MODELING AND BENCHMARKING THE PERFORMANCE OF LIQUID PROCESSING TECHNOLOGIES

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ABSTRACT

Trends in the reduction of liquid Low Level Waste volumes and activities show that the U.S. nuclear power industry continues to be successful in responsibly managing environmental effluents and in improving performance. As part of the industry's commitment to environmental excellence, effluent activity and dose are already well below regulatory limits. However, US plants continue to search for opportunities to improve which in turn creates significant challenges to individual stations.

A wide range of liquid radioactive wastes processing technologies is available to the operators of nuclear plants. This wide range of technologies makes it difficult to assess which is the best option for a particular station. EPRI therefore, has initiated a three-year project, which will benchmark and empirically model the performance of various liquid processing technologies using such variables as influent/effluent quality, influent/effluent radioactive contamination and waste generation. This paper provides an initial benchmark of the performance of various radwaste processing systems.

BACKGROUND

Operators of nuclear plants are challenged with the goal of effectively and economically managing the radioactive effluents generated by their facilities. Limits on activity discharge have been set forth by regulations at the federal and state levels. Utility goals and their performance indices represent only a small fraction of the regulatory limits. However, it is important to recognize that using activity as a measurement of the associated scientific based risk can be misleading. Individual isotopes do not have the same biological effect on a person. A more accurate indicator is the dose attributable to the radioactivity in the liquid effluents produced by nuclear power plants. Figure 1 below indicates various sources of radiation exposure to the US Population (Strategies for Managing Liquid Effluent- Options, Actions, and Results, EPRI, Palo Alto, CA: 2003. 1008015). The figure was generated using data obtained through the 49th session of UNSCEAR in Vienna, Austria in May 2000.

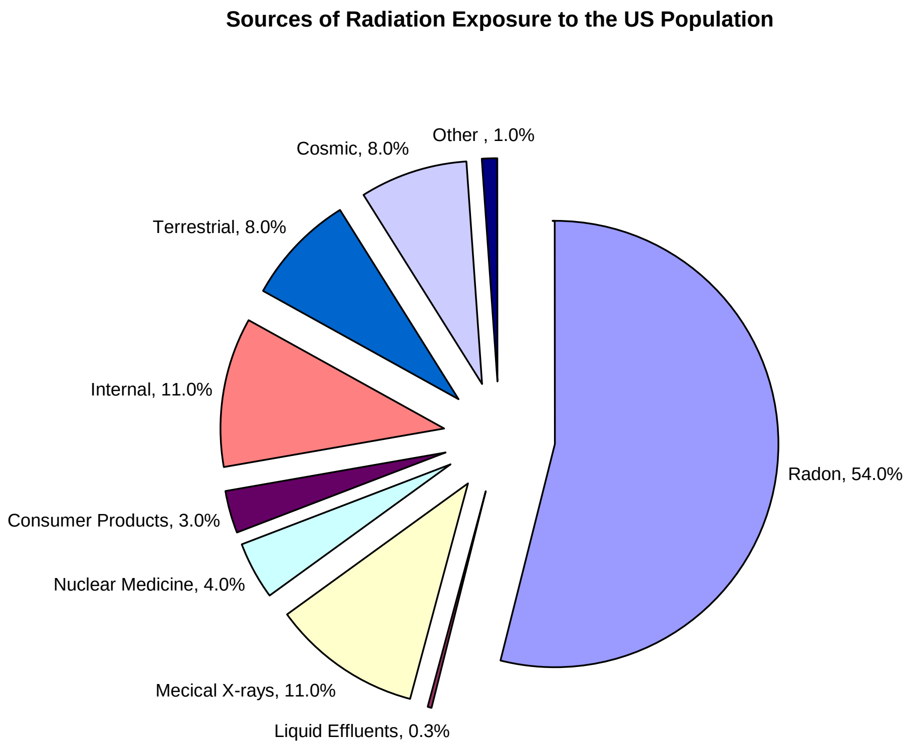

Fig. 1 Sources of radiation exposure to the US population

The greatest contribution to the US population’s dose comes from natural background radiation. The second largest contribution comes from medical radiation procedures. Human activities cause further radiation exposure in addition to the natural exposure. Occupational radiation exposure is incurred by workers in industry, medicine and research. It is important to note that dose received through exposure of liquid effluents represents the smallest fraction ~0.3% of all sources of radiation exposure to the US population.

