

Chernobyl

The accident scenario and its
global impact

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Chernobyl reactor 4

- graphite moderated light water reactor (RBMK) with an output of 1000 MWe
- pressure tubes boiling water reactor with direct steam feed to the turbines
- positive void coefficient at low power: emergency cooling pumps required in case of a power failure
- control bars have voids

The accident

- planned test
- Friday 25 April
- Saturday 26 April
- the explosion
- main causes

The test

- in case of a power failure, emergency generators start after a few seconds
- the test was to check if the inertia of the turbines provides enough power to keep the cooling pumps operational during the time required to start the emergency generators
- this required the emergency cooling system to be disconnected

Friday April 25

- 01.00 a.m.: the operators decrease the power of the reactor
- 02.00 p.m.: the reactor runs at half power
- 11.00 p.m.: decision to start the test. Due to an error, the power is much lower than normal. The operators try to increase the power by lifting many more control bars than allowed (only 6-8 remain, rather than an absolute minimum of 30 out of 211).

Saturday April 26 1/2

- 01.22 a.m.: start of the test. The reactor operates in non-authorized conditions. The operators switch off the safety mechanism that should stop the reactor in case of loss of steam supply to the turbine
- 01.23.04 a.m.: turbines shut down, cooling pumps stop. The steam content in the tubes increases. The reactor power increases rather than decreases due to the positive void coefficient

Saturday April 26 2/2

- 01.23.40 a.m.: attempt to manually stop the reactor by releasing the control bars. The control bars take about 20 s to reach the core, and their design is such that reactivity increases during the first seconds (voids). Fuel elements start breaking apart.
- Power in fuel increases from 200 MW to 300.000 MW in seconds

The explosion

- 01.23.47 a.m.: shocks felt and explosions heard: steam explosions destroy the reactor core and blow the roof off the reactor building. Fires start all over the place. The worst civil nuclear accident just occurred.
- 01.28 a.m.: the first fireman arrive
- 02.30 a.m.: the largest fires are under control
- 05.00 a.m.: the graphite fire starts...

Main causes

- unsafe and unstable reactor design
- suitable for Pu production:
restricted safety mechanisms
- political and military context in the
former Soviet Union
- no safety culture
- chronic lack of training and
knowledge by operators
- accidents officially unthinkable and
secret

Health (radiation induced)

Reducing human suffering to a number of deaths is much too restrictive, but that number is on everyone's mind

- number of casualties
 - certainly due to the accident among people who received high radiation doses
 - highly probable among people initially suffering from radiation sickness
 - estimated among rescue workers and 'liquidators'
 - estimated among the general population
- other effects

Casualties: 'certain'

- 2 due to explosion
- in total 134 people suffered from radiation sickness
- high radiation doses: 28 within 4 months, certain;
- 19 between 1987 and 2004: highly probable (had radiation sickness)
- thyroid cancer among children: 10 (out of > 4000)
- Total: 59

Question

- 134 people suffer from acute radiation sickness
- 28 die shortly afterwards
- remain: 106 people, of whom only 19 die over 15 y: normal death rates

How come ?

Rescue workers, liquidators

- number between 200.000 and 600.000
- about 1000 receive doses of a few hundred mSv
- average dose around 100 mSv
- > 150 mSv: 21 cases of leukaemia: 2 x normal occurrence
- cancer increase = most probably screening effect

Estimates

- Based on best knowledge: 2000 radiation induced cancers expected over life-time
- *Question: In the model used, which normal life expectancy was assumed for the workers? The current numbers in Ukraine or Belarus are now as low as 60 - 65 y for adult males. Many solid cancers may not have the time to develop before those ages.*

The general population

- increase of thyroid cancer among children (I + Cs contamination): most probably not a screening effect: correlation with soil contamination (Belgium > 40% thyroid cancer upon autopsy)
- cataract

Estimates

- probably based on LNT model: 2000 extra cancer deaths = 3 % of normal incidence (Chernobyl forum)
- x 33 gives ± 65.000
- normal incidence 25 % gives a population group of 250.000
- forum report: 200.000 liquidators + 116.000 evacuees + 270.000 residents = 600.000 people, not 250.000

Question

- *Question: Why the discrepancy between 250.000 and 600.000 ? Was a radiation threshold taken into account to limit the number of 'extra' exposed people?*
- If not, then even a small threshold level would strongly decrease the expected number of 2000 cancer cases.
- If yes, it would be an acknowledgement that a threshold should be taken into account.

More questions

- *Question: is it reasonable to speak about 'extra cancer deaths' as if those people would not have died without radiation? Would it not be better to speak about 'early cancer deaths'?*
- *Question: does an increase in cancer deaths necessarily mean a decreased life expectancy in general, or may it be that survivors live (much) longer? Is cancer the best indicator?*

Social

- evacuation
- resettlement
- mental health
- privileges

Evacuation

- April 27, 11.00 a.m.: population of Pripyat informed about evacuation. 2h30 later: farewell forever to house, friends, neighbours, cats, dogs, ...
- later extended to radius of 30 km around Chernobyl: 116.000 people
- following years: total grew to 350.000

Psychological drama

- forced relocation gave rise to mental health problems, alcohol and tobacco abuse etc..., in what the Chernobyl forum reports as **"the largest public health problem unleashed by the accident today"**.
- resettlements: exclusion of 'contaminated strangers'
- *Question: If we can understand that the first evacuations had to be decided in a situation of emergency, what other reasons led to the evacuation, months or years after the accident of an extra 200.000 residents ?*

Privileges, disabled status

- 7.000.000 people receive some privileges
- 100.000 are considered disabled
- 5 - 7 % of public spending in Ukraine, Belarus
- *Question: how many people are objectively entitled to specific support, and how many have obtained this through less acceptable channels, or simply to survive as their poverty is unbearable ?*

Environment

- geographical aspects
- countermeasures
- wildlife
- water

Geographical aspects

- 4300 km² forbidden zone
- 7000 km² rather strongly Cs contaminated
- in inhabited zones: remaining radioactivity responsible for < 1mSv/y/person

Countermeasures

- many other factors than public health (economics, politics,...)
- Becquerel versus Curie !
- decision taking process:
difficulty for experts to communicate with authorities,
and for authorities to know to which expert to listen

Wildlife

- malformations in first generation
- no obvious hereditary effects
- blooming biodiversity: no human predators !

Water and ecosystems

- contamination of groundwater and downstream water ecosystems, on top of industrial pollution

Regulations

- IAEA, EURATOM, ICRP, ...
- major change in safety approach. The world is much safer now (nuclear and non-nuclear)
- public perception: strong regulations = great danger !

Nuclear power 1970 - 2005

- Club of Rome (1972): in 2000, 900.000 nuclear MW in US...
- TMI, Chernobyl changed the scene
- green movements: nuclear = evil
- nuclear stop in West, expansion in East

Nuclear power 2006 - ?

- more objective reading
- economics
- security of supply
- CO_2

Perception

- no accident since twenty years: maturity, safety or amnesia?
- comparisons by number of casualties: public perception = feelings, not numbers
- one major accident: bye nuclear

Political

- Chernobyl allowed (or forced ?) Gorbatchov to impose glasnost. It was a catalyst in starting the chain reaction that led to the disintegration of the Soviet Union.

Thank you

