
Level 3 Certificate / Extended Certificate APPLIED SCIENCE

Unit 3 Science in the Modern World

June 2018

Pre-release Material

- This pre-release material should be opened and issued to learners on or after **31 March 2018**.
- **A clean copy of the pre-release material will be provided at the start of the examination.**

Information

This pre-release material is to be issued to learners for use during preparation for this examination. The pre-release material consists of four sources (**A–D**) on the subject of the Chernobyl accident.

This material is being given to you in advance of this examination to enable you to study each source in preparation for questions based on the material in **Section A** of the examination.

A wider understanding of the topics and issues raised in the sources would be beneficial for the assessment. You are not required to understand any detailed scientific explanations beyond that outlined in **Sources A–D** and that in the Applied Science specification.

You may write notes on this copy of the pre-release material, but you will not be allowed to bring this copy, or any other notes you may have made, into the examination room. You will be provided with a clean copy of this pre-release material at the start of the examination.

It is suggested that a minimum of three hours detailed study is spent on this pre-release material.

Source A: Adapted article from World Nuclear Association website, November 2016

Chernobyl Accident 1986

(Updated November 2016)

- **The Chernobyl accident in 1986 was the result of a flawed reactor design that was operated with inadequately trained personnel.**
- **The resulting steam explosion and fires released at least 5% of the radioactive reactor core into the atmosphere and downwind – some 5200 PBq (I-131 eq).**
- **Two Chernobyl plant workers died on the night of the accident, and a further 28 people died within a few weeks as a result of acute radiation poisoning.**

On 25 April 1986, prior to a routine shutdown, the reactor crew at Chernobyl 4 began preparing for a test to determine how long turbines would spin and supply power to the main circulating pumps following a loss of main electrical power supply. This test had been carried out at Chernobyl the previous year, but the power from the turbine ran down too rapidly, so new voltage regulator designs were to be tested.

A series of operator actions, including the disabling of automatic shutdown mechanisms, preceded the attempted test early on 26 April. By the time that the operator moved to shut down the reactor, the reactor was in an extremely unstable condition. A peculiarity of the design of the control rods caused a dramatic power surge as they were inserted into the reactor.

The interaction of very hot fuel with the cooling water led to fuel fragmentation along with rapid steam production and an increase in pressure. The design characteristics of the reactor were such that substantial damage to even three or four fuel assemblies can – and did – result in the destruction of the reactor. The overpressure caused the cover plate of the reactor to become partially detached, rupturing the fuel channels and jamming all the control rods, which by that time were only halfway down. Intense steam generation then spread throughout the whole core (fed by water dumped into the core due to the rupture of the emergency cooling circuit) causing a steam explosion and releasing fission products to the atmosphere. About two to three seconds later, a second explosion threw out fragments from the fuel channels and hot graphite. There is some dispute among experts about the character of this second explosion, but it is likely to have been caused by the production of hydrogen from zirconium-steam reactions.

Two workers died as a result of these explosions. The graphite (about a quarter of the 1200 tonnes of it was estimated to have been ejected) and fuel became incandescent and started a number of fires, causing the main release of radioactivity into the environment. A total of about 14 EBq (14×10^{18} Bq) of radioactivity was released, over half of it being from biologically-inert noble gases.

About 200-300 tonnes of water per hour was injected into the intact half of the reactor using the auxiliary feedwater pumps but this was stopped after half a day owing to the danger of it flowing into and flooding units 1 and 2. From the second to tenth day after the accident, some 5000 tonnes of boron, dolomite, sand, clay and lead were dropped on to the burning core by helicopter in an effort to extinguish the blaze and limit the release of radioactive particles.

Immediate impact of the Chernobyl accident

The accident caused the largest uncontrolled radioactive release into the environment ever recorded for any civilian operation, and large quantities of radioactive substances were released into the air for about 10 days. This caused serious social and economic disruption for large populations in Belarus, Russia and Ukraine. Two radionuclides, the short-lived iodine-131 and the long-lived caesium-137, were particularly significant for the radiation dose they delivered to members of the public.

It is estimated that all of the xenon gas, about half of the iodine and caesium, and at least 5% of the remaining radioactive material in the Chernobyl 4 reactor core (which had 192 tonnes of fuel) was released in the accident. Most of the released material was deposited close by as dust and debris, but the lighter material was carried by wind over Ukraine, Belarus, Russia and to some extent over Scandinavia and Europe.

