Ten Years After Chernobyl

Research Paper 96/31

1 March 1996

The large scale release of radioactivity which resulted from the 1986 Chernobyl accident has had widespread consequences for the environment, agriculture and health. A significant excess of childhood thyroid cancers has appeared in parts of Belarus, Ukraine and Russia, and over 400,000 people have been displaced from their homes. Today, two reactors are still operating at Chernobyl, and the concrete sarcophagus covering reactor 4 is in need of replacement or repair; these are problems which funds from the G7 countries are designed to alleviate.

Grahame Danby
Science and Environment Section

House of Commons Library

Summary

The accident at the Chernobyl nuclear power station in Ukraine occurred in April 1986. An explosion in one of the four reactors on the site released large quantities of radioactive material into the environment, leaving a legacy of contamination and ill-health. Ten years on, significant excesses in radiation-attributed thyroid cancers have been observed in children over a wide area surrounding the plant, though the anticipated increase in leukaemia cases has not yet materialised. This paper also examines the evidence for a range of other health effects.

Belarus received some 70% of the total radioactive fall-out, with more than 20% of its cultivable land affected, but the impact on agriculture has been even more widespread. In parts of North Wales, Cumbria, Scotland and Northern Ireland restrictions are still in place to prevent the sale of contaminated sheep meat.

At today's Chernobyl site, two reactors are still operating, providing 6% of Ukraine's electricity supply. The ill-fated reactor 4 is entombed in a concrete sarcophagus, the condition of which is causing concern. The G7 countries and Ukraine have signed a Memorandum of Understanding, underpinned by US$2.3 billion of grants and investment, aimed at facilitating the early closure of the reactors, establishing replacement electricity generating capacity, and solving the problems associated with the unit 4 sarcophagus.

CONTENTS

		Page
I	The accident	7
II	Fatalities	8
III	Radiation doses	8
IV	Agriculture and food restrictions	11
V	Other environmental consequences	12
VI	The clean-up campaign	14
	A. The Sarcophagus	15
	B. Replacing Chernobyl	16
	C. Lessons from Chernobyl	18
VII	Further reading	20

I The accident

On 26 April 1986, at about 1.23am Moscow time, a chemical explosion occurred in the Number 4 reactor at the Chernobyl nuclear power station, blowing off the top of the reactor and releasing radioactive material into the environment. The chain of events which led to this disaster was a consequence of some experiments on the plant's safety equipment. Firstly, the reactor's emergency cooling system was shut down, a practice strictly forbidden by the Soviet authorities. Secondly, practically all of the reactor's control rods were removed from the reactor core - another forbidden practice - to maintain the energy-producing chain reaction at low power levels. Under these two conditions it was possible to perform an experiment to see how changes in electricity supply affected the feedwater pumps. These are responsible for supplying the reactor with cooling water.

Under the above conditions even a small variation in the power from the reactor could increase the amount of steam in the tubes through which the cooling water passes. When an RBMK-type reactor like Chernobyl is operating at low power, this increase in steam can cause a run-away surge of power. This danger was recognised too late and was in fact exacerbated when the control rods were lowered back into the reactor in an attempt to avert danger. The resulting rapid rise in temperature in the reactor ruptured the cans containing the radioactive fuel. The chemical explosion responsible for releasing radioactivity resulted from water coming into contact with this very hot fuel.[1]

The explosion led to thirty separate fires, the main fire in the reactor core taking some 5 hours to extinguish. In addition to the water poured onto the reactor, the days following the accident saw the airdropping of thousands of tonnes of boron, sand, clay, dolomite and lead. This served to absorb the subatomic particles called neutrons which are responsible for nuclear fission, as well as forming a temporary barrier against the continuing release of radioactive material.

