Environment Agency

Evidence

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Chemical discharges from nuclear power stations: historical releases and implications for Best Available Techniques

Project summary SC090012/S

A new generation of nuclear power stations may be built in England and Wales. The Environment Agency is working with the Office for Nuclear Regulation (ONR) to assess two proposed designs (AP1000™ and UK EPR™), both of which use pressurised water reactor (PWR) technology. Part of this assessment is to determine whether the designs incorporate Best Available Techniques (BAT) for minimising non-radioactive chemical discharges and using chemicals with the lowest environmental impact and toxicity.

The Environment Agency commissioned consultants AMEC to carry out a survey of operating PWRs in England, the USA, France and Germany that included predecessors to, or earlier versions of, the AP1000™ and UK EPR™. The survey collected data on:

- type and quantity of chemicals discharged;
- information on how the discharges were permitted;
- discharge limits set by the regulatory bodies.

A PWR power plant consists of a water-filled reactor system (primary circuit) that generates useful heat which is transferred to a secondary circuit via steam generators. The steam raised is used to drive a turbine generator in the same way as in a fossil fuel power station. The steam is condensed using an external source of cooling water. In general, plants at coastal locations use once-through seawater cooling, while those inland use cooling towers where cooling water can be recirculated. All PWR plants have smaller systems (for example, water and waste water treatment plants) that use a range of chemical additives. Apart from the primary circuit, the processes that use chemicals in a PWR are broadly the same as those in a fossil fuel power station.

How chemical discharges from PWRs are regulated varies significantly between countries and this affects how these discharges are monitored and reported. There is no straightforward relationship between the amounts of chemicals discharged and number of reactors on a site or electrical output (even between reactors of the same design at different locations). Discharges depend, for example, on the type of cooling water system, whether the plant is operating as normal or is shutdown, how plant-specific issues of corrosion and biofouling are dealt with, and how the effluent is treated.

Primary circuit chemicals

The main chemicals used in the primary circuit are boric acid to adjust nuclear reactivity and lithium hydroxide to control pH. Over each fuel cycle (of about a year) some of the reactor coolant needs to be treated and discharged.

Boric acid in waste effluent can be recovered for reuse by using evaporators or ion exchange systems. It may be directed to a solid waste route or treated to allow it to be safely discharged to the environment. Reuse of boric acid may cause higher radiation doses to workers because the recovered solutions may contain tritium and other radioactive impurities. The location of the plant will determine whether boric acid can be discharged to the environment.

While the concentration of boron in the discharges from a PWR with a once-through cooling system is negligible compared with that present naturally in seawater, this is not the case for inland sites that may need to discharge to more sensitive freshwater bodies. Discharges of boric acid can be reduced by using a special form of this chemical, but this is more expensive.

Lithium hydroxide is usually discharged to the environment, because only very low concentrations are present in the effluent, it is of low toxicity, and recovered material would be contaminated with radioactive materials that are chemically similar.

Secondary circuit chemicals

The main chemicals used in the secondary steam circuit of most PWRs are:

- hydrazine to remove oxygen from the water (and thus minimise corrosion);
- ammonia or amines to control pH.

Small amounts of these chemicals are discharged in effluents from the secondary circuit. When the reactor is shutdown, water in parts of this system can become stagnant and the risk of corrosion increases. Higher concentrations of hydrazine may then be used and need to be discharged.

There are concerns over the use of hydrazine due to its toxicity to humans and wildlife. While much research has been done to find alternatives, there is little information to suggest that any are used in the secondary circuits of operating PWRs. Hydrazine in effluents is either destroyed using chemical treatment or discharged to the environment after being diluted in the main cooling water flow. This survey found that discharges of hydrazine have generally decreased over time, probably in response to regulatory pressure.

Under the pH and temperature conditions of discharges, ammonia is mostly in the form of the much less toxic ammonium ion. There are processes available to remove ammonia from effluent (such as electro-deionisation or steam stripping) but these are not suitable for treating large, dilute volumes. Amines such as ethanolamine or morpholine can be used as alternatives to, or in combination with, ammonia, and offer some operational benefits. Effluents from plants using amines will contain some small residues of the amines in use plus their breakdown products.

Cooling water chemicals

Around five million cubic metres of cooling water are required every day for the steam circuit of a single PWR. As in all large power plants, this may need to be treated with biocides to prevent the cooling water system becoming infested by algae or colonised by shellfish (biofouling). Chlorine is usually used in once-through seawater cooling systems (in the form of sodium hypochlorite), while monochloramine and chlorine are commonly used in cooling towers. Additional proprietary chemicals may be needed to control certain specific invasive species such as zebra mussels and Asiatic clams in the USA.

Some of the chlorine added persists in the outlet of the cooling water systems from all power plants. This residual chlorine reacts with natural organic material, producing chlorinated by-products such as bromoform. Both chlorine and chlorinated by-products are toxic to aquatic wildlife. Discharges can be reduced by only chlorinating when the water temperature is greater than 10°C (when biofouling becomes more likely) or by using specific techniques such as pulse chlorination. Water containing chlorine and chlorinated by-products can be treated with chemicals, but these techniques are not suitable for the large volumes of cooling water discharged from a large power plant.

Other chemicals

Many other chemicals are used at, and discharged from, PWRs. These include:

- trace metal corrosion products;
- detergents from plant laundries;
- salts from neutralising acids and alkalis used to regenerate ion exchange beds;
- oil, grease and suspended solids from rainwater run-off from areas of hard standing;
- proprietary chemicals used in many different systems such as herbicides and cleaning solutions.

Best Available Techniques (BAT)

Whether a particular technique represents BAT will depend on plant-specific and local conditions.

In general, application of BAT will include:

- optimising the plant design;
- minimising the use of chemicals at source;
- using less hazardous chemicals where possible;
- segregating waste streams to allow tailored treatment prior to discharge;
- preventing leaks and spills.

For the PWRs surveyed, the greatest emphasis for BAT was the use of biocides (especially chlorine) in cooling water. Other important areas included the use of chemicals to prevent corrosion during reactor shutdowns (especially hydrazine) and the discharge of chemicals from the secondary circuit and water treatment plants.

This report provides the Environment Agency, government and others with detailed data and information about the types and levels of chemicals discharged from PWRs, and how these might best be regulated should nuclear power plants based on the AP1000™ and UK EPR™ designs be built in England and Wales.

This summary relates to information from project SC090012, reported in detail in the following output(s):

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Project manager: Laura Newsome, Evidence Directorate

Research Contractor: AMEC, The Renaissance Centre, 601 Faraday Street, Birchwood, Warrington, WA3 6GN

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