The casualties included firefighters who attended the initial fires on the roof of the turbine building. All these were put out in a few hours, but radiation doses on the first day were estimated to range up to 20,000 millisieverts (mSv), causing 28 deaths – six of which were firemen – by the end of July 1986.

The next task was cleaning up the radioactivity at the site so that the remaining three reactors could be restarted, and the damaged reactor shielded more permanently. About 200,000 people ('liquidators') from all over the Soviet Union were involved in the recovery and clean-up during 1986 and 1987. They received high doses of radiation, averaging around 100 millisieverts. Some 20,000 of them received about 250 mSv and a few received 500 mSv. Later, the number of liquidators swelled to over 600,000 but most of these received only low radiation doses. The highest doses were received by about 1000 emergency workers and on-site personnel during the first day of the accident.

Initial radiation exposure in contaminated areas was due to short-lived iodine-131; later caesium-137 was the main hazard. (Both are fission products dispersed from the reactor core, with half lives of 8 days and 30 years, respectively. 1.8 EBq of I-131 and 0.085 EBq of Cs-137 were released.) About five million people lived in areas of Belarus, Russia and Ukraine contaminated (above 37 kBq/m² Cs-137 in soil) and about 400,000 lived in more contaminated areas of strict control by authorities (above 555 kBq/m² Cs-137). A total of 29,400 km² was contaminated above 180 kBq/m².

The plant operators' town of Pripyat was evacuated on 27 April (45,000 residents). By 14 May, some 116,000 people that had been living within a 30-kilometre radius had been evacuated and later relocated. About 1000 of these returned unofficially to live within the contaminated zone. Most of those evacuated received radiation doses of less than 50 mSv, although a few received 100 mSv or more.

In the years following the accident, a further 220,000 people were resettled into less contaminated areas, and the initial 30 km radius exclusion zone (2800 km²) was modified and extended to cover 4300 square kilometres. This resettlement was due to application of a criterion of 350 mSv projected lifetime radiation dose, though in fact radiation in most of the affected area (apart from half a square kilometre) fell rapidly so that average doses were less than 50% above normal background of 2.5 mSv/yr.

Environmental and health effects of the Chernobyl accident

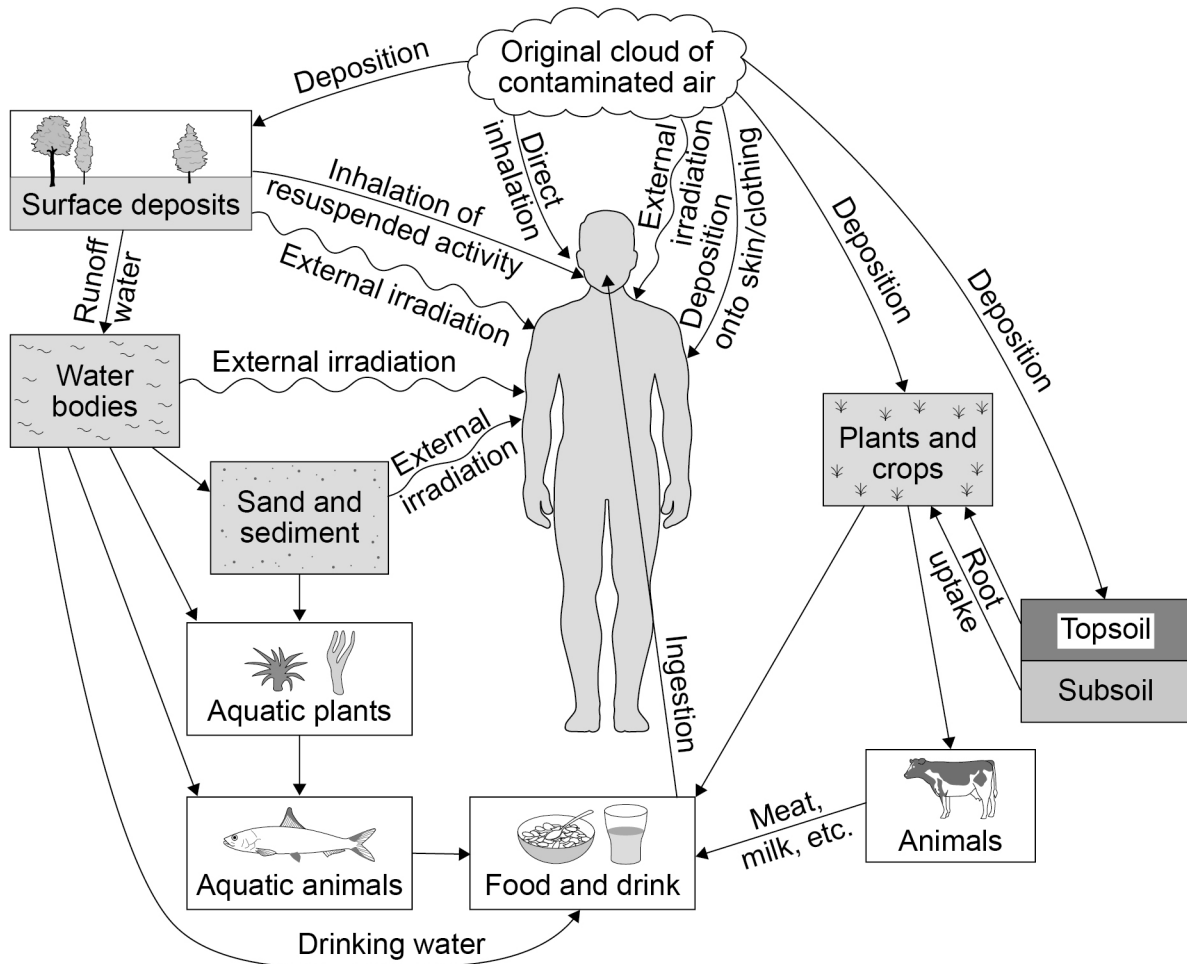
Several organisations have reported on the impacts of the Chernobyl accident, but all have had problems assessing the significance of their observations because of the lack of reliable public health information before 1986.