A recent, and more detailed, analysis of the accident sequence has appeared in an article entitled "Chernobyl theories: treat with caution" which appeared in the November 1995 issue of *Nuclear Engineering International.*

---

1 *The Chernobyl Accident. A Review* Malcolm C Grimston (AEA Technology, 24 April 1991)

II Fatalities

More than 150 people present at the site during, or in the immediate aftermath of, the accident suffered from acute radiation sickness. In the more severe cases, this led to death. One person was killed by the actual explosion, and others by burns (including those caused by radiation) and falling masonry. Altogether 31 people died as a result of injuries sustained at the Chernobyl site.[2] More recently this figure has been revised upwards to 42,[3] mostly due to people succumbing to acute radiation sickness.[4]

Many of those who contracted higher degrees of radiation sickness, and who survived, have been classified as up to 100% disabled. Of the 105 people who acquired 1st degree radiation sickness, the result of an absorbed radiation dose of less than 2 **grays**, 70 were able to return to normal work after 8-9 weeks. The gray is the unit of absorbed dose, a measure of the energy deposited in the body by radiation. The **sievert** is the unit of absorbed dose-equivalent which takes into account the fact that different types of ionising radiation differ in their capacity for inflicting harm. In assessing the long term health impact of Chernobyl on both the workforce and the surrounding population, one has to estimate the absorbed dose-equivalent.[5]

III Radiation doses

The total amount of radiation released from the vicinity of the reactor came to 50 million curies, or 1.85 exabecquerels (1.85 million million million becquerels), some 2,000 times more than that released during the 1957 Windscale fire. The number of becquerels gives the number of radioactive atoms in the material which release radiation every second. Given the amount and type of radiation, the weather conditions which govern how it is distributed, and information on the ways in which radioactive substances are taken up by the body, it is possible (if difficult) to estimate the absorbed dose-equivalent. Although this was too low to cause early effects in the surrounding off-site population (with one exception), there is a great deal of legitimate concern about the scale of the late, or delayed, effects of lower levels of radiation exposure. The time from exposure to the onset of radiation-induced cancers - the latency period - is at least 10 years for most cancers, though the onset of leukaemias often comes several years earlier than this.

---

2 *Five Years After Chernobyl: 1986-1991. a review* The Watt Committee on Energy 1991
3 "The Chernobyl Legacy" *Science & Public Affairs* Spring 1994
4 "Chernobyl death toll put at 42" *Financial Times* 15 November 1993
5 "Radioactivity" *New Scientist* 11 February 1988

According to a letter in the *British Medical Journal*[6], the Gomel region of Belarus, to the north of Chernobyl, has seen in recent years a 200-fold increase in the rate of childhood thyroid cancer (143 cases in 1991-94). Substantial increases in the number of reported cases have also occurred in other parts of Belarus, and in areas of Ukraine and Russia. All the regions identified in the letter were heavily contaminated by radioactive fall-out from Chernobyl. The authors[7], from institutes in Belarus, Russia, Ukraine, and the WHO, ended: "This led to unprecedented exposure of a population to ionising radiation, which demands an international response."

Generally, less than 1 in 10 cases of thyroid cancer prove fatal.[8] Most of the cancers have been treated successfully by removing the thyroid gland, leaving the affected person permanently dependent on regular doses of the hormone thyroxine.[9] The increased incidence of thyroid cancers is most likely the result of the radioactive iodine present in the radioactive cloud.[10,11,12,13]

There has not yet been the significant increase in radiation-triggered cases of leukaemia that some expected,[14] though monitoring of the situation continues as part of the International Programme on the Health Effects of the Chernobyl Accident (IPHECA). This has been operating under the aegis of the WHO.[15] Increases in cancers of the breasts, lungs, bladder and kidneys have been reported by doctors in Belarus, but these could be due to the better monitoring and greater public awareness of ill-health since the Chernobyl accident. That said, it is widely expected that the incidence of other cancers will measurably increase as a result of the increased radiation exposure.[16]

Work is currently under way to see if children born in contaminated areas of Belarus, Ukraine and Russia suffer from a greater degree of mental retardation and behavioural disorders.[17] Other health effects of the Chernobyl accident will include stress brought about not by

---

6 "Childhood thyroid cancer since accident at Chernobyl" *BMJ* 25 March 1995 p.801
7 V A Stsjazhko, Head of Chernobyl Accident Health Effects Department, Ministry of Health, Belarus.
A F Tsyb, Director, Research Institute of Medical Radiology, Academy of Medical Sciences, Russia.
N D Tronko, Director, Kiev Research Institute of Endocrinology and Metabolism, Ukraine.
G Souchkevitch and K F Baverstock, Radiation Scientists with the WHO
8 *Five Years After Chernobyl: 1986-1991. a review* The Watt Committee on Energy 1991 p.9
9 "Terrifying outlook for Chernobyl's babies" *New Scientist* 2 December 1995 p.4
10 "Chernobyl, eight years on" *Nature* 13 October 1994 p.556
11 "Chernobyl's Thyroid Cancer Toll" *Science* 15 December 1995 p.1758
12 "Chernobyl victims are not mere objects of research" *The Lancet* 2 December 1995 p.1482
13 "Thyroid cancer in the Ukraine" *Nature* 1 June 1995
14 "Call for more research into health effects of Chernobyl accident" *Nature* 30 November 1995 p.429
15 "WHO brings order to Chernobyl efforts" *Nuclear Engineering International* October 1993 p.46
16 "Will it get any worse?" *New Scientist* 9 December 1995 p.14
17 ibid.

