Study of historic nuclear reactor discharge data and associated arisings of solid radioactive waste

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INTRODUCTION

The UK Government's has now stated that private sector energy companies should have the option of investing in new nuclear power stations. The Environment Agency and the Nuclear Installations Inspectorate of the Health and Safety Executive (HSE) are together assessing four generic designs of new nuclear power stations from four reactor vendors (HSE, New Reactors Website). Generic design assessment (GDA) is one of a number of facilitative actions proposed by Government in its May 2007 Consultation Document to improve the process of consulting on and approving new nuclear power stations. It is expected that the robust and detailed assessments will take about 3½ years to complete.

The Environment Agency is particularly interested, from an environmental perspective, in assessing whether proposals for new reactor designs represent the 'best available techniques' (BAT). To achieve this, there is a need to assemble historic discharge data for operating reactors from which the four new designs have evolved or from experiences of operating the new designs and to draw technical links between discharge performance and plant specification, abatement technologies, operation and maintenance.

METHODS

At the moment four reactor designs have met the Government's criteria laid down in the consultation document "The Future of Nuclear Power: The Role of Nuclear Power in a Low Carbon UK Economy" and these are listed in Table 1.

These new designs all aim to improve safety, efficiency and reliability. They all use water technology for neutron moderation and heat removal. The first three designs use light water reactor (LWR) technology whereby light water acts as the moderator and as the method for heat removal from the core. The fourth design uses heavy water as the moderator and light water for heat removal. Of the three LWE designs, two (the AP1000 and the EPR) are pressurised water reactors (PWRs) and one (the ESBWR) is a boiling water reactor (BWR). Within the project, the following information has been sought:

- The gaseous and liquid discharge data for at least six (see Table 1) of the existing operational reactor power stations for each of the proposed new designs. Where possible, this information has been collated for an operational period of 10 years. This discharge data has then been normalised to electrical and/or thermal output.
- Differences between individual reactor performances in terms of their design, operation and maintenance against environmental impact for example, how the discharges are affected by operational matters such as refuelling and maintenance.
- Solid waste arisings for the reactor over the 10 year operational period.

The operational period of 10 years was chosen as it provides sufficient data to identify characteristics and trends in discharges relevant to operational practices and thus allowed the:

- Analysis of any trends and step changes in discharge performance to identify key parameters that influence the level of discharges and may help identify what is good practice operationally.
- Evaluate whether better performance on gaseous or liquid discharges may be achieved at the expense of increased quantities (volume and/or activity) of solid wastes, worker dose or non-radiological impact on the environment.

RESULTS

Table 1 lists the reactors considered to be analogues for the four proposed new reactor designs. A reactor was accepted as an analogue if they have a design which is an immediate predecessor to the new design and, ideally, if they have been operational for a period of 10 years or more. For example the two EDF(N4) reactor power stations at Chooz and Civaux are immediate predecessors to the EDF/Areva EPR but have only been operational for eight years. Therefore, the two EDF reactors at Golfech and Penly, predecessor designs to the EDF (N4), have been added to the list because they have been operational for at least 10 years.

Table 1 List of new reactor designs and their analogues used for data gathering

Reactor Class	Type	Power Station
EDF/Areva EPR	EDF (N4)	Chooz & Civaux, France
	EDF	Golfech & Penly, France
	Konvoi	Neckarwestheim – 2, Emsland & Isar-2
Westinghouse AP1000	Westinghouse	Beaver Valley – 2, Byron – 2, Comanche Peak – 1 & Seabrook – 1, USA
	Westinghouse	Sizewell B, UK
	Westinghouse	Takahama, Japan
GE-Hitachi ESBWR	BWR, ABWR	Kashiwazaki, Hamaoka & Shika, Japan
	BWR	Shimane, Japan
	BWR	Clinton – 1 & Nine Mile Point – 2, USA
AECL ACR1000	Candu	Bruce, Darlington, Gentilly – 2, Point Lepreau, Cernavoda, Wolsong & Pickering, Canada

Having identified the reactor types, information was sought via direct contact with the vendors and operators along with the relevant regulatory bodies (e.g. the NRC Effluents Database). In addition other sources, often available online, have been used along with international compilations of data from the IAEA (Power Reactor Information System; DIRATA), UNSCEAR (2000), NEA and the EU (reports for 1995-1999 and 2000-2003). The discharge data for each reactor has been extracted from these sources and, where possible, independently verified from different sources (e.g. IAEA data were used to verify data from NEA and vice versa).

