developing countries will reduce child mortality and improve women's health," WHO Director General Lee Jong-wook said.

Inhaling indoor smoke doubles a child's risk of pneumonia and makes adults three times as likely to suffer chronic pulmonary disease than those who cook with electricity, gas and other clean-burning fuels, it said.

Halving the 3 billion people worldwide cooking with solid fuels by 2015 would cost between US\$13 billion to US\$43 billion a year depending on the new energy source used, WHO said. Using liquefied petroleum gas would be cheaper than ethanol.

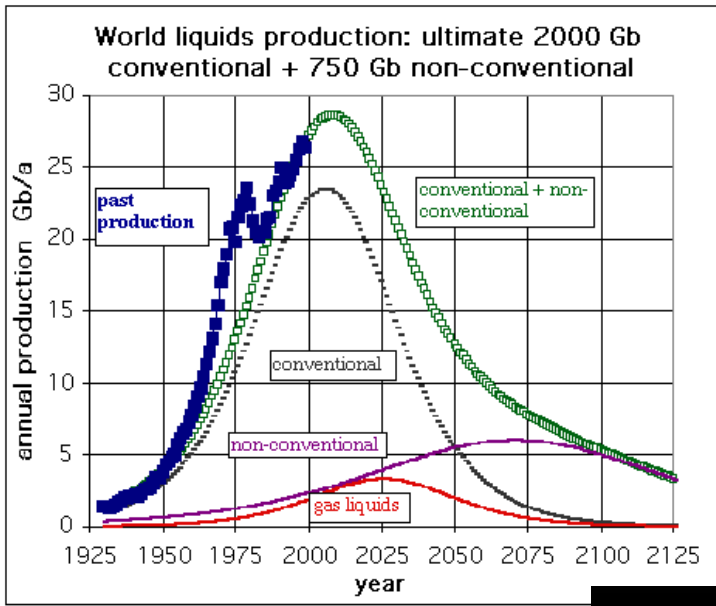
But it would save up to US\$91 billion a year over 10 years due to health care savings, less illness, fewer deaths, and higher productivity due to less time-intensive fuel collection and cooking.

"With more time available, children would do better at school, while their mothers could engage in child care, agriculture or other income-generating activities," it said.

Making better-ventilated stoves available to half of those currently using inefficient cookers could save US\$34 billion in fuel expenditure each year, it said.



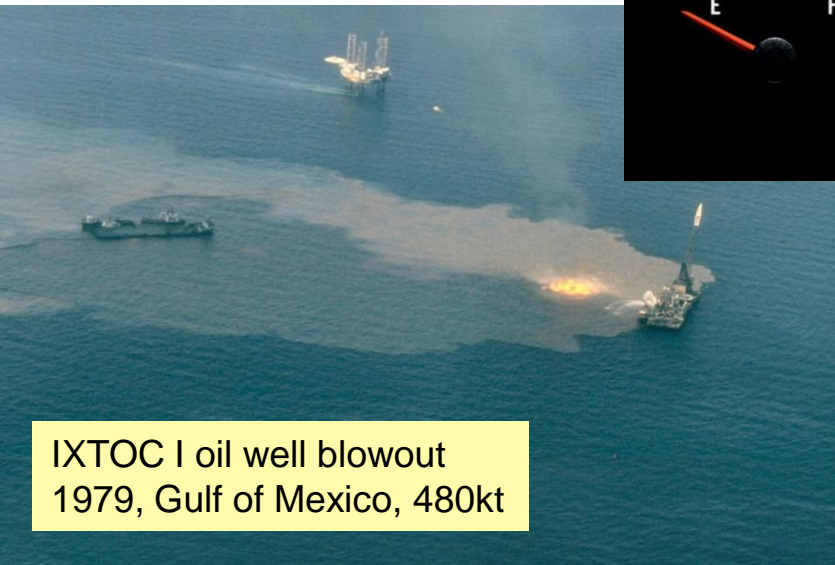
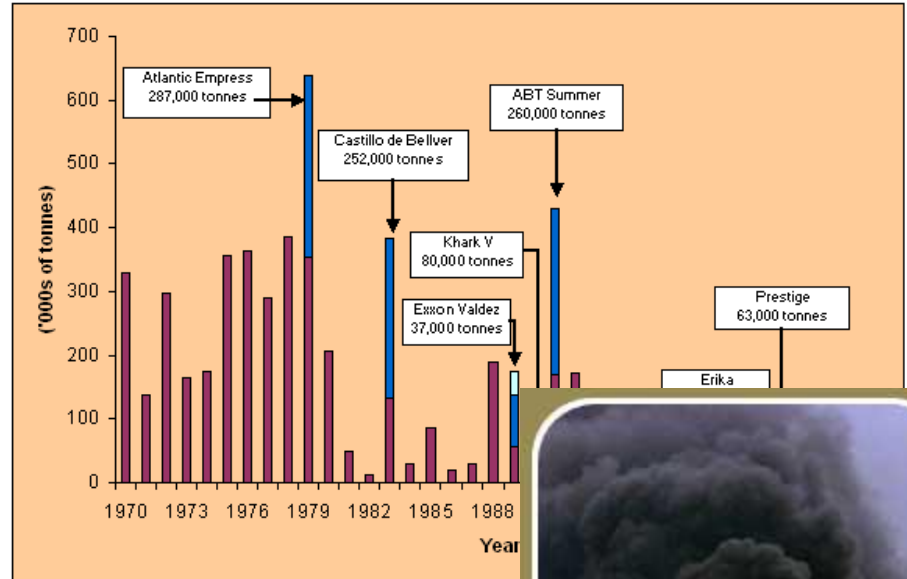
# THE HUBBERT CURVE