In 1989, the World Health Organization (WHO) first raised concerns that local medical scientists had incorrectly attributed various biological and health effects to radiation exposure. Following this, the Government of the USSR requested the International Atomic Energy Agency (IAEA) to coordinate an international experts' assessment of accident's radiological, environmental and health consequences in selected towns of the most heavily contaminated areas in Belarus, Russia, and Ukraine. Between March 1990 and June 1991, a total of 50 field missions were conducted by 200 experts from 25 countries (including the USSR), seven organisations, and 11 laboratories. In the absence of pre-1986 data, it compared a control population with those exposed to radiation. Significant health disorders were evident in both control and exposed groups, but, at that stage, none was radiation related.

Subsequent studies in Ukraine, Russia and Belarus were based on national registers of over one million people possibly affected by radiation. By 2000, about 4000 cases of thyroid cancer had been diagnosed in exposed children. However, the rapid increase in thyroid cancers detected suggests that some of it at least is an artifact of the screening process. Thyroid cancer is usually not fatal if diagnosed and treated early, and all but nine children were successfully treated.

In February 2003, the IAEA established the Chernobyl Forum, in cooperation with seven other UN organisations as well as the competent authorities of Belarus, the Russian Federation and Ukraine. In April 2005, the reports prepared by two expert groups – "Environment", coordinated by the IAEA, and "Health", coordinated by WHO – were intensively discussed by the Forum and eventually approved by consensus. The conclusions of this 2005 Chernobyl Forum study (revised version published 2006) are in line with earlier expert studies, notably the UNSCEAR 2000 report which said that "apart from this [thyroid cancer] increase, there is no evidence of a major public health impact attributable to radiation exposure 14 years after the accident. There is no scientific evidence of increases in overall cancer incidence or mortality or in non-malignant disorders that could be related to radiation exposure." As yet there is little evidence of any increase in leukaemia, even among clean-up workers where it might be most expected. However, these workers – where high doses may have been received – remain at increased risk of cancer in the long term. Apart from these, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) says that "the great majority of the population is not likely to experience serious health consequences as a result of radiation from the Chernobyl accident. Many other health problems have been noted in the populations that are not related to radiation exposure."

Main environmental pathways of human radiation exposure



END OF SOURCE A

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Source B: Adapted article from the Daily Mail online, March 2016

Children are still drinking radioactive milk 30 YEARS after the Chernobyl disaster, tests reveal

- **Scientific tests were conducted on behalf of Greenpeace**
- **Contamination from key isotopes continues to linger in nearby forests**
- **Residents in these areas are coming into daily contact with radiation**
- **It is in 'food they eat, what they drink and the wood they use to keep warm'**

By Victoria Woollaston for MailOnline

Published: 05:09, 9 March 2016 | Updated: 11:09, 10 March 2016

People living near the site of the devastating Chernobyl explosion are still eating contaminated food, 30 years after the disaster. According to scientific tests conducted for Greenpeace, overall contamination from key isotopes such as caesium-137 and strontium-90 continues to linger, especially in places such as forests. Residents in these affected areas are still coming into daily contact with dangerously high levels of radiation in the 'food they eat, what they drink and the wood they use for construction.'