radiation per se, but by fear of radiation and the upheaval associated with extensive relocation of populations.[18,19] In total, over 400,000 people have been displaced from their homes, with attendant social problems.[20]

In order to minimise the cumulative radiation dose to members of the public, evacuations of the surrounding areas were carried out, starting with the town of Pripyat on 27 April 1986, the day after the explosion. By 7 May all 116,000 people living within 30km of the Chernobyl site had been evacuated. Subsequently over 1,000 people returned to this 30km exclusion zone and people over 50 were allowed to remain. The rationale for this is that over their remaining life, they were not expected to exceed a maximum dose of 350 millisieverts.[21,22] Although the health effect of low radiation doses is highly uncertain, a total dose of 350 millisieverts is currently thought to carry a lifetime fatal cancer risk of about 1 in 60.[23] It has been estimated that among those living within 30km of the reactor, about 800 radiation induced cancer deaths will result. This compares with 30,000 cancer deaths which would ordinarily be expected in this population, and may be a large enough departure from the normal rate to be detected.[24] The new town of Slavutich, home to the present day work force, is 50km from the plant.[25]

Winds carried the radioactive plume to Scandinavia, where it arrived on 27 April. Thereafter it split into three parts leading to measurable contamination of areas as far apart as China and Japan, North America and Western Europe. The total **collective effective dose equivalent commitment**, in other words the doses received by individuals summed over the world population over all time[26], has been estimated as being 600,000 man-sieverts.[27] Based on current assumptions about the effect of low radiation levels,[28] Chernobyl could ultimately be responsible for 30,000 cancer deaths worldwide. A figure of 40,000 has also been cited; in either case cancer deaths from other causes will far outweigh those from Chernobyl.[29]

---

18 HC Deb 27 November 1995 cc523-4W
19 "Chernobyl health effects: radiation or stress?" *Nuclear Engineering International* November 1995 p.38
20 "Casualties of Chernobyl" *Radiological Protection Bulletin* January 1996 p.24
21 one millisievert equals one thousandth of a sievert
22 "Impressions of Chernobyl" *ATOM* August 1989 p.10
23 "Biological effects of low doses of ionizing radiation: a fuller picture" *IAEA Bulletin* December 1994
24 *The Chernobyl Accident. A Review Malcolm C Grimston (AEA Technology, 24 April 1991)*
25 "Slavutich - the town that loves Chernobyl" *Nuclear Engineering International* January 1996 p.37
26 dividing the total collective effective dose equivalent commitment by the world population would give an idea of the average dose received by an individual
27 "Sources, Effects and Risks of Ionizing Radiation" UNSCEAR 1988
28 "Biological effects of low doses of ionizing radiation: A fuller picture" *IAEA Bulletin* December 1994
29 *The Chernobyl Accident. A Review Malcolm C Grimston* (AEA Technology, 24 April 1991)

Radiation doses received by a foetus may also give rise to birth defects. Over the period 1986-2056, it has been estimated that in the controlled decontamination areas 35 deformed babies may be attributable to environmental radiation originating from the Chernobyl accident. This compares with 18,900 such cases which would ordinarily be expected in the affected population. Of these 35 excess cases, only 5 would occur after the year 2016, a reflection of the way in which radioactive substances lose their activity over time. It should be restated that all these numerical estimates are highly uncertain due to poor knowledge of the actual doses received and to far from complete understanding of the health effects of low radiation doses.[30,31]

IV Agriculture and food restrictions

Radioactive substances reaching ground level, particularly as a result of rain falling through the airborne plume, can be assimilated by plants and animals. In order to prevent unacceptable levels of radioactive materials entering humans through consumption of agricultural products, several controls were put in place both in the former Soviet Union and beyond.