# Oil spills



THE INTERNATIONAL TANKER OWNERS POLLUTION FEDERATION LIMITED



IXTOC I oil well blowout  
1979, Gulf of Mexico, 480kt



Gulf war oil spill,  
1991, 0.8 - 1.5Mt



# Oil: pipeline ruptures, platform accidents



## Nigeria

1998: At Jesse, Nigeria in the Niger Delta in Nigeria, a petroleum pipeline exploded killing about 1200 villagers, some of whom were scavenging gasoline. The worst of several similar incidents in this country

2000: Another pipeline explosion near the town of Jesse killed about 250 villagers

2000: At least 100 villagers died when a ruptured pipeline exploded in Warri

2000: A leaking pipeline caught fire near the fishing village of Ebute near Lagos, killing at least 60 people

2003: A pipeline punctured by thieves exploded and killed 125 villagers near Umuahia, Abia State

2004: A pipeline punctured by thieves exploded and killed dozens of people in Lagos State

2006: An oil pipeline punctured by thieves exploded and killed 150 people at the Atlas Creek Island in Lagos State.

2006: A vandalized oil pipeline exploded in Lagos. Up to 500 people may have been killed.

2008: 2008 Ijegan pipeline explosion

## Russia

1989: Sparks from two passing trains detonated gas leaking from an LPG pipeline near Ufa. Up to 645 people were reported killed



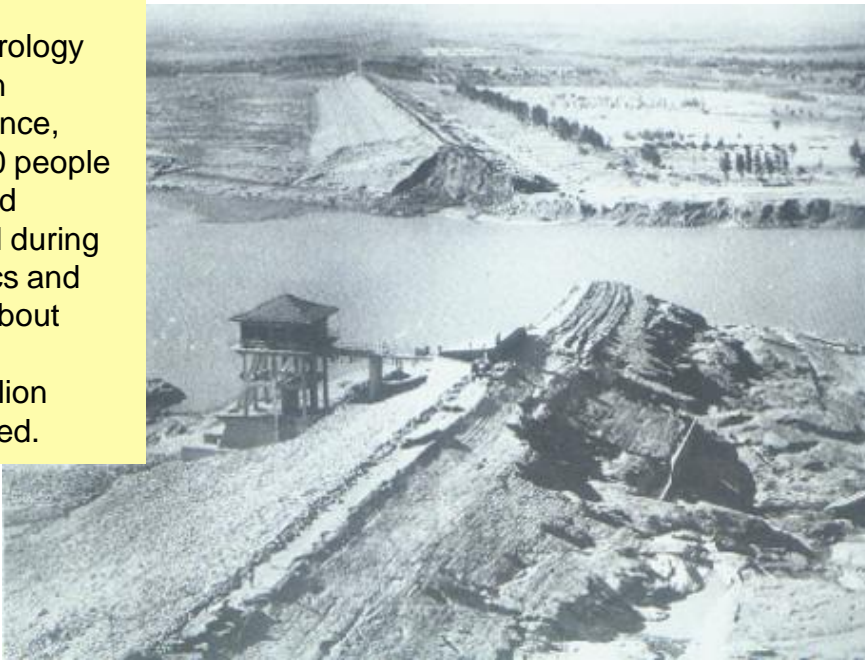
**Piper Alpha** was a North Sea oil production platform operated by Occidental Petroleum (Caledonia) Ltd. The platform began production in 1976, first as an oil platform and then later converted to gas production. An explosion and resulting fire destroyed it on July 6, 1988, killing 167 men. Total insured loss was about US\$ 3.4 billion.



