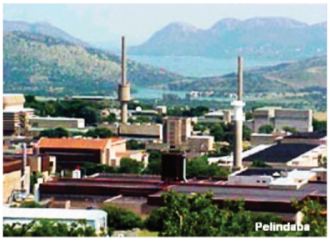
RADIOACTIVE EFFLUENTS

Nuclear facilities routinely discharge small, carefully monitored and controlled quantities of radioactive material into the air and water environment. In the case of Koeberg Nuclear Power Station 28km north of Cape Town the liquid effluent is mixed with the fast-moving cooling water outfall that discharges into the Atlantic Ocean. In the case of Necsa's Pelindaba site which includes the SAFARI-1 research and isotope production reactor the liquid effluent is released into the Crocodile River upstream of the Hartbeespoort dam.

At both sites, gaseous effluent is discharged through the ventilation stacks.

How concerned should we be about these radioactive effluents

Koeberg Nuclear Power Station



Pelindaba, SAFARI-1 building extreme left

LEGAL REQUIREMENTS

Many organisations study the ever-growing body of scientific data on the effects of ionising radiation. They include the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the International Commission on Radiological Protection (ICRP). The ICRP publishes recommendations concerning safe limits of exposure to radiation for radiation workers and substantially lower limits for members of the general public.

National nuclear safety authorities such the South Africa's National Nuclear Regulator (NNR) consider these recommendations and establish legally binding requirements for their own countries.

For South Africa, the NNR has determined that no member of the general public, including people living around nuclear installations, may be exposed to more than the internationally accepted limit of 1 millisievert per year (shortened to 1 mSv/y) from all sources. This is in addition to natural background radiation.

To allow for the possibility of other sources, possibly further reactors close to Koeberg, the permissible public exposure level due to operation of the currently operating twin reactor units has been set at 0.25 mSv/y.

The same dose constraint applies to the facilities currently in operation at the Pelindaba site.

The health effects of ionising radiation are discussed in NIASA Fact Sheet 4. 1 mSv/y is an extremely low level of radiation exposure. It is to be compared with the world average natural background radiation level of 2.4 mSv/y rising in places to over 100 mSv/y and to the 20 mSv/y limit for radiation workers. No ill-effects attributable to radiation have ever been observed for exposures below 100 mSv whether received over the long or short-term.

Eskom and Necsa, monitored by the NNR, must therefore ensure that no one receives more than 0.25 mSv/y (in addition to the natural background radiation level) as a result of effluent discharged from respectively Koeberg and Pelindaba.

EFFLUENT SOURCES

KOEBERG

The radioisotopes in the Koeberg effluent are of two types, fission products and activation products. See Fact Sheet 3.

Inspection of a new uranium fuel assembly

Traces of uranium ('tramp' uranium) may remain on the outside of new nuclear fuel assemblies on arrival at the power station. Moreover, minute leaks may develop in the fuel in the course of operation. Both sources may contribute to fission product isotopes in the reactor cooling water, particularly the more mobile radioisotopes iodine-131 and caesium-137.

In addition, other radioisotopes such as cobalt-58, cobalt-60 and silver-110m arise as a result of wear or corrosion of reactor components. They become radioactive due to neutron bombardment as they circulate through the reactor with the primary circuit cooling water. See Fact Sheet 6.

The greatest source of radioactivity in the reactor coolant circuit is, however, irradiation of the coolant itself. Neutron bombardment of nitrogen dissolved in the water gives rise to carbon-14. Moreover, irradiation of boron dissolved in the coolant water creates hydrogen-3, i.e. tritium, the radioactive isotope of hydrogen.

To a very limited extent during normal operation and particularly during maintenance, coolant water leaks from the reactor coolant systems and some evaporates. This can lead to limited airborne radioactivity in ventilation air. The ventilation discharge stack is monitored continuously to provide the required record of gaseous and particulate emissions.

Liquid effluent (contaminated water) is collected in hold-up tanks and is monitored before authorisation to discharge it is given by senior personnel authorised to do so. The water is treated as necessary to remove radioactivity. A point is reached, however, at which the environmental impact of the residual radioactivity becomes so low that no further treatment is warranted.

PELINDABA

Necsa operates a research reactor, SAFARI-1, which generates effluent with similar radiological properties to that from Koeberg, but in much smaller quantities. Other facilities on the site such as the radioisotope production facility also generate liquid and gaseous effluent.