In the UK, lamb containing more than 1,000 becquerels per kilogram of meat is considered unfit for human consumption. This is a rather conservative level in that the consumption of two kilograms (4.4 pounds) of such meat has been estimated as running "... a risk of early death equivalent to that of smoking one cigarette, or of driving about 40 miles".[32] Although restrictions on the movement and slaughter of sheep in North Wales, Cumbria and parts of Scotland and Northern Ireland[33] are progressively being relaxed as radiation levels fall[34], some are still in place.[35] *The Food Protection (Emergency Prohibitions)(Radioactivity in Sheep)(England)(Partial Revocation) Order* SI 1996/62 and an associated news release[36] provide a good example of the way in which restrictions are lifted.

The continued existence of restrictions on the movement and slaughter of sheep is a consequence of the unexpectedly long time caesium-137 has remained in the soil when it had

---

30 "Radiation and cancer - new moves in the threshold debate" *Nuclear Engineering International* December 1995 p.14

31 "NRPB cuts up the cut-off theory" *Nuclear Engineering International* December 1995 p.15

32 *The Chernobyl Accident. A Review Malcolm C Grimston* (AEA Technology, 24 April 1991)

33 HC Deb 25 January 1996 c.386W

34 Scottish Office News Release 17 January/0025/95
MAFF News Release 18/95 18 January 1995
Welsh Office Press Release W95025 16 January 1995
Department of Agriculture for Northern Ireland Press Release 33/94 14 February 1994

35 "Nuclear fallout disaster that just won't go away" *The Western Mail* 23 January 1996 p.8

36 "Removal of Post-Chernobyl Sheep Controls in Cumbria" *MAFF News Release 15/96*, 17 January 1996

hitherto been thought that it would drain away, and thereby disperse, more quickly. As an example, restrictions in Wales still apply over an area of approximately 580 square kilometres (220 square miles). Originally, over 4,000 square kilometres (1,500 square miles), containing 2 million sheep, were affected. So far, farmers in Wales have received £7,900,000 through the sheep compensation scheme.[37] The total for the UK amounted to £12,096,842 as at 31 January 1996.[38]

In the Chernobyl region, where the level of radioactivity was of course very much higher, the intervention levels of radioactivity in foodstuffs were broadly similar to those adopted by the UK.[39] Among the steps taken by the then Soviet authorities to keep radiation doses at acceptable levels were a range of controls on drinking water and food. Details of the maximum allowed radioactivity levels for different foodstuffs appear in V.M. Chernousenko's book *Chernobyl. Insight from the Inside.*[40] Most concerns centred on three radioisotopes (radioactive versions of chemical elements): iodine-131, caesium-137 and caesium-134. For the latter two isotopes, the maximum allowed levels in meat were set at 3,700 becquerels per kilogram in 1986, falling to 37 becquerels per kilogram in 1990-93. This drop reflects the importance of keeping down the cumulative dose of radiation received over time. The importance of restrictions on meat, milk, vegetables and other foods is underlined by the estimate that some 70% of the collective radiation dose received by the population of Europe as a whole is attributable to ingestion. Most of the rest comes from external irradiation from radioactive substances deposited near ground level, with small contributions from the cloud itself and from inhalation.[41]

V Other environmental consequences

The most important remaining source of radioactive contamination from Chernobyl is caesium-137 which has a half-life of 30 years. In other words half the atoms of caesium-137 will decay in 30 years, emitting radiation and changing into barium-137 (which is not radioactive). Half the remaining caesium-137 will decay during the next 30 years, leaving a quarter of the original amount and so on. The iodine-131 which accumulates in the thyroid gland and can cause cancer decays much more quickly with a half-life of 8 days.