Trends in the reduction of liquid Low Level Waste volumes and activities show that the U.S. nuclear power industry continues to be successful in improving performance and in responsibly managing environmental effluents. Effluent activity and dose, already well below regulatory limits, continue to be driven downward.

METHOD

Data was obtained through the EPRI RadBench benchmarking program and NATC/ISOE effluents database. Additional station processing information was obtained previously through various EPRI studies.

The EPRI RadBench benchmarking program contains data provided by individual operating nuclear stations. Formal requests are made on an annual basis capturing data for both liquid and dry active wastes.

Effluent data discussed in this paper represents total mixed fission products (excluding tritium). The data was obtained through the NATC/ISOE database which was generated from 1.21 reports from nuclear plants reported each year.

RESULTS AND DISCUSSION

Plant data obtained through EPRI's RadBench benchmarking program and through the NATC/ISOE effluents database clearly indicate that radioactive effluents from commercial nuclear power plants have decreased significantly over the last decade. Figure 2 below show the average liquid effluent activity released in curies by US pressurized water reactors (PWRs) from 1993 to 2002.

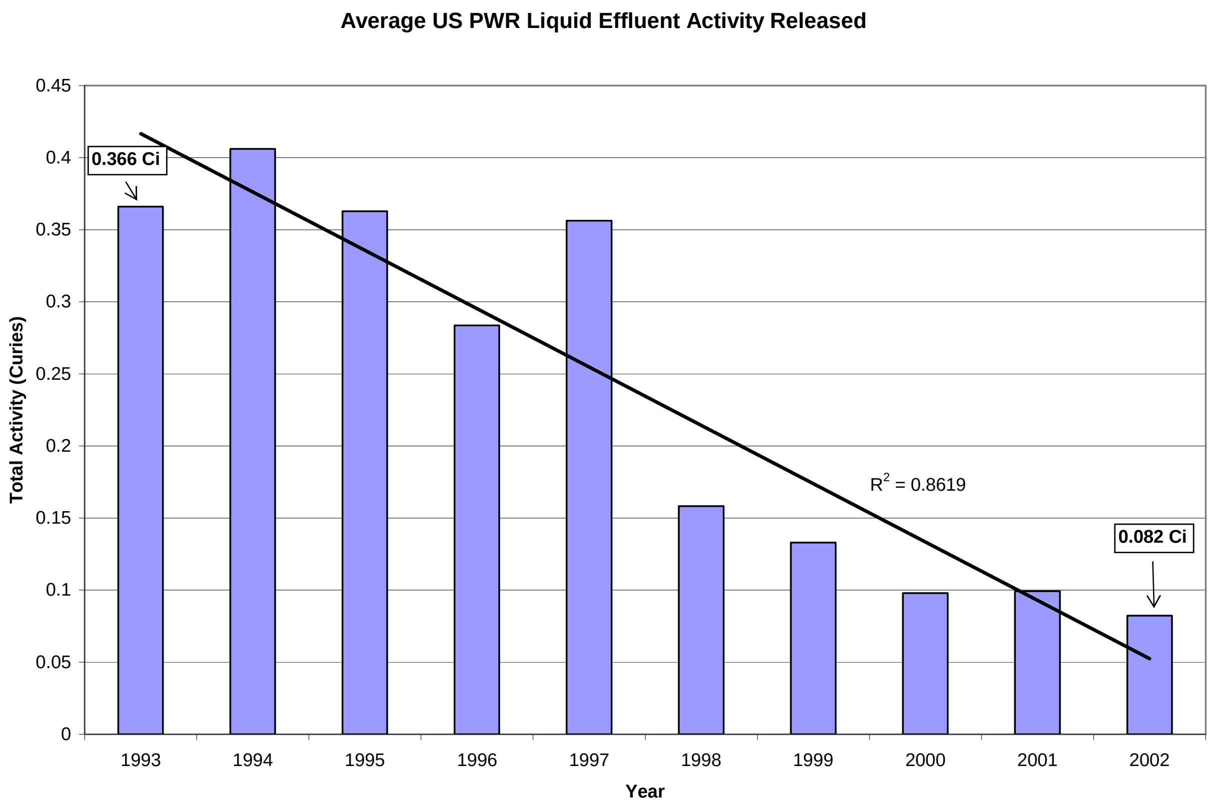

Fig. 2 - Average US PWR liquid effluent activity released

Careful tracking and trending of this data not only benefits currently operating stations, but also is critical information for development of strategies and technologies for the next generation of advanced reactors. The knowledge that effluent activities are trending downward presents a clear challenge to reactor suppliers to identify and incorporate plant design considerations that will result in continued performance improvement in this area.