As at Koeberg, all liquid effluent is collected in holding tanks, monitored, treated if necessary to ensure that discharge limits and water quality requirements are observed, and then discharged into the Crocodile River.

All ventilation stacks are subject to operational constraints to ensure compliance with discharge limits. The air vented through them is monitored continuously.

ANNUAL AUTHORISED DISCHARGE QUANTITIES (AADQs)

It is necessary to ensure that discharged radioisotopes lead to minimal radiation exposure off-site. Of principal interest is the exposure of the surrounding population due to the inhalation or ingestion of radioactive material. For each of the possible radioisotopes in the effluent there is a 'critical path' from the release point on the site to uptake by members of the local population.

One of the most important isotopes in this context for Koeberg is the isotope silver-110m. Silver is contained in the reactor control rods which are subject to wear. Shellfish concentrate silver and other heavy metals in their bodies and the critical path for silver-110m is via consumption of white mussels taken from the beach immediately south of the cooling water outfall.

Knowing how much radioactive silver is discharged it is possible to estimate the resultant radiation exposure to human mussel-eaters. The calculation involves an estimate of the concentration of silver-110m in the seawater, knowledge of the extent to which silver is concentrated by mussels and an estimate of how many kilograms of mussels the most voracious beachcomber is likely to consume in the course of one year.

Koeberg site looking South

With that information, it is possible to calculate a limit for the discharge of silver-110m to ensure that the most highly exposed individual cannot be exposed to more than a given amount of radiation.

In other words, it is possible to calculate and apply an Annual Authorised Discharge Quantity (AADQ) for silver-110m and for other radioisotopes contained in the Koeberg liquid effluent.

As discussed below, mussels are routinely collected and monitored for radioactivity to check the calculations.

Critical pathways have been determined for some sixty-five radioisotopes found or expected to be found in Koeberg effluent. Discharge limits have been established for each one. Even if all were discharged at the maximum (AADQ) allowed, and in the impossible event that the critical paths for all the isotopes in the liquid and gaseous effluent irradiate the same local resident, that individual would still receive less than the permitted 0.25 millisievert per year.

OPERATING EXPERIENCE

KOEBERG

Eskom sends quarterly and annual reports to the NNR detailing the isotopes discharged and the calculated radiation exposure of the hypothetical most highly exposed individual discussed above. The results are also published in Eskom Annual Reports.

Typically, the radioisotopes responsible for the exposure to liquid effluent include silver-110m, cobalt-58, cobalt-60 and carbon-14.

Annual discharge quantities vary but typically, for the past several years, the calculated radiation exposure of the most highly exposed individual off-site has been less than 0.005 mSv.

Collecting beach samples

For the discharge to atmosphere, the most important isotopes in terms of public exposure include carbon-14 and iodine-131. The critical path for carbon-14 is uptake by plants downwind of the site and their subsequent consumption. For iodine-131 it is uptake in grass and the subsequent consumption of milk.

The calculated exposure of the hypothetical most highly exposed individual in recent years due to gaseous isotopes has been 0.0054 mSv or less.

PELINDABA

Necsa also sends quarterly and annual reports to the NNR and summarises the results in its Annual Reports.

Typically, the radioisotopes responsible for off-site exposure due to liquid effluent comprise a mixture of beta/gamma-emitting fission and activation products. The dose to the hypothetical most highly exposed individual is determined by conservatively assuming that all the radioactivity discharged is the relatively 'toxic' strontium-90.

Over the past five years the annual exposure of the most highly exposed individual due to liquid effluent has been less than 0.007 mSv/y.

In the discharge to atmosphere, the most important isotopes are iodine-131 and the noble gas isotopes xenon-133 and xenon-135. The critical path for iodine is uptake in grass and the subsequent consumption of milk and vegetables. Noble gases are not concentrated in the body but contribute to off-site exposure by direct radiation 'shine' as the plume from the ventilation stacks passes overhead.

The calculated exposure of the most highly exposed individual over the past five years due to gaseous effluent has been less than 0,003 mSv/y.

Doses of this order are considered trivial and must be calculated because, against a natural background radiation level of around 2.4 mSv/y, they are far too small to measure. Internationally accepted computer codes are used for these calculations.