# Dam disasters

## Banjiao dam failure – 1975

According to the Hydrology Department of Henan Province, in the province, approximately 86,000 people died from flooding and another 145,000 died during subsequent epidemics and famine. In addition, about 5,960,000 buildings collapsed, and 11 million residents were affected.



## Val di Stava dam disaster – 1985

268 deaths

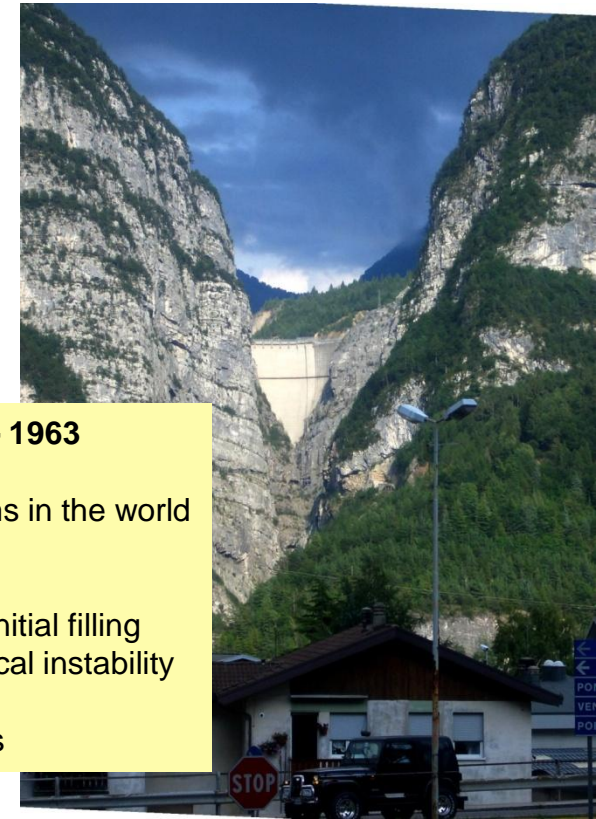


## Vajont dam disaster – 1963

One of the highest dams in the world measuring 262 metres

Its 1963 failure during initial filling was caused by geological instability

Total of 1910 casualties



# *International Nuclear Event Scale*



International Atomic Energy Agency



Level 7: Major accident	Chernobyl	Large off-site impact
Level 6: Serious accident	Mayak	Significant off-site release
Level 5: Accident with wider consequences	Windscale, Three mile island	Severe reactor damage, limited off-site release
Level 4: Accident with local consequences	Sellafield, Saint-Laurent, Tokaimura	Public exposure (near limits), fatal exposure
Level 3: Serious incident	Thorp Sellafield, Paks	Public exposure (below limits), near accident
Level 2: Incident	Asco, Forsmark	No off-site impact, overexposure of worker
Level 1: Anomaly	Tricastin	Anomaly (water leak, contamination)

# *First nuclear accidents*

## **Harry K. Daghlian, Jr., (1921 – September 15, 1945)**

Physicist of Armenian descent with the Manhattan Project who accidentally irradiated himself on August 21, 1945 during a critical mass experiment at the remote Omega Site facility at Los Alamos National Laboratory in New Mexico, resulting in his death 21 days later.

Daghlian was irradiated as a result of a criticality accident that occurred when he accidentally dropped a small tungsten carbide brick onto a 6.2 kg delta phase plutonium bomb core.

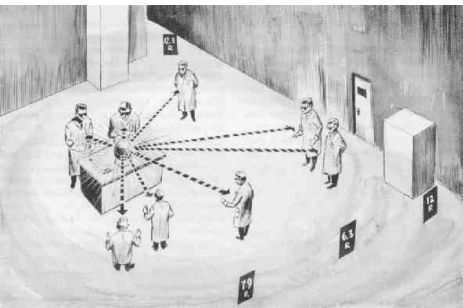
This core was later nicknamed the "Demon core"



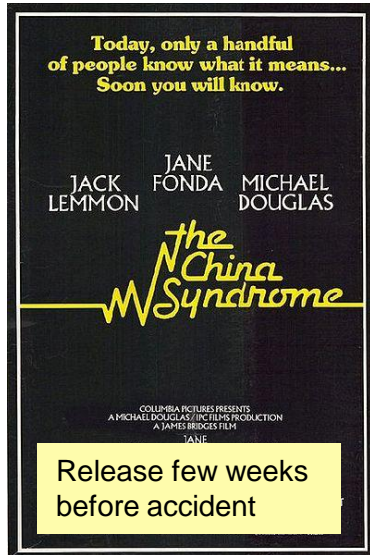
## **Louis Alexander Slotin (December 1, 1910 – May 30, 1946)**

Canadian physicist and chemist who took part in the Manhattan Project. Performed experiments with uranium and plutonium cores to determine their critical mass values. After World War II, Slotin continued his research at Los Alamos National Laboratory.

