Nuclear Decommissioning

is a safe well understood process

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The Chernobyl Nuclear Power Plant

by Andrew Kenny

Nuclear decommissioning is neither mysterious nor very expensive. In the USA alone, more than a dozen nuclear facilities have already been successfully decommissioned, and all around the world many more are being decommissioned or are about to be. New nuclear plants are easier to decommission than old ones, so as time passes the process of decommissioning will become easier and cheaper. Furthermore, as techniques improve, especially with the increased use of robotics instead of humans to dismantle the plants, costs will come down and exposure to radiation will decrease.

Nuclear decommissioning simply means; the safe disposal at the end of its working life of a nuclear facility. This could be a nuclear power plant such as Koeberg Nuclear Power Station near Cape Town or a nuclear research reactor like SAFARI-1 at Pelindaba near Pretoria. The site on which the decommissioning plant operated can then be safely re-used, either for another nuclear plant or for other purposes.

All industrial facilities, including coal and gas power stations, wind turbines and solar farms, should be decommissioned at the end of life. Nuclear is unexceptional in this regard. What distinguishes nuclear plants from most others, but not all, is the potential danger of radiation, essentially the only environmental threat from nuclear power.

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Andrew Kenny is holding a South African made nuclear fuel element.

Nuclear Radiation is entirely natural. All living things have been bathed in radiation for all of their lives since life began on Earth 3.8 billion years ago. The levels of radiation which people receive from nuclear power activities are miniscule, in reality hundreds of times lower than natural radiation. Radiation is only harmful above a certain high threshold. This threshold is much greater than the allowed limit for nuclear workers, and much, much greater than the natural radiation which we all receive all the time from the earth and the sky.

A fundamental characteristic of radiation is this: the ***longer*** the life of a radioactive material, the ***less*** radioactive it is. If it lasts five minutes, it is extremely radioactive and very dangerous. If it lasts five billion years, it is very feebly radioactive and quite safe. If a material lasts forever, which most elements do, then they are not radioactive at all. This reality is important for nuclear decommissioning. If you leave the plant alone for a number of years, the radioactivity drops rapidly.

The legal requirement for a nuclear facility to be declared fully decommissioned is to end up with very low levels of radioactivity. Around the world, nuclear regulators not only demand that these levels should be lower than those that can cause harm but far, far lower. A slight absurdity is that regulators allow higher levels of radioactivity to be released from non-nuclear facilities, such as gas plants. (The gas contains radioactive radium which is found in natural gas).

Fission

By far the greatest radioactivity in a nuclear power plant comes from the nuclear fuel. Fission, the splitting of heavy nuclei, occurs in the fuel, releasing intense radiation. Some fission products have very short half-lives and are therefore highly radioactive. At the end of life, the spent fuel and associated equipment is removed from the nuclear reactor and then taken to a place of storage for high level waste. This action removes over 99% of the radiation in the plant.

The radiation which is left is in the walls and structure of the reactor vessel, in the piping, tanks and other components, and to a lesser extent in the concrete around the reactor. There are two sources of radiation: **neutron activated materials and contaminated materials.**

SOURCES OF RADIATION

NEUTRON ACTIVATED MATERIALS

While the nuclear reactor is working, it experiences an intense flow of neutrons. Some neutrons cause fission in the uranium fuel which results in more neutrons being produced. These neutrons impinge upon the metal surfaces of the reactor vessel and on its internal structures, including the control rods.
The reactor is by far the most radioactive component of a nuclear plant. But the metals of adjoining pipes, vessels and heat exchangers are also radioactive to some degree.

Steel contains iron and carbon, plus alloying materials such as chrome, manganese, nickel, antimony, cobalt and vanadium, and also trace metals such as copper.

Neutrons can cause nuclear reactions with these atoms, and transmute them into other elements and isotopes, many of which are radioactive. Some examples are Fe-55 (an isotope of iron), with a half-life of 2.73 years, and Co-60 (cobalt), with a half-life of 5.3 years.

CONTAMINATED MATERIALS

Small amounts of radioactive fission products in the fuel can leak out of the fuel cladding into the reactor water, in the form of small particles and debris. These can lodge on surfaces of the reactor vessel and in its internal structures, and also in those of adjoining pipes and vessels. At decommissioning, much of this radioactive debris is loose and can be washed or scrubbed away to form a sludge that can then be disposed of. Some of it is more firmly stuck and cannot be so easily removed.

When is radiation dangerous?

The standard unit of radiation dose which is the radiation received by a person, is the Sievert (Sv). One thousandth of it is the millisievert (mSv), one millionth is the microsievert (μSv).

The usual annual radiation dose for people living by the coast, like in Cape Town, is about 2 500 microsievert. People living at higher altitude, say in Johannesburg, or close to granite formations, say in Paarl, will receive higher doses.

Very high radiation is certainly dangerous but no harm to humans has ever been seen below 100 000 microsieverts per year. In a place called Ramsar in Iran, because of the geology, some people receive 260 000 microsieverts in a year and no harm has ever been observed in them. It is unscientific and inaccurate to say "there is no safe level of radiation".
Below 100 000 microsieverts is quite safe.

In fact, overwhelming evidence shows that slightly enhanced radiation received by a person at levels which are rather higher than most of us would ever receive normally, actually **reduce** the chances of getting cancer. This is because extra radiation improves the body's repair mechanisms for DNA damage.

A famous example of this occurred in Taiwan in the 1980's. A group of large residential buildings were constructed, in which the steel reinforcing bars used in the concrete were accidentally radioactive. The radiation came from Co-60 which had been accidentally melted into the steel when the reinforcing bars were made. Decades later this error was discovered by chance, and relatively high levels of radioactivity were measured inside the buildings. More than 2 000 people were found to have received high radiation doses for years. When the authorities examined the medical records of these people many years later, they found that they had exhibited dramatically less illness and fewer cancers than similar people not exposed to the radiation.