Once all the data had been checked, the data was summarised, first by each reactor and then by each reactor class, to show the main trends observed in discharges. Importantly, the data was also used to identify points of interest (e.g. high discharge peaks or where data were missing) for each reactor. Figure 1 provides an example of the reactor discharge data for the Byron reactor (an analogue for the AP1000 design). Figure 2 shows the summary discharge information for the reactor class representing the AP1000 design). In this graph, it was assumed that the range represented by the average (mean) and the maximum (mean plus the standard deviation) is representative of the range of discharges expected during normal operation.

Figure 1 Total activity of liquid discharges from Byron in GBq/a

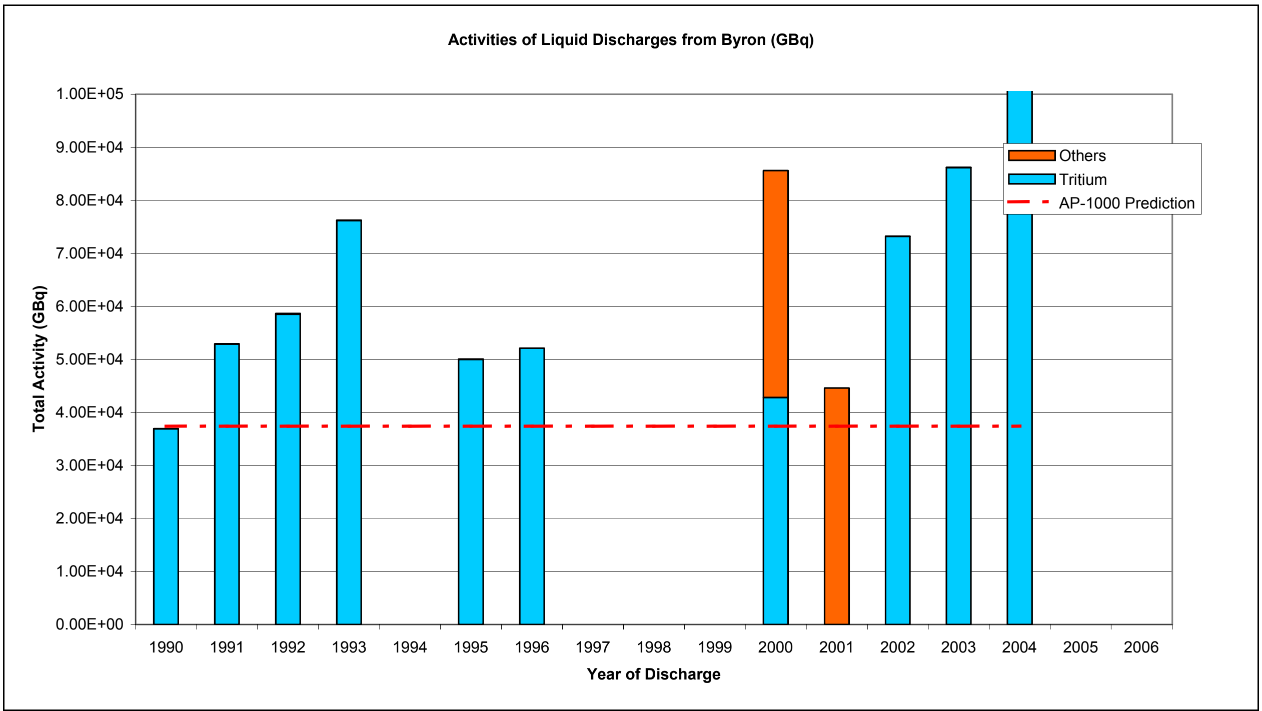
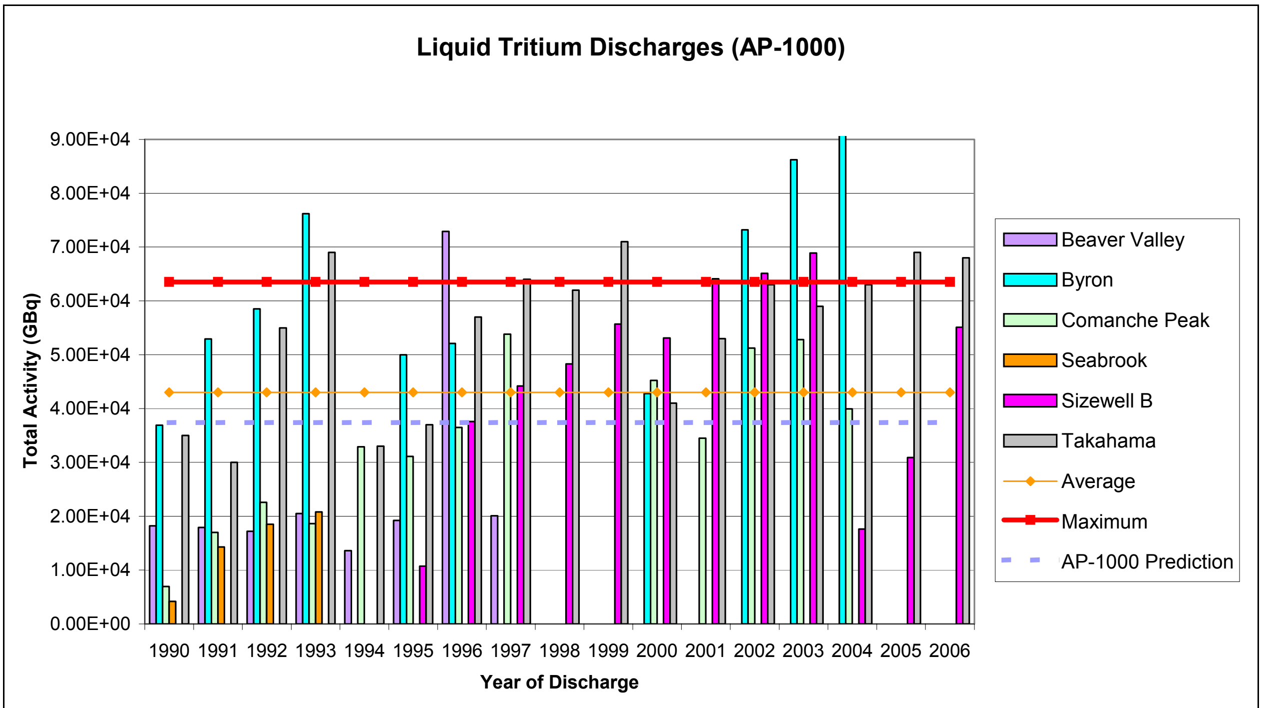