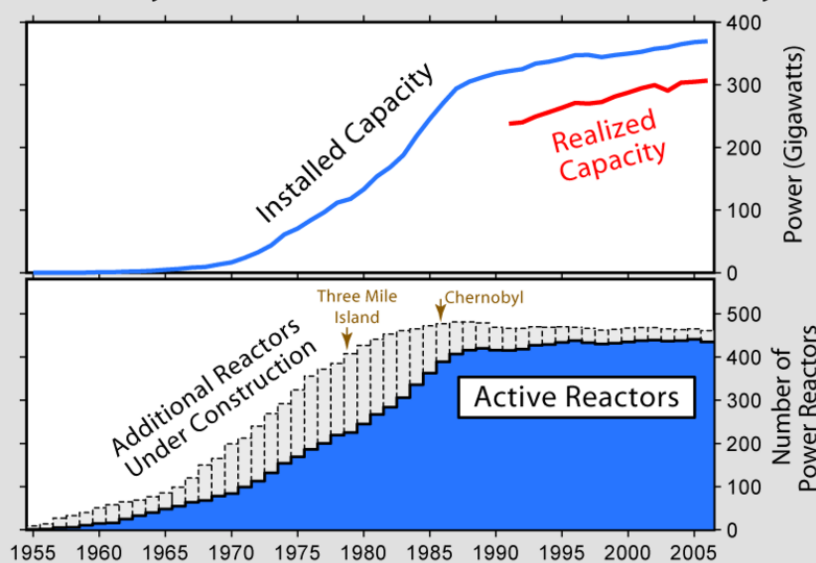
On May 21, 1946, Slotin accidentally began a fission reaction, which released a burst of hard radiation. He was rushed to hospital, and died nine days later.



# Three Mile Island – TMI-2



## History of the Global Nuclear Power Industry



### TMI-2: PWR (Babcock & Wilcox)

March 28, 1979. Biggest nuclear accident in USA. Pump of secondary non-nuclear cooling fails. Turbine and reactor are shutdown (normal procedure).

Temperature and pressure in reactor rise (normal). Relief valve of pressurizer (PORV) opens.

PORV should close, but fails to do so (not noticed by operators). Pressure keeps dropping, cooling water pours out of PORV. Reactor core overheats.

Backup system failed since after tests prior to accident people forgot to open valves (human error). Half of the core melted. All contained. Radioactive noble gases (~43 kCi krypton) were vented (<20 Ci of I-131).

Average dose to people within ten miles was 8 mrem. Nobody received more than 100 mrem (power plant workers norm: < 5 rem per year. Estimate of additional cancers <~ 1.

# *Mayak – Russian nuclear fuel reprocessing plant*

## **Mayak plant**

Built in 1945 – 48 in total secrecy for Soviets Union's nuclear weapon program. Five nuclear reactors were built.

On 29 September 1957, when the failure of the cooling system for a tank storing tens of thousands of tons of dissolved nuclear waste resulted in a non-nuclear explosion having a force estimated at about 75 tons of TNT (310 gigajoules), which released some 20 MCi (740 peta-becquerels) of radioactivity.

At least 200 people died of radiation sickness, 10,000 people were evacuated from their homes, and 470,000 people were exposed to radiation.




# *Nuclear power – October 2008*

Reactor type	In operation		Under construction	
	Number	net capacity MWe	Number	net capacity MWe
PWR	265	243,295	27	24,195
BWR	94	85,287	3	3,925
AGR, GGR	18	9,034	-	-
CANDU/D <sub>2</sub> O-PWR	44	22,390	4	1,298
RBMK	16	11,404	1	925
SNR	2	690	2	1,220
<b>total</b>	<b>439</b>	<b>372,100</b>	<b>34</b>	<b>31,563</b>





# Energy reserves – 2006



european nuclear society  
largest nuclear society for science and industry

- Natural gas 235 billion t coal equivalent
- Mineral oil/shales/liquid gas 232 billion t coal equivalent
- Natural uranium 27 billion t coal equivalent
- Coal (all forms) 726 billion t coal equivalent.

The world total annual energy consumptions amount to 14 billion coal equivalent.

# *Nuclear installations in The Netherlands*

- ▲ research reactor
- power reactor
- power reactor, out of service
- ≡ radwaste storage
- ⊞ radionuclide production (for medical purposes)
- ⌢ enrichment facility
- accelerator facility (research)