The individual station effluent release, although well below regulatory limits, varies amongst each station as seen in Figure 3. The average effluent released in 2002 by 69 operating PWR units was 0.083 Curies. This value is 4.5 times lower than average seen almost a decade earlier which was 0.366 Curies.

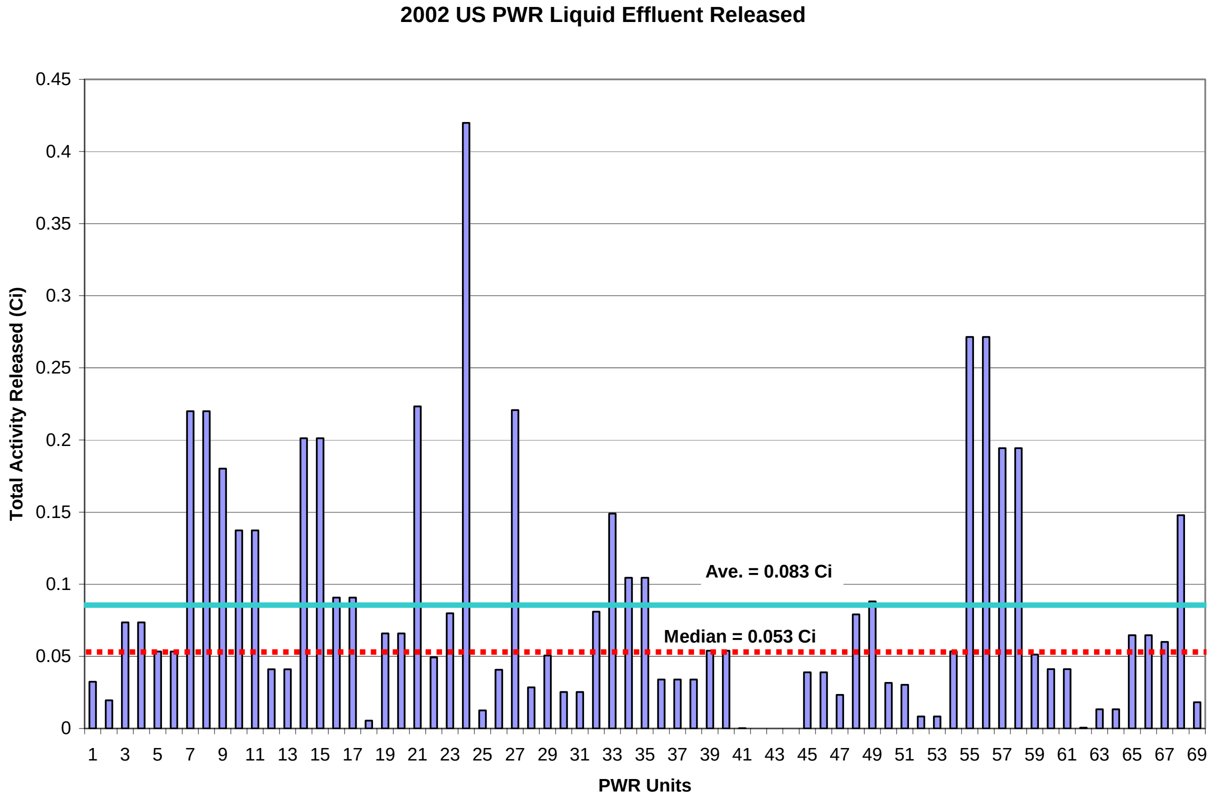

Fig. 3 2002 US pwr liquid effluent released

In the U.S., the majority of liquid radwaste systems were equipped with filters (e.g. cartridge, precoat or deep bed charcoal) and evaporators followed by a series of deep bed ion exchangers. During the past few years new technologies have gained acceptance for the processing of this waste stream. Membrane based systems have been shown to deliver high quality effluent water with extremely low levels of radioactive contaminants. Newer approaches include the use of Ultra-Filtration followed by deep bed demineralization, Reverse Osmosis followed by deep bed polishing demineralizers. Similarly, newer filter and demineralizer arrangements combined with the injection of polyelectrolyte coagulants have proven to be equally effective.