SUMMARY

The conservatively calculated annual off-site exposure around Koeberg and Pelindaba due both to liquid and gaseous effluent is maintained below 0.01 mSv/y. This is 1% of the internationally accepted annual limit for the general public. The world average background radiation level is 2.4 mSv/y. It therefore seems reasonable to describe off-site radiation exposure due to effluents as negligible.

Nevertheless, in this field as in others, improved methodologies are under continuous development. Limits such as the AADQs and the dose conversion factors used to derive them are therefore modified from time to time.

ENVIRONMENTAL SURVEY

The conclusion reached above, namely that off-site radiation exposure is minute compared with the permitted level, is based on computer calculations based in turn on the measured releases of radioactivity.

To add further reassurance, nuclear installations are obliged by national safety authorities to implement approved environmental surveillance programmes. The radioactivity in a range of routinely collected environmental samples is determined in radio-analytical laboratories.

Measuring the radioactivity in environmental samples...

To establish base-line radioactivity levels, surveillance programmes around Pelindaba and Koeberg began well before reactor start-up on those sites.

The materials sampled typically include air, surface water, sea or river water, sediment, soil, fish, shellfish, milk, grass and locally-grown farm produce. 'Control' samples are taken from locations far away from the installations.

In addition to the discharge-limiting AADQs, safety authorities specify environmental sample reporting levels for each isotope. The authority must be notified of any sample that exhibits radioactivity above the reporting level for that isotope.

Sampling river water..

KOEBERG

Terrestrial samples. Caesium-137 and sometimes strontium-90 are detected at levels consistent with the background attributable to global nuclear weapons testing largely in the 1960s. These levels are far below the relevant reporting levels imposed by the NNR. Only in one sample possibly associated with Koeberg (strontium-90 in a sample of vegetables in May 1986) has an isotope reporting level ever been exceeded.

Marine samples. It is normal to find traces of radioactivity downstream of nuclear power stations. Radioisotopes from Koeberg are routinely found in some marine samples, most importantly in white mussels found in the sand south of the cooling water discharge channel. The isotopes measured are silver-110m, cobalt-58 and cobalt-60. The reporting levels for these isotopes, however, have never been exceeded. Since 1995, the highest annual average level of silver-110m has been 7% of the reporting level. The comparable figures for cobalt-58 and 60 have been respectively 0.5% and 2%.

Sewerage samples. Traces of radioactivity are also found routinely in local sewerage plants – including those serving areas around nuclear power stations. Koeberg is no exception. Minute traces of cobalt-58 and cobalt-60 activity have been found. Higher levels of iodine-131 and some technetium-99m are also found and are mainly if not entirely due to nuclear medicine procedures performed on members of the local population unconnected with the power station. See Fact Sheet 12

Boundary-post monitoring. Further reassurance is provided by sensitive radiation detecting devices mounted on the fence surrounding the site. While those at Koeberg detect very low level radiation from the near-by store for radioactive waste drums on the northern boundary of the site, they have never recorded radiation levels attributable to gaseous effluent from the ventilation stack.

PELINDABA

Necsa carried out radiological environmental surveys in the mid-1960s before SAFARI-1 was commissioned and has also instituted an environmental monitoring programme to ensure that discharges do not result in the build-up of radioactivity in the environment.

Media routinely sampled include:

- water, sediment and fish from the Crocodile River and the Hartbeesport Dam
- milk from surrounding farms
- plant material from the surrounding area
- air filters on the Pelindaba site.

These measurements have given no reason for concern regarding radiation safety in the environment around Necsa in its many years of operation.

Air sampling equipment..

INTERNATIONAL LIMITS

The Codex Alimentarius Commission publishes guidelines for maximum acceptable levels of radioactivity in foodstuffs traded internationally after a major accident. Codex assumes that 10% of the food eaten is contaminated and that, as a result of eating it, the consumer must not receive more than 1 mSv/y. For listed isotopes such as cobalt-60 and caesium-137 the Codex action level is 1 000 Bq/kg. See Fact Sheet 3. If listed, cobalt-58 and silver-110m would be included in the same Codex group. For comparison, since 1995 the maximum annual average levels in white mussels, the most highly contaminated marine organisms found around Koeberg, have been 14.7 Bq/kg for silver-110m, 2.39 for cobalt-60 and 1.29 for cobalt-58.

These levels may also be compared with 100 Bq/kg of naturally-occurring potassium-40 typically measured in shellfish samples.

Nuclear Industry Association of South Africa
www.niasa.co.za
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