From: Call, Michel
To: gwstenerson@outlook.com
Cc: Tate, Travis
Subject: Response to question to NRC Chairman regarding Shielding Nuclear Waste
Date: Friday, March 29, 2019 1:28:03 PM

Hi Grant,

I am Mike Call and a nuclear engineer here at the NRC in the Division of Spent Fuel Management. I am one of the folks here that evaluate the shielding designs for the storage of spent fuel after it has been removed from the spent fuel pool at a reactor facility. I have received your question to the NRC Chairman and so am sending you this email as a response.

First, congratulations on your selection as a semi-finalist at the IJAS regional science fair earlier this month and good luck at the IJAS State science fair in May. That is awesome! I also think it is great that your project relates to radiation shielding and spent nuclear fuel storage.

As you have rightly pointed out, lead is a more effective shield for gamma radiation than concrete. Materials like lead that have high density and high atomic mass numbers (large numbers of protons and neutrons in the nucleus) are always more effective shields for gamma shielding than are materials that are made of low density and low atomic mass numbers. So, you would also see a similar trend if you were to use materials like tungsten and depleted uranium in place of lead in your project and compare them versus concrete.

What that means is that it will take a greater amount of concrete to shield gamma radiation to the same degree as a given thickness of lead. For example, using Figures 7.10 and 7.11 on page 230 of *Radiation Shielding* by Shultis and Faw (published in 2000 by the American Nuclear Society), you will see that it takes about 17 cm of lead to attenuate gammas from cobalt-60 to a fraction of 10^{-4} of the beam impacting on the lead. From those same figures, you will see that 90 cm of concrete, for the concrete composition used to produce that data, will attenuate the cobalt-60 gammas to the same amount. At a fraction of 10^{-3}, about 12.5 cm of lead is needed whereas about 70 cm of concrete is needed. I would note that the figures are in terms of attenuation for air kerma, but also work for dose equivalent. These are different quantities and units than what you've used in your experiment but are related. Dose units, such as dose equivalent, are what we look at in terms of the shielding ability of the storage cask design since the regulatory requirements are in terms of dose to individuals.

As to the type of systems used for storage of spent fuel, a variety of factors play into the decisions by designers of the storage systems, including casks, and a licensee's selection of the storage system design to use at their facility. The NRC's objective is to ensure that the storage of spent fuel is done safely, to ensure adequate protection of public health and safety. The NRC's standards and regulatory requirements for that purpose are contained in Title 10, *Energy*, of the Code of Federal Regulations (CFR) Part 72 (or 10 CFR Part 72), "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste." If the storage system design and facility design and operations are shown to meet these requirements, then the NRC will approve the design and operations and thereafter will periodically verify that the licensee continues to meet the requirements through inspections. Thus, selection of storage system design, including the materials to be used in the design, is based on the choices of the system designers and the licensees that will use them, within the constraints of meeting the NRC's requirements for safe storage of spent fuel.

As you have pointed out, lead offers great benefits for gamma shielding, and less lead is required to provide the same amount of gamma shielding that concrete can provide. However, in addition to gamma shielding, the storage systems must also be able to perform other functions that are necessary to ensure the spent fuel is stored safely. These functions include adequately shielding against neutron radiation and protecting against structural damage to fuel as a result of the impacts of accidents and natural phenomena. For systems that use lead, additional materials and design features would be needed to perform these other functions. This may include the use of polymer-based neutron shields (unlike for gammas, low atomic mass number materials are best for shielding against neutrons). In addition, components made of steel, reinforced concrete, or other structural materials would be needed to provide the necessary protection against accidents and natural phenomena. For a concrete cask storage system, the reinforced concrete performs all three functions (i.e., gamma shielding, neutron shielding, and structural protection).

Of course, cost is another factor that system designers and licensees consider in storage system design. With materials for cement and aggregate for concrete being less expensive than lead and the materials that would be needed to perform the required functions lead cannot perform while still meeting the same regulatory requirements for safety, this would be another reason why storage system designers and licensees that use them would consider selecting a concrete cask design. It may also be worth noting that the type of material that is used as concrete aggregate can be varied in order to increase the concrete's effectiveness in shielding gamma radiation at reasonable cost.

There may be additional considerations in selecting a cask type storage design versus a design that does not use casks. These considerations may include that the other designs may require active systems and maintenance activities that are not required for cask systems that are designed to be completely passive (i.e., not require active systems and operator actions) and minimal maintenance, which enables the ability of the licensee to ensure safety in a cost-effective manner.

I hope that you find this information to be useful. I would be happy to assist with any additional questions you may have. You can contact me by my email (michel.call@nrc.gov) or by phone at 301-415-5374. Also feel free to contact Travis Tate, my supervisor, at travis.tate@nrc.gov or 301-415-3901. Again, good luck at the IJAS State science fair in May.

Regards,
Mike