In the EPRI study, plant data will be correlated to the technologies in use at specific plants and significant events and strategies impacting the data set. Figure 4 provides an initial view of this correlation utilizing several plants' specific effluent benchmarking data relative to their radwaste processing systems. This figure is simply another depiction of a portion of the data shown in the previous graph grouped by the identified radwaste processing system. The majority of commercial operating nuclear plants utilize some form of filter + demineralizer system for processing liquid effluents. Only a few stations utilize more advanced processing technologies. Although those stations were not depicted in these graphs, they will be incorporated into the final study. As expected, the preliminary comparison appears to indicate that stations utilizing boron recycle by evaporation with radwaste filtration followed by demineralization, in general, released lower total activity than the other evaluated system.

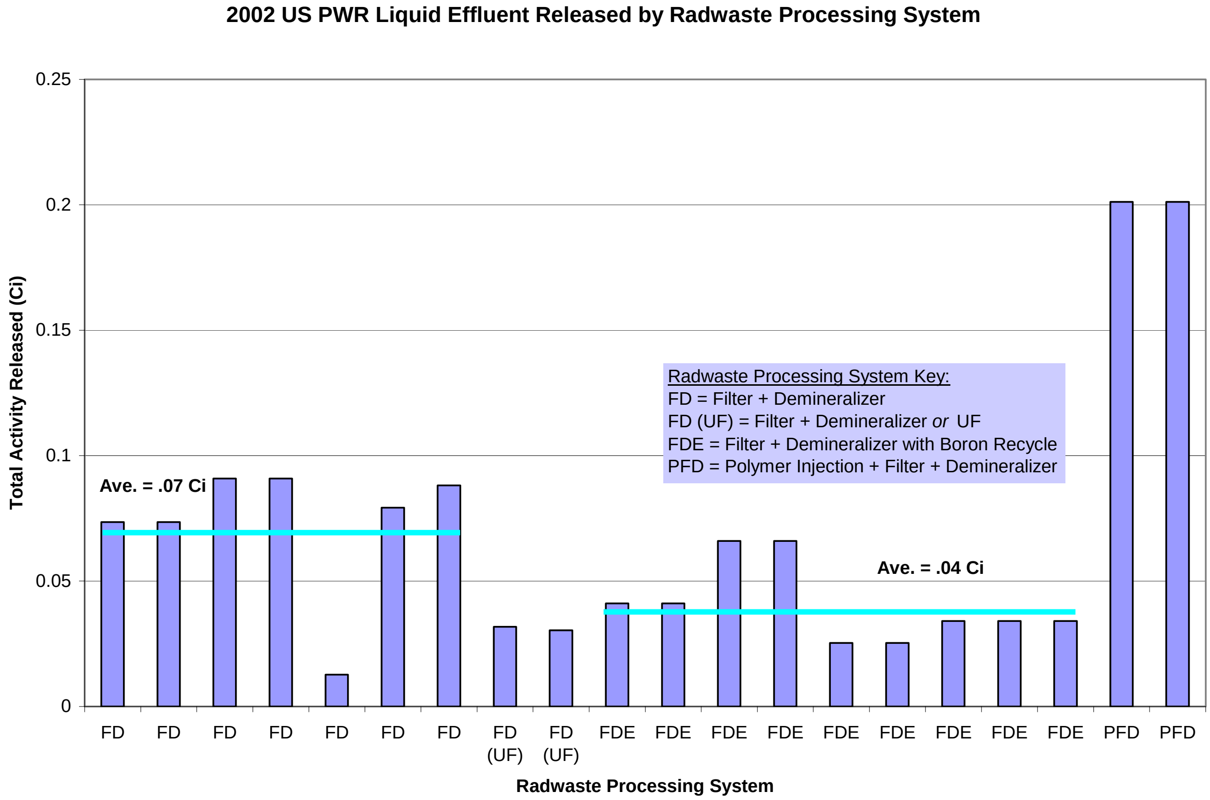

Fig. 4 - 2002 US PWR liquid effluent released by Radwaste Processing System

An additional criterion often used to assess the performance of a radwaste processing system is the calculation of the percentage of activity removed by the system. Figure 5 shows the percentage of activity removed by each radwaste processing system. Although all processing systems removed approximately 95% or greater of the influent activity, it is important to remember that many of the performance indices set forth by the individual stations target the last few decile of activity. The difference in the percentage of activity removed by each system can be more clearly seen in their averages. On average, the filter + demineralizer approach discussed above removes 99.6% of the total influent activity. This is approximately 1.2% more activity removed than the traditional filter + demineralizer system. 1.2% may not seem significant, but it translates to a difference of 0.03 Ci, which is significant when compared to the average industry effluent release of 0.083 Ci. (0.03 Ci represents 36% of the industry average).