Economic crises in Russia, Ukraine and Belarus mean testing in areas contaminated by the nuclear disaster has been cut or restricted, the environment group added. The research report said Ukraine 'no longer has sufficient funds to finance the programmes needed to properly protect the public... this means the radiation exposure of people still living in the contaminated areas is likely increasing.'

The report found that in some cases, such as in grain, radiation levels in the contaminated areas - where an estimated 5 million people live - had actually increased. 'And just as this contamination will be with them for decades to come, so will the related impacts on their health,' the report added. 'Thousands of children, even those born 30 years after Chernobyl, still have to drink radioactively contaminated milk.'

Long-term exposure to radiation can lead to severe illnesses. Doctors in the areas worst affected by Chernobyl have long reported a sharp rise in certain cancer rates.

Victor Khanayev, a surgeon in the Russian district of Novozybkov, said many people were too poor to ensure they only ate food that was not contaminated. 'It is impossible for rural people and even the district town's residents to refuse local produce from the land and their garden, especially with the official monetary compensation being so small,' he told researchers.

Halina Chmulevych, a single mother of two living in a village in Ukraine's Rivne region, was cited in the report as saying she too sometimes had little choice but to feed her children contaminated food.

'We have milk and bake bread ourselves that yes is with radiation,' she was quoted as saying. 'Everything here is with radiation. Of course it worries me, but what can I do?'

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Source C: Adapted article from Ripley's website, April 2016

CHERNOBYL'S DEADLY ELEPHANT'S FOOT

“There's a structure at the heart of the Chernobyl Power Plant known as the elephant's foot, and it can kill you in 300 seconds.”

Ripley's Believe It Or Not April 29, 2016

THE CHERNOBYL DISASTER

On April 26, 1986, during a routine test, the Number 4 reactor at the Chernobyl Nuclear Power Plant had a power surge and triggered an emergency shutdown. Instead of shutting down, the reactor kept surging power, and in no time at all the plant was in full disaster mode. The control rods used to manage the core's temperature were inserted too late into the process. Instead of cooling down, the rods cracked in the rising heat from the core and locked into place.

As if that wasn't bad enough, the water used to cool the entire reactor vaporised, resulting in a massive explosion. The first explosion blew the lid of the reactor through the roof of the building. The second explosion followed shortly thereafter and sent broken core material, fire, and radioactive waste into the air.

Without the tons of steel and concrete typically used to shield it, the core of the reactor began to melt. The result of the melting process is a substance called Corium. Corium is a lava-like molten mixture of portions of the nuclear reactor core, nuclear fuel, fission products, and control rods. At Chernobyl, the corium melted through the bottom of the reactor vessel, oozed through pipes, ate through concrete, and eventually cooled enough to solidify.

THE ELEPHANT'S FOOT

The spot where the Corium solidified wouldn't be discovered until December in 1986. To contain the fallout, a large concrete enclosure named the sarcophagus was built on the site. Access points were left in the sarcophagus for researchers.

During one such research trip, their equipment registered levels of radiation so high that it would kill anyone who got too close for more than a few seconds. In order to see what was causing the readings, the scientist attached a camera to a wheeled contraption and rolled it in the direction the readings were emanating from. What they saw was dubbed the Elephant's Foot.

The Elephant's Foot is so deadly that spending only 30 seconds near it will result in dizziness and fatigue. Two minutes near it and your cells will begin to haemorrhage. By the time you hit the five-minute mark, you're a goner.

Even after 30 years, the foot is still melting through the concrete base of the power plant. Its existence makes the city uninhabitable to humans for at least the next 100 years. If it melts down into a source of ground water, it could trigger another explosion or contaminate the water of nearby villages.

And yet, in spite of the Elephant Foot's toxic presence in Chernobyl, something strange is happening.

ANIMALS FLOURISH

Biologists from the University of Georgia set up cameras in the Belarus evacuation zone to try and track animal activity in the area. What they found was surprising.

