Predicting the Cherenkov light intensity of irradiated nuclear fuel assemblies in wet storage for nuclear safeguards purposes

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Images courtesy of Channel Systems
Outline

1. The Digital Cherenkov Viewing Device (DCVD).

2. Current method for partial defect verification with the DCVD, and why predictions of the intensities are needed.

3. Simulations of the Cherenkov light intensity from a fuel assembly

4. Proposed prediction method.

5. Conclusions
1. The Digital Cherenkov Viewing Device

- Measures Cherenkov light from fuels in wet storage.

- Approved by IAEA for gross and partial defect verification.

![Fuel](image1.png)  ![Non-fuel](image2.png)
1. The Digital Cherenkov Viewing Device

- Portable system.
- Easy setup
- Non-intrusive
- Quick measurements
2. Current method for partial defect verification with the DCVD

- A 50% partial defect is expected to reduce the measured intensity by at least 30%.

- Partial defect verification compares measured and expected total Cherenkov intensities.

- Central to the current partial defect verification method is thus accurate predictions.
2. Current method for partial defect verification with the DCVD

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- To predict the intensity from a fuel, the burnup and cooling time is currently used.

- Current predictions are often based on a single fuel type or of a simplified geometry, a single rod in water.

- Works well for long-cooled fuel, where Cs-137 generate most Cherenkov light.

- Less accurate for short-cooled fuel, when the irradiation history strongly influences the results.
3. Simulations of the Cherenkov light intensity from a fuel assembly

• A simulation study has been done on two different fuel geometries (BWR 8x8 and PWR 17x17).

• The geometries were representative of real fuel assemblies, including pellet size, cladding thickness, pitch and guide tubes/water channels.

• Simulations were run with initial particles being either gamma-rays or electrons.

• The simulations investigated the produced Cherenkov light, not its detection.
3. Simulations of the Cherenkov light intensity from a fuel assembly

Some results of the simulations:

- The fuel geometry affects the production of Cherenkov light. Predictions based on the BWR and the PWR simulations can differ systematically up to 10%.

- For fuels with thin cladding and long cooling time, beta-decays from Y-90 contributes noticeably to the Cherenkov light intensity, and causes 5-10% of the intensity.
3. Simulations of the Cherenkov light intensity from a fuel assembly

Some results of the simulations:

- For short-cooled fuel, the irradiation history should be taken into account. The inventory of short-lived isotopes mainly depends on the power level near the end of the cycle.
4. Proposed prediction method

Based on the results of the simulation study, the following should be considered when making predictions:

• Predictions should be based on the fuel geometry under study.

• The vertically directed Cherenkov light should be analyzed for predictions.

• Contributions from both gamma decays and beta decays (mainly Y-90) should be included.
4. Proposed prediction method

Before measurements, the transfer function must be calculated, which turn gamma and beta intensities into Cherenkov light intensities. Computationally expensive step.

- Gamma simulations for various energies
- Beta simulations for isotopes of interest
- Analysis
- Transfer function
4. Proposed prediction method

With the transfer function calculated, predictions can be done quickly
4. Proposed prediction method

Possible improvements to the method:

• Also include light transport to a detector position and its detection. Requires knowledge about vertical burnup profile, reflectivity of surfaces, and knowledge about structural components such as spacers.

• Neighbouring fuel assemblies can create Cherenkov light in the assembly under study. This should be taken into account for accurate measurements.

• Verify results with measurements.
Thank you for your attention!

Questions?