---

37 HC Deb 2 February 1996 cc977-8W

38 HC Deb 22 February 1996 c.270W

39 *Five Years After Chernobyl: 1986-1991. a review* The Watt Committee on Energy 1991 p.20

40 Springer-Verlag 1991, p.209

41 *Five Years After Chernobyl: 1986-1991. a review* The Watt Committee on Energy 1991 p.35

So far as the general contamination of the environment is concerned, Belarus received some 70% of the total fall-out, losing more than 20% of its cultivable land as a result.[42] Large areas of Belarus, northern Ukraine and parts of eastern Russia have ground levels of caesium-137 standing at more than 185 kilobecquerels per square metre.[43] The levels of caesium-137 have been used as a measure of the radioactive contamination of the land and three zones defined accordingly.[44]

The "zone of strict control" covers an area of 10,000 square kilometres where 272,000 people were living and where the contamination amounted to more than 15 curies per square kilometre (this is equivalent to 555 kilobecquerels per square metre). The "zone of permanent control", covering an area of 21,000 square kilometres with some 1.5 million inhabitants, has a level of contamination ranging between 5 and 15 curies per square kilometre (185 - 555 kilobecquerels per square metre). A third zone in which some 6.7 million people live is contaminated with more than 1 curie per square kilometre (37 kilobecquerels per square metre). It has been argued, by what an article in *New Scientist* terms "specialists",[45] that farmland contaminated at this level should be abandoned. Annual doses in this latter zone could amount to 3 millisieverts,[46] which is significantly less than that received by residents of Cornwall from natural sources.[47]

A **map** showing the worst affected areas, taken from the *Radiological Protection Bulletin* (August 1994 p.10) is reproduced on the next page. The shaded areas relate to the concentration of caesium-137 (denoted ^{137}Cs) in kilobecquerels per square metre (kBq m^{-2}). The darkest shading corresponds to a ground contamination level of greater than 185 kilobecquerels per square metre.

---

42 "An ill wind from Chernobyl" *New Scientist* 20 April 1991 p.26

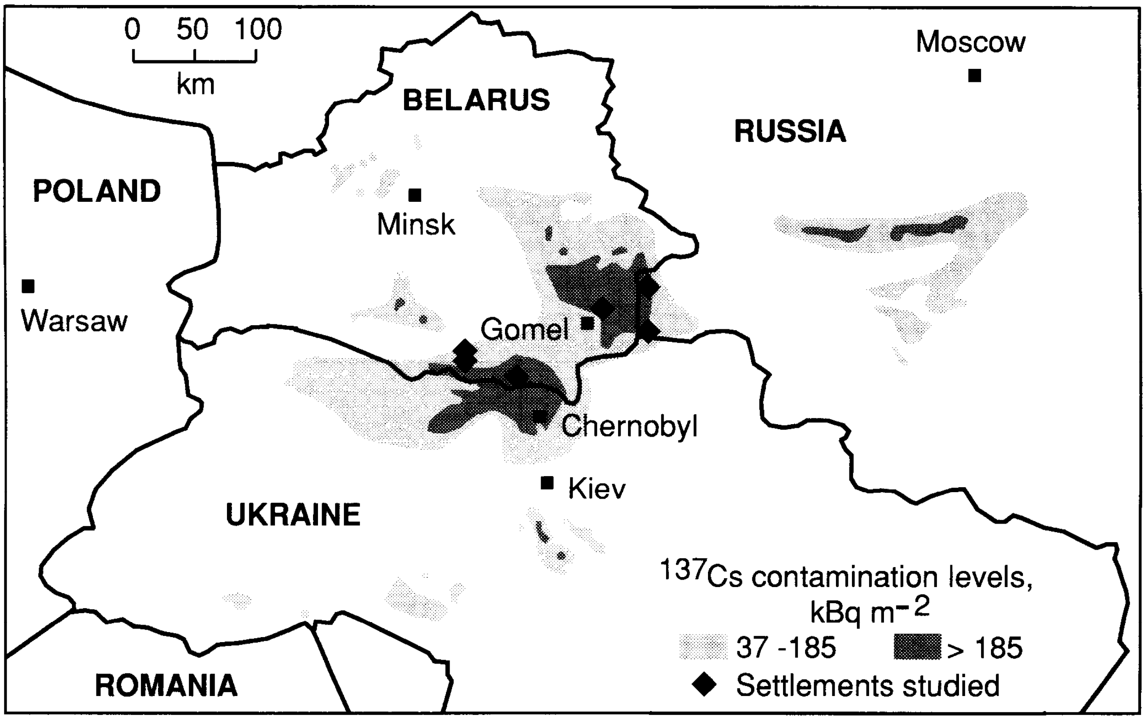
43 "Dose distributions in rural areas affected by Chernobyl" *Radiological Protection Bulletin* August 1994 p.9

44 "The legacy of Chernobyl" *New Scientist* 20 April 1991 p.30

45 ibid.