On the one hand... and the other

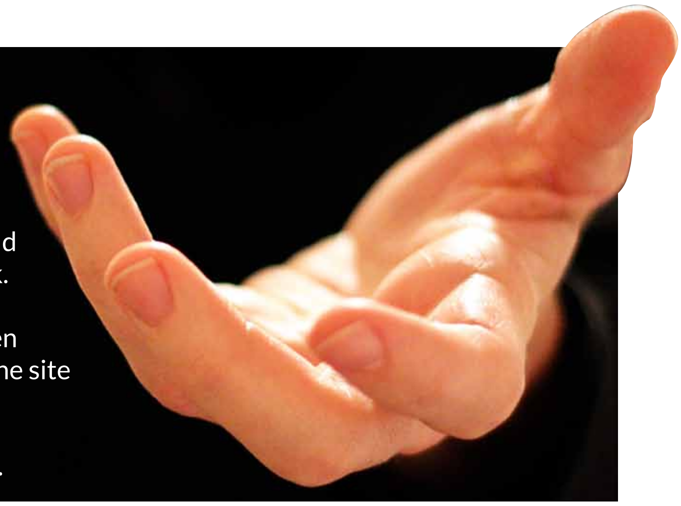
An international point of debate is:

Exactly what must be decommissioned at an old nuclear plant?

On the one hand, all that needs to be dismantled and removed is the old nuclear reactor vessel and some of its associated pumps and pipework.

On the other hand, some people argue that the entire building and even associated buildings, plus the car park, have to be removed to return the site to original Greenfield status.

So the decommissioning debate can be loaded with emotional opinion.



There are three different methods of decommissioning, each with advantages and disadvantages.

The abbreviations for each are from the USA

1 Immediate Dismantling "Decon"

The facility is dismantled soon after shutdown, within a few months or years. The advantage of this approach is that the site is soon available for other use and is signed off by the nuclear regulator. The disadvantage is that radiation levels from the reactor and other components are much higher than they would be later, so requiring more difficult and expensive removal and disposal.

2 Safe Enclosure "Safstor" or Deferred Dismantling

Here disposal only happens after a period of 50 years or more. By then the radiation will be greatly reduced, making the dismantling easier and cheaper. Furthermore, techniques for dismantling are bound to improve as time goes on. The disadvantage is that the site has to be quarantined in the meantime and there is a risk of regulation change as time goes on.

3 Entombment "Entomb"

Here there is no disposal of the nuclear plant. Its components are moved into a small volume surrounding the reactor vessel and then encased in concrete. The advantage of this is low cost and simplicity. The disadvantage is that the radioactive material remains on site, and so limits its use for any other purpose.

In the first two cases, the radioactive materials of the nuclear plant would be taken to a place of final disposal. In South Africa, Vaalputs in the Northern Cape, now used for low level and intermediate level radioactive waste, would be ideal.

The costs of decommissioning nuclear facilities depend on their type and age. The world's first nuclear facilities were built without decommissioning in mind and are more expensive to decommission than subsequent ones. By far the most complex are the early nuclear weapons facilities in the USA and the UK.

For nuclear power plants, the cheapest types to decommission are PWRs (Pressurised Water Reactors), like Koeberg. They are also the most popular reactors around the world.

Next are BWRs (Boiling Water Reactors). The most expensive to decommission are gas cooled, graphite moderated reactors, such as the old Magnox and AGR (Advanced Gas Reactors) in the UK.

A nuclear submarine reactor being decommissioned.

An example of decommissioning

The USA is the pioneer of nuclear power, and so has been the first country to decommission some of its old nuclear facilities.

An example is the Maine Yankee nuclear power plant, a 860 MWe PWR. It was closed down in 1996 after 24 years of operation. It was decommissioned by immediate dismantling, the most expensive method. This was completed in 2005, leaving a Greenfield site, with unrestricted use by the public.

MWt stands for MegaWatts (thermal) and it is the total heat energy produced by a reactor. MegaWatts (electrical) or MWe is the amount of electricity which can be produced out of the heat energy. MWt is always larger than MWe.

The owners of nuclear facilities are usually required to set aside money at the onset, usually around 10 to 15% of the total capital cost, for decommissioning. The money usually goes into a ring-fenced investment fund, which can never be used for anything else.

If the discount rate, which is the interest rate that could be earned over the period concerned, is high, decommissioning will be cheap because the final money in the fund will exceed the cost of decommissioning.

The Nuclear decommissioning of modern plants is straight-forward, routine, and not very expensive.

Decommissioning of the containment dome of Conneticut Yankee Nuclear Power Plant

An OECD (Organisation for Economic Cooperation and Development) survey in 2003 reported that the cost of decommissioning a PWR was $200 – 500 per installed kWe in 2001 dollars. Allowing for inflation, assuming a figure of $400 per kWe, this means that the cost of decommissioning Koeberg, which has a capacity of 1 860 MWe, would be $744 million – or R11 billion at 15 Rand to the dollar. This is obviously a very rough figure but it gives an idea of its order.

It might not be appropriate to use the same figures for the SAFARI reactor at Necsa, which is a Research Reactor, and has more highly enriched fuel but far fewer components. But assuming it is, this means that the cost of decommissioning SAFARI, which has a capacity of 20 MWt, which is equivalent more-or-less to about 8 MWe, would be approcimately $3.2 million – or R48 million. Again this is a very rough figure.

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