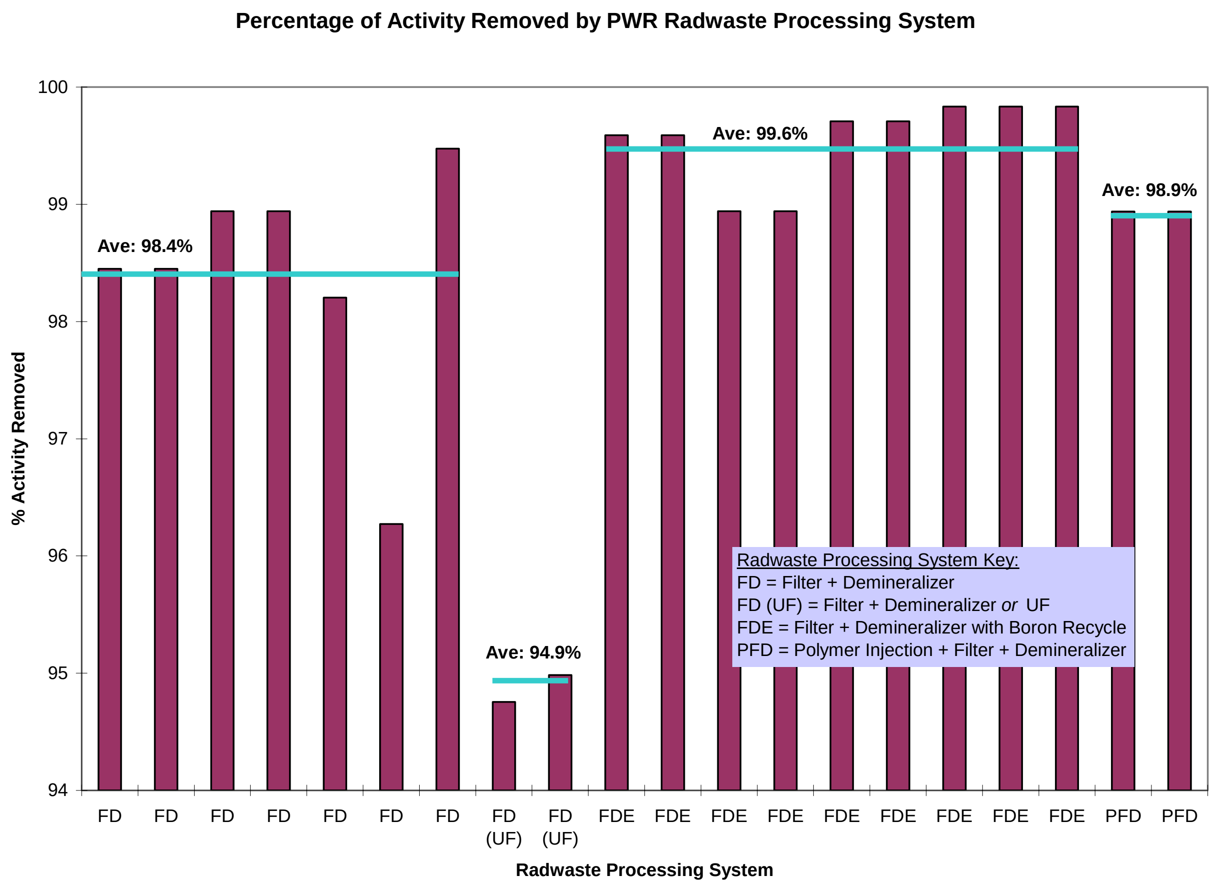

Fig. 5 - Percentage of activity removed by Radwaste Processing System

Another criterion often used to assess the performance of a radwaste program is the monitoring of the total liquid volume processed by that system. Figure 6 shows the total liquid volume processed in 2002 for PWR plants utilizing the identified radwaste processing system. Although a direct correlation cannot be made of the performance of the system with the amount of liquid processed, it does give an indication of operating experience. As expected, it appears that filter + demineralizer with boron recycle processes the least amount of liquid.

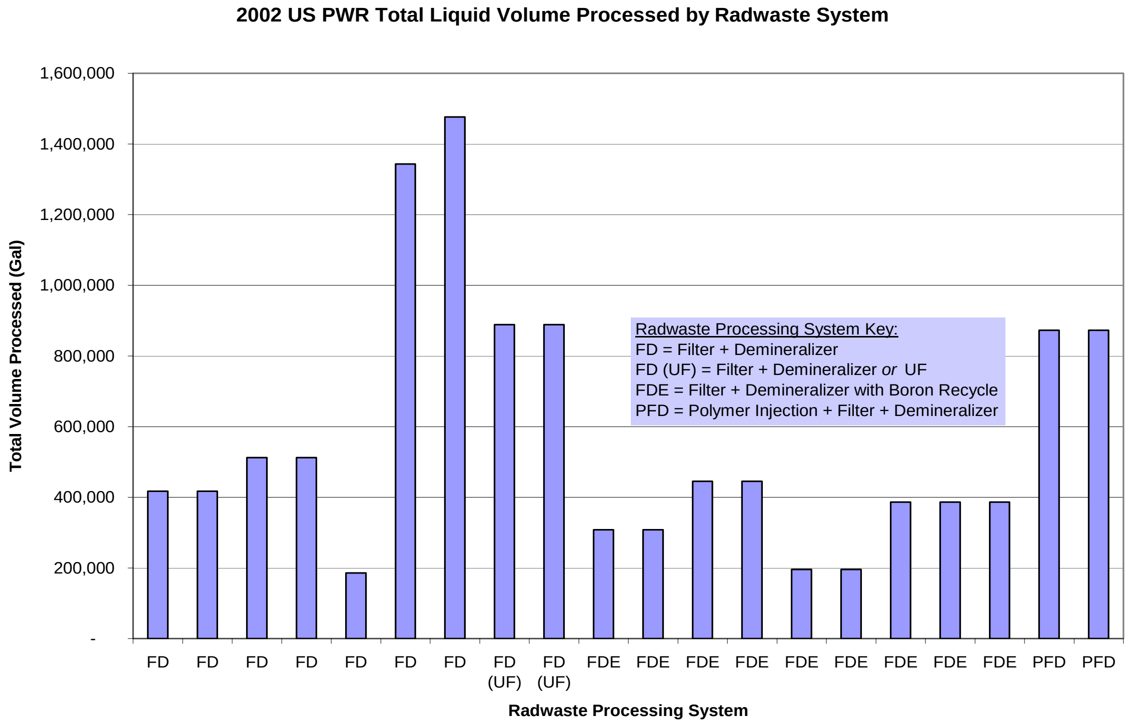

Fig. 6 - 2002 US PWR total liquid volume processed by Radwaste System

CONCLUSION

The data and results discussed in this paper are preliminary, and will be investigated in the upcoming EPRI study with additional evaluation and benchmarking for all processing systems. The ultimate goal is to empirically model various liquid processing technologies to aid in assessing the performance of these processing options and identify opportunities for improvement.

Trends in the reduction of liquid Low Level Waste volumes and activities clearly demonstrate that the U.S. nuclear power industry continues to support environmental stewardship with measurable results. Further, the industry is clearly not accepting its current excellent performance and continues to improve its collective environmental release management. Effluent activity and dose, though already a small fraction of regulatory limits, continue to be driven downward to minimize the industry's environmental impact.