46 "Doses around Chernobyl" *Nuclear Energy* October 1993 p.268

47 *Radiation Exposure of the UK Population - 1993 Review* NRPB-R263



Much lower, though still significant, contamination extends to parts of western Europe, most notably in Scandinavia. In large parts of Norway, for example, the soil has retained 90% of the radioactive caesium in its top two centimetres resulting in levels of activity in excess of 5 kilobecquerels per square metre. This is expected to take 20 years to fall to half its present level meaning that significant contamination will persist for some time.[48]

VI The clean-up campaign

In the months following April 1986, radioactive debris around the Chernobyl site which had been thrown out by the explosion had to be cleared up manually. Some 600,000 "liquidators" took part in these operations, working for no more than 2 minutes to keep down radiation exposure.[49] Dams had to be built to prevent radioactive substances being washed by rainwater into the Kiev reservoir and the top few centimetres of soil were stripped off and disposed of with other waste in 800 pits scattered around the exclusion zone. There have been fears that radioactive materials disposed of in this way could leach into the water table which lies as little as 60 centimetres below the surface in some areas.[50]

---

48 "An ill wind from Chernobyl" *New Scientist* 20 April 1991 p.26

49 "The Chernobyl Legacy" *Science & Public Affairs* Spring 1994

50 "The legacy of Chernobyl" *New Scientist* 20 April 1991

A. The Sarcophagus

Between June and November 1986, a 60 metre high concrete sarcophagus was constructed to house what remained of reactor 4. There are a significant number of cracks and holes in this structure, which incorporates parts of the original building housing the reactor. There is a possibility that the roof of the sarcophagus could collapse, though it is more likely that some of the radioactive structures inside may collapse "at any time".[51] A collapse of the roof is the "maximum hypothetical accident"[52] and would cause a "considerable radiological hazard on site"[53] due to remnants of the reactor core. Another concern is the effect falling debris would have on the adjacent reactor - unit 3 - which is still operating.

Last year, articles in *The Observer*[54] claimed that a secret report prepared by Western scientists concluded that there was imminent danger of a significant collapse occurring. This point was raised by Mr Jeff Rooker during oral questions to the Duchy of Lancaster[55] and Mr John Horam agreed that " ... all information on the matter should be made available". The report referred to is part of an EU-funded feasibility study into a second shelter for containing the substantial amount of radioactive material remaining in the sarcophagus. The contract for the feasibility study was awarded to the Alliance consortium, consisting of Campenon Bernard, AEA Technology, Bouygues, SGN, Taywood Engineering, Walter Bau and some Ukrainian and Russian organisations. Their "Phase 1" findings were presented at a closed meeting in Kiev on 14-16 March 1995.[56] An Executive Summary has been placed in the House of Commons Library.[57] The principal conclusions regarding the existing sarcophagus, also called the "Ukritiye", and the proposed replacement, "shelter 2", were as follows:

> The existing Ukritiye is not stable and collapse may occur during a seismic or any other major natural events. Long-term stabilisation of Ukritiye is not feasible.
>
> Block "B" adjacent to Ukritiye is not stable, and may collapse under seismic events.
>
> The construction of Shelter 2 is considered an urgent requirement.
>
> Formal approval of the initial Shelter 2 design criteria are urgently required.
>
> Prior to the construction of Shelter 2, Waste Management Facilities will be required.

The results of a more detailed study (Phase 2) were presented in Kiev on 11-13 July 1995,

---

51 "The Chernobyl sarcophagus yesterday and today" *Nuclear Engineering International* August 1993 p.21
52 ibid.
53 *The Chernobyl Accident. A review* Malcolm C Grimston, AEA Technology, 24 April 1991
54 "West faces new radiation threat"; "Horrifying legacy of Chernobyl disaster" *The Observer* 26 March 1995
55 HC Deb 27 March 1995 c.688
56 "Alliance solutions to sarcophagus problems" *Nuclear Engineering International* June 1995 p.40
57 *Stabilisation of the existing shelter and the containment of both the existing shelter and the damaged remains of reactor 4 at the Chernobyl Nuclear Power Plant* deposited paper 1817(3S), 19 April 1995

and the necessary work costed at ECU 1.2 billion (US$1.6 billion) over ten years. One option would leave the reactor 3 building uncovered, allowing continued operation.[58] Given the poor state of the existing sarcophagus it will be necessary to stabilise this and ultimately to disassemble, remove and dispose of the radioactive structures as well as the core fuel they house. The new sarcophagus will accordingly have to be designed in such a way as to accommodate this activity. The feasibility study has been funded to the tune of 3 million ECUs[59] by the EU's TACIS[60] programme.