Figure 2 Liquid Tritium Discharges (AP-1000- GBq Vs Year)



The caveats to this information are that the liquid tritium discharge for Bryon for 2004 of 1.19×10^{11} GBq was significantly greater than all other discharges of this reporting group and for the Byron reactor in other years. Consequently, this discharge was viewed as being greater than that which would be expected during normal operations, and has been excluded from the average and standard deviation calculations. Figure 2 shows a broad distribution of liquid tritium discharges for the various reactors. The most significant peaks are for: Byron (1993, 2002, 2003 and 2004) and Beaver Valley (1996). Overall, when these data are used to predict the normal operational discharge, it appears to be slightly greater than the AP-1000 prediction from the vendors. This needs to be verified once the data has been normalised to electrical and thermal output.

During this work a number of significant gaps have been identified. These include lack of information on the solid waste arisings from liquid and gaseous effluent treatment and information on relevant reactor plant abatement techniques that could provide further explanation of the identified trends in the discharge data.

Future work will involve the normalisation of the raw discharge data relevant to the following parameters: electrical output; thermal output; and operator dose, if such data can be extracted from the vendors of abatement systems/techniques.

CONCLUSIONS

The data presented have been used to identify trends in the discharges of relevant radionuclides from each of the predecessors to the four generic reactor designs included in this study. The graphs presented show both consistency and variation in the levels of the same radionuclides discharged from the power stations using the same reactor type. However, it is acknowledged that these discharge levels are dependent on operational factors relevant at each power station, such as: the number of reactor units present; the electrical and thermal power output by the reactor; and operational factors such as plant shut-down, maintenance and refuelling. The effects of these parameters are being investigated at the moment. Additionally, it is acknowledged that the current trend recognition analysis has been limited to the analysis of raw activity data and that in some cases the dominant radionuclides are different. Consequently, these data do not necessarily represent the true radiological significance of discharges from each candidate power station or relevant radionuclide group.

These data will be used to inform the Environment Agency's review of the environmental performance of the proposed new nuclear power station designs that might be permitted for use in the United Kingdom in the future.

REFERENCES

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