Many different kinds of animals aren't simply living in the irradiated area; they're thriving in it. The cameras spotted grey wolves, red foxes, wild boars, moose, and deer.

It's not that the area isn't still dangerous to humans, but instead, the animal life seems to have found a way to thrive in spite of it. And even more important than that, the flourishing animal life shows just how destructive the presence of human beings can be on the animal population of any given area.

Whatever the reason, the area of the Chernobyl disaster has become a kind of wildlife refuge for many different species of animals. At least some small amount of good was able to come from one of the worst disasters in the last three decades.

END OF SOURCE C

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Source D: Adapted article from the Guardian online, November 2016

Chernobyl disaster site enclosed by shelter to prevent radiation leaks

The Guardian Tuesday 29 November 2016

Reactor No 4 at Chernobyl, the scene of the worst nuclear accident in history, has been enclosed by a vast steel shelter designed to prevent radiation leaks from the site.

The structure covers the reactor and the unstable “sarcophagus”, which was hastily built around it by Soviet authorities in the immediate aftermath of the disaster 30 years ago. The shelter is said to be the largest land-based movable object ever constructed. It took several years to build and cost more than €1.5bn (£1.27bn).

The huge steel arch was moved into place over several weeks, and the completion of this procedure was celebrated with a ceremony at the site, attended by the Ukrainian president, Petro Poroshenko, diplomats and site workers. Poroshenko paid tribute to the Chernobyl workers who built the initial sarcophagus, despite dangerous radiation levels at the scene of the disaster. “It was designed to last for 30 years to protect Kiev, Ukraine and the whole world from nuclear contamination. Thirty years later, we are present here just 100 metres away from reactor No 4 and we can say that this new historical construction has been completed,” he said.

The explosion at Chernobyl’s reactor No 4 occurred during the night shift on 26 April 1986, and news of the disaster was initially covered up by Soviet authorities. About 50 people were killed as a direct result of the accident, but medical estimates suggest up to 4,000 people will die prematurely due to radiation exposure. Thousands more still suffer health effects, and a 20-mile (32 km) exclusion zone around the plant remains in place.

Suma Chakrabarti, the president of the European Bank for Reconstruction and Development (EBRD), which coordinated the construction project, said: “The old shelter has now disappeared from our sight, but we’re never going to forget the human toll of the 1986 accident and we owe our thoughts today to the victims of that accident.”

Vince Novak, the EBRD’s director of nuclear safety, said the shelter eliminated a number of fears and risks that had persisted since the accident, including a collapse of the sarcophagus or a fresh nuclear reaction inside the structure, given the tonnes of uranium still present at the site. There was also a danger that radioactive liquids could seep out of the site and into the water supply, because the sarcophagus was not watertight, he said. “This is the first project of its kind, and I very much hope the last one too,” Novak said.

The shelter is 162 metres (531 ft) long and 108 m high. The metal used in the construction weighs 3.5 times more than the Eiffel Tower. Construction was complicated by the high radiation levels near the reactor, meaning that in order for workers to be able to spend extended periods of time building the shelter, it had to be assembled several hundred metres away and then slid slowly into place.

Prior to the process, tens of thousands of tonnes of radioactive soil were removed from the construction area and replaced with clean soil. Much of the machinery and engineering equipment used had to be designed and built from scratch, including special cladding and a huge crane system.

Hans Blix, director general of the International Atomic Energy Agency at the time of the accident, who visited Chernobyl shortly after the explosion at the reactor and has been involved in the shelter project, said: “Moving together the two halves of the huge arch of this gigantic shelter is like closing a wound, a nuclear wound that belongs to all of us.”

Over the coming year, work will continue on the structure to make it airtight and dismantle parts of the sarcophagus inside, using remote-controlled cranes inside the structure. When it is completed in November 2017, the final structure should ensure that the site is airtight for 100 years.

People are banned from living in the zone around Chernobyl and access is only granted by special permit, but a few residents have returned in defiance of the ban. There are plans to develop solar power facilities in the area and Ukrainian authorities want to rebrand the exclusion zone as a destination for tourists, who can visit the city on a day trip from the capital, Kiev, and take an excursion around Pripyat, the ghost city near Chernobyl. The nearly 50,000 residents of Prip'yat, which was built to house Chernobyl workers, were evacuated the day after the disaster and never returned. Its eerie, deserted streets give a snapshot of the late Soviet period.

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There are no more sources printed on this page

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