B. Replacing Chernobyl

At present the Chernobyl site has two operational reactors, units 1 and 3. Reactor 2 has been closed since a fire in 1991, though it could be repaired. The entombed reactor, unit 4, is most certainly beyond repair. The construction of two further reactors, units 5 and 6, was abandoned following the unit 4 accident.

Mikhail Umanets, the chairman of Goscomatom (Ukraine State Committee on Nuclear Power Utilisation) has itemised the costs of shutting down Chernobyl:[61]

- Decommissioning units 1, 2 and 3 would require at least $1.4 billion
- Dealing with the sarcophagus covering unit 4 would cost about $1.6 billion. As noted above, an engineering feasibility study conducted by a consortium led by Campenon Bernard of France concluded that the existing sarcophagus is in danger of collapse and needs to be replaced.
- A further $400 million would be needed to provide a high voltage electricity substation for Kiev.

Providing replacement power would also add substantially to the overall cost, and there would be little difficulty in a figure of $4 billion being ultimately required. Ukraine has plans to complete five new reactors of the VVER-type which are in various stages of completion.[62] These are of a safer design than the RBMKs at Chernobyl and are analogous to the pressurised water reactors in widespread use throughout the West. Completing the VVER

---

58 "Alliance proposes an overarching solution" *Nuclear Engineering International* September 1995 p.5
59 "The new sarcophagus" *Nuclear Engineering International* November 1995 p.33
60 Technical Assistance for the Commonwealth of Independent States
61 "Chernobyl manager questions G7 plan" *Nuclear Engineering International* December 1995 p.6
62 "Could Ukraine go it alone?" *Nuclear Engineering International* November 1995 p.36

reactors alone would cost in the region of US$2.7 billion,[63] though three could be finished for US$560 million.[64] It should be noted that a combination of options for replacing Chernobyl's electricity generating capacity have also been under consideration. Upgrading Ukraine's coal-fired plants, increasing hydroelectric capacity and accelerating the development of wind energy may all have important, or even dominant, roles to play.[65]

The Chernobyl station manager, Sergei Parashin, is known to favour upgrading units 1,2 and 3 to allow them to run until the end of their design lives. This approach would allow these three reactors to continue running until 2010,[66] earning funds for their eventual decommissioning.

A recent briefing by the British Nuclear Industry Forum entitled *Chernobyl: Ten Years After* makes the point that the best solution would involve the provision of international funds to provide alternative supplies of electricity, thereby facilitating early closure. These alternatives could comprise new nuclear power stations of a safer design than the RBMKs at Chernobyl, or power stations fuelled by coal or gas. One legal obstacle to involvement in this work by Western contractors is the fact that Ukraine is not a party to the Vienna Convention on civil liability for nuclear damage,[67] which would raise the prospect of contractors rather than just operators being held liable for any future accidents.[68] The Vienna Convention is based on the same principles as the Paris Convention which was set up in 1960 to govern third party liability insurance in Western Europe.[69]

On 20 December 1995, the G7 and Ukraine signed a Memorandum of Understanding (MoU) on the closure of the Chernobyl plant by 2000. A DTI press notice[70] describes the MoU in the following terms:

> "The MoU sets out the framework for a comprehensive programme of measures to support the closure of Chernobyl, by the year 2000, in the context of wider energy sector reform. It includes projects at Chernobyl to upgrade safety in the short term and to prepare for decommissioning. It also provides support for power sector restructuring and investment in energy alternatives including safer nuclear power plants. Cooperation to develop solutions to the

---

63 "West funds reactors to replace Chernobyl" *New Scientist* 16 July 1994 p.4
64 "Could Ukraine go it alone?" *Nuclear Engineering International* November 1995 p.36
65 "Options for replacing Chernobyl" *Nuclear Engineering International* October 1994 p.20
66 "Could Ukraine go it alone?" *Nuclear Engineering International* November 1995 p.36
67 *Liability and Compensation for Nuclear Damage. An International Overview* NEA/OECD 1994
68 *Chernobyl. Ten Years After* British Nuclear Industry Forum 1996
69 *Third Party Liability* OECD/NEA 1990
70 P/95/903, 22 December 1995

> problem of the Unit 4 shelter and a social support plan for the Chernobyl work force are also included. The programme is underpinned by some $500 million in grant assistance and $1.8 billion in projected investments by the International Financial Institutions (including 400 million ECU in EURATOM loans offered at the Naples Summit)...
>
> ... The UK is contributing to the comprehensive programme both bilaterally and through the European Union's substantial assistance programmes. Bilaterally, the UK has already pledged 7 million [in pounds according to a DTI spokesman] to the Nuclear Safety Account managed by the European Bank of Reconstruction and Development and has also committed more than 3 million [pounds] of Know How Fund assistance for Ukraine's energy sector restructuring programme."

An attachment at the end of the Memorandum of Understanding specifies how the funds are to be spent. The grant assistance is to go on power sector restructuring, an energy investment programme, improvements in nuclear safety, and a social impact plan. Energy investment, including the completion of two VVER nuclear reactors, will be funded largely through loans, since such projects will generate revenue.[71]

So far as the timetable for the closure of Chernobyl is concerned, the year 2000 apparently only occurs once in the body of the text of the MoU.[72] The available funding clearly falls short of the $4 billion which the Ukrainian Government has insisted will be needed, and Deputy Prime Minister Yevtuhov has indicated that the MoU may not be binding until ratified by the Ukrainian Parliament.[73] Supreme Council Chairman Oleksandr Moroz has confirmed that Ukraine has not made a decision to close Chernobyl, citing the absence of adequate non-returnable grants from the West.[74]

C. Lessons from Chernobyl

On the tenth anniversary of the reactor 4 accident, there will be a simple ceremony at Chernobyl dedicated to the memory of those who died.[75] To some, it will serve as a tragic reminder of the folly of the nuclear enterprise and add weight to assertions that this form of electricity generation is intrinsically unsafe. Observations that the RBMK design of reactor

---

71 "Chernobyl closure agreed - but left open-ended" *Nuclear Engineering International* February 1996 p.2
72 ibid.
73 "Timing on Chernobyl Shutdown Still Unclear" *Europe Environment* 20 February 1996 p.13
74 "Finance still the key to Chernobyl closure" *Nuclear Engineering International* March 1996 p.7
75 "Being at Chernobyl" *Nuclear Engineering International* January 1996 p.38

could never, even with recent safety improvements, obtain a licence to operate in Western countries will bring far from universal reassurance. The nuclear industry will invite comparisons with major non-nuclear accidents, such as the methyl isocyanate release at Bhopal which killed 2,850 people and injured 200,000.[76]

Last year the Nuclear Energy Agency's Committee on Radiation Protection and Public Health concluded:[77]

> "The history of the modern industrial world has been affected on many occasions by catastrophes comparable or even more severe than the Chernobyl accident. Nevertheless, this accident, due not only to its severity but especially to the presence of ionising radiation, had a significant impact on human society.
>
> Not only it produced severe health consequences and physical, industrial and economic damage in the short term, but, also, its long-term consequences in terms of socio-economic disruption, psychological stress and damaged image of nuclear energy, are expected to be long standing.
>
> However, the international community has demonstrated a remarkable ability to apprehend and treasure the lessons to be drawn from this event, so that it will be better prepared to cope with a challenge of this kind, if ever a severe nuclear accident should happen again."

---

76 *Chernobyl. Ten Years After* British Nuclear Industry Forum 1996

77 *Chernobyl. Ten Years On. Radiological and Health Impact* NEA/OECD November 1995

VII Further reading

"Casualties of Chernobyl" *Radiological Protection Bulletin* January 1996

Chernobyl. Ten Years On. Radiological and Health Impact OECD Nuclear Energy Agency November 1995

Chernobyl. Ten Years After British Nuclear Industry Forum 1996

"The Chernobyl Legacy" *Science & Public Affairs* Spring 1994

Chernobyl Fall-Out POST Briefing Note 45, July 1993

"The Chernobyl accident reviewed" Malcolm C Grimston (*ATOM*, May 1991)

Five Years After Chernobyl: 1986-1991. a review The Watt Committee